Identification of land use/cover transfer hotspots in the Ejisu-Juabeng District, Ghana

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by

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I certify that although I may have conferred with other people in the preparation of this work, and drawn upon a range of sources cited in this study, the content of this thesis is my personal work.

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Abstract

Available information on land use/cover transfer is at global and national levels while change processes are widespread at the local hotspots. Natural resources monitoring and assessment programmes in Ghana focus on maintenance of quality, quantity of merchantable species and diversity of forest resources in forest reserves and off reserves with less attention on the land use transfers taking place. There is the need to generate land use/cover transfer information in Ghana at all levels of aggregation using remote sensing and GIS techniques. The study sought to identify prevalent land use transfers and link them to socio-economic factors that drive them using hotspot identification procedures in a forestry context in the off reserve and forest reserve interface of Ejisu-Juabeng District. To achieve this post classification change detention was conducted between two years using Landsat TM 1986 and ETM 2004 to detect changes at the district level to produce a change matrix of the two years and change map. Hotspot identification procedures were also applied to identify local areas with high concentration of land use/cover transfers. Fragment statistics including number of patches, largest patch index, patch density, mean patch size were computed for the district; and total core area, mean core area, total core area index and all district statistics also computed in four largest hotspots for description and comparisons. The analysis of the change detection revealed that forest area has decreased from 20385.04 ha in 1986 to 12824.62 ha in 2004 due to transfers to grass indirectly via agriculture. Forest fragmentation also decreased in 2004. Hotspot identification resulted in nine hotspots of which the four (Adokrom, Duapompo, Kubease and Yeboah) analysed indicated that Yeboah is the area undergoing most forest transfers followed by Kubease, Duapompo and Adokrom in order in decreasing transfers in forest. District rate was only higher than Duapompo and Adokrom. Forest not concentrated in hotspots but scatter in across the study area in smaller fragments. Forest in Yeboah remained the most fragmented hotspot followed by Kubease, Adokrom and Duapompo in the order of decreasing fragmentation. Adokrom and Duapompo are driven by economic, technological and market factors whiles Kubease and Yeboah are also driven by soil infertility problems and migration. The differences in identified in the nature of forest transfers in the study area are essential for planning and prescribing specific measures to mitigate forest transfers at each hotspot.

Key words: hotspot, fragments , land use/cover transfers

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Dedication

I dedicate this piece of work to my father, Mr. R K. Owusu Asubonteng and all mothers especially Madam Felicia Okyere

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1. Introduction

1.1. Background

Environmental changes, modifications in ecosystem structures and the loss of biodiversity affecting the whole planet have aroused worldwide public concern. Scientific and political debates on these issues both nationally and internationally started since the beginning of the 20th century (Boletta et al., 2006). Land use/cover change is one of such important human and nature induced environmental changes. Generally land use/cover change refers to the alteration in the physical land surface and biotic components on it.

Monitoring land use/cover change has become an important theme of research due to the extent to which these changes influence the global fluid system; the atmosphere, world climate and sea level (Meyer and Turner II, 1992). Land use/cover change has enormous effect on hydrological balance and biodiversity through the fragmentation of natural habitats (Turner *et al.*, 2003; Verburg *et al.*, 1999; Vitousek, 1994); diminish soil quality on cultivated deforested lands (Islam and Weil, 2000) and accounts for a significant amount of atmospheric carbon and climate change (Vitousek, 1994). Land use and the rapid alteration of land cover have great implications for the very existence of humans as dependants of natural biophysical systems for survival. According to Vitousek (1994) the impact of land use change are felt at all levels of association, from genetic to global.

Food and Agriculture Organisation of the United Nations (2001) estimated that the world’s forests were converted to other land uses at rate of 0.38 percent (i.e. deforested) annually in the 1990s. The issue is more rapid and diverse in developing tropical countries. Lambin *et al* (2001) remarked that tropical deforestation, rangeland modification, agriculture expansion and urbanization are the major land use/cover changes around the globe. According to Nagendra *et al* (2004) the driving forces of land use/cover change vary and their dynamic interactions result in diverse chains and trajectories of change, depending upon the specific environmental, social, political and historical context from which they arise. The resulting changes from these drivers exist as a complex between subtle modification and total conversion as seen in a change in forest density and forest to agriculture land (Geist and Lambin, 2001; Meyer and Turner II, 1992; Veldkamp and Lambin, 2001).

Research has shown that landscape conversion is easily monitored and documented. Hence, over emphasis on conversion diverts attention from land cover modification which also has important effects on the landscape (Geist and Lambin, 2001; Meyer and Turner II, 1992). The complexity of land cover change is illustrated by the functional differences within types of land cover, structural variance between types of land cover change with regards to spatial arrangement and temporal patterns of change (Geist and Lambin, 2001). The high spatial variability in land cover , biophysical and socio-economic drivers of land use change world wide result in the variability in the causes and processes of land use change (Serneels and Lambin, 2001). The dynamic nature of land use/cover change makes it impossible to have an ideal solution for all problems associated with land use/cover change in different areas and at different spatial extents. It is crucial to capture the understanding of land use/cover change dynamics and their socio-economic drivers at local hotspots where they are most prominent.

1.1.1. Land use/cover change in Ghana

Ghana like many other developing countries whose economies depend largely on the utilization of natural resources is not an exception to land use/cover change problems. Forests play an important role in the economy of Ghana. Forest products include timber, fuel wood, medicinal plants, wildlife (bush meat) and fruits. The forest offers a conducive microclimatic condition for the production of the country's cash crops, namely cocoa and coffee; main watersheds and rivers which serve as source of drinking water directly for rural areas and indirectly for urban centres. The forestry sector provides 43% of the Gross Domestic Product, 50% of export earnings and 70% of total employment (Agyarko, 2001).

Ghana's landscape has been categorized into land use classes such as small and large scale farming, forestry, wood fuel, cattle grazing, urbanization, tree plantations of exotic and indigenous species (cocoa, rubber, timber), and game/park reserves in order to provide the above mentioned goods and services (Agyarko, 2001). However deforestation stands out as the most prominent change factor within the Ghanaian landscape.

Deforestation as a measure of land use change in Ghana usually begins with the gradual degradation of well-stocked forests by excessive logging, slash-and-burn agriculture, mining and quarrying, and fuel wood collection. The process is often completed by wildfires, illegal occupation and/or conversion to other land-use (ITTO, 2006). Lambin *et al* (2001) demystified the causes of land use/cover change to a function of economic opportunities offered by local and national markets as well as polices rather than just population and poverty mentioned in most discussions in the field. The 1948 forest policy of Ghana emphasized the protection of forest reserves but gave out the off–reserves for agriculture and cocoa expansion. This was replaced by 1994 Forest and Wildlife Policy, which sought for the creation of the conditions suitable for sustainable forest resource management throughout the country, reversing the policy of "liquidation without replacement" in the off-reserve areas (Kotey *et al.*, 1998).

The Structural Adjustment Program which was prescribed for the country by the World Bank in the 1980s also encourage the expansion of timber companies and increased timber exploitation to raise foreign exchange earnings to service Ghana's debt (Kufuor, 2000); and redeployed civil servants turning them into self made loggers with a reduced number of forest guards (Mensah *et al.*, 2002). In support of the above, Hawthorne and Abu-Juam (1995) observed that most forest conversion activities that took place in the past were legal, intentional and necessary for national development.

The combined effect of the above land cover change process resulted in the drastic decline of Ghana's tropical high forest from 8.2 million ha at the beginning the 20th century to 1.7 million ha (Friends of the Earth International, 1999), with an estimated annual forest cover change of 120,000 hectares between 1990 and 2000 (FAO, 2001).

The decline in forest resources has diverse implications for Ghana as nation. The nation is now faced with sustaining the livelihoods of its relatively large forest dependant population, raising funds to meet national commitments and satisfying the trade requirement of exporting forest products from certified sustainably managed forests. In order to match up the challenge there is the need for information on land use activities and their resulting land cover alterations that affect forests for effective management. The role of land use/cover change in the future of natural resource distribution can be better appreciated by measuring where and when changes took place, understanding the driving forces and mechanisms of the changes from fine spatial scales (Lambin and Ehrlich, 1997). There is the need to generate land use/cover transfer information in Ghana at all levels of aggregation using remote sensing and GIS techniques.

1.2. Problem statement

National monitoring and assessment programmes focus on maintenance of quality, quantity of merchantable species and diversity of forest resources in forest reserves (Hawthorne and Abu-Juam, 1995) and off reserves (Affum-Baffoe, 2001), with less attention on the land use transfers taking place. The available information is at the global and national levels while land use/cover change processes are widespread at the local level. It is important to note that detection and measurement of change depends on spatial scale; the higher the spatial level of detail, the larger the changes in the areal extent of land use and land cover which can be detected and recorded (Briassoulis, 2000).

The off reserve area of Ghana, an important source of economic timber species and a range of biodiversity is plunged into a rapid land use transfers. These consist mainly of rain-fed agriculture usually with mixed cropping of maize, cassava, cocoyam and plantain for subsistence and commercial purposes; abandoned fallow lands made of *Chromolena Spp*.; forest patches, settlement areas and cocoa plantations. The resulting land cover changes are mainly from forest to settlement areas, food crop farms and plantation farms. The changes in cover and use have rendered the off reserve areas patchy with bush fallow and marshy grasslands interspersed with farmlands. Yet little is known about the amount of transfers occurring in terms of areal extent. Further, the protected permanent forest estate that boarders the off-reserves has also come under great pressure from non-timber forest product collectors and illegal chainsaw operation since these products are least available in the outside reserve areas.

The meagre nature of resources and the complexity of land use change processes in off reserve and forest reserve interface calls for tackling the problem with respect to their intensity at specific local areas rather than making decisions based on national and regional information. Van Laake and Sanchez-Azofeifa (2004) noted the inadequacy of such administrative and ecological zone statistics in explaining the heterogeneity in deforestation at the landscape levels.

The essential information needed by forest and land mangers in order to understand the land use/cover change processes for decision making and resource allocation is lacking at the local level. Hence, there is the need for local spatial information on prominent land use transfers and changes in the land cover of the district.

1.2.1. Main objective

The aim of the study is to identify prevalent land use transfers and link them to socio-economic factors that drive those land use transfers using hotspot identification procedures in a forestry context in the off reserve and forest reserve interface

1.2.2. Specific objectives

- To quantify land use transfers and their contribution to landscape fragmentation.
- To adapt procedures for better identifying land use transfer hotspots
- To identify and describe areas where land use transfers are most prevalent.
- To link socio-economic drivers to the major land use transfers in the hotspots.

1.2.3. Research questions

- How much land use change has occurred between 1986 and 2004?
- How has fragmentation changed between 1986 and 2004?
- How can hotspot analysis be adapted to better identify prevalent land use transfers?
- Which socio-economic factors drive the major land use transfers?

1.3. Study approach

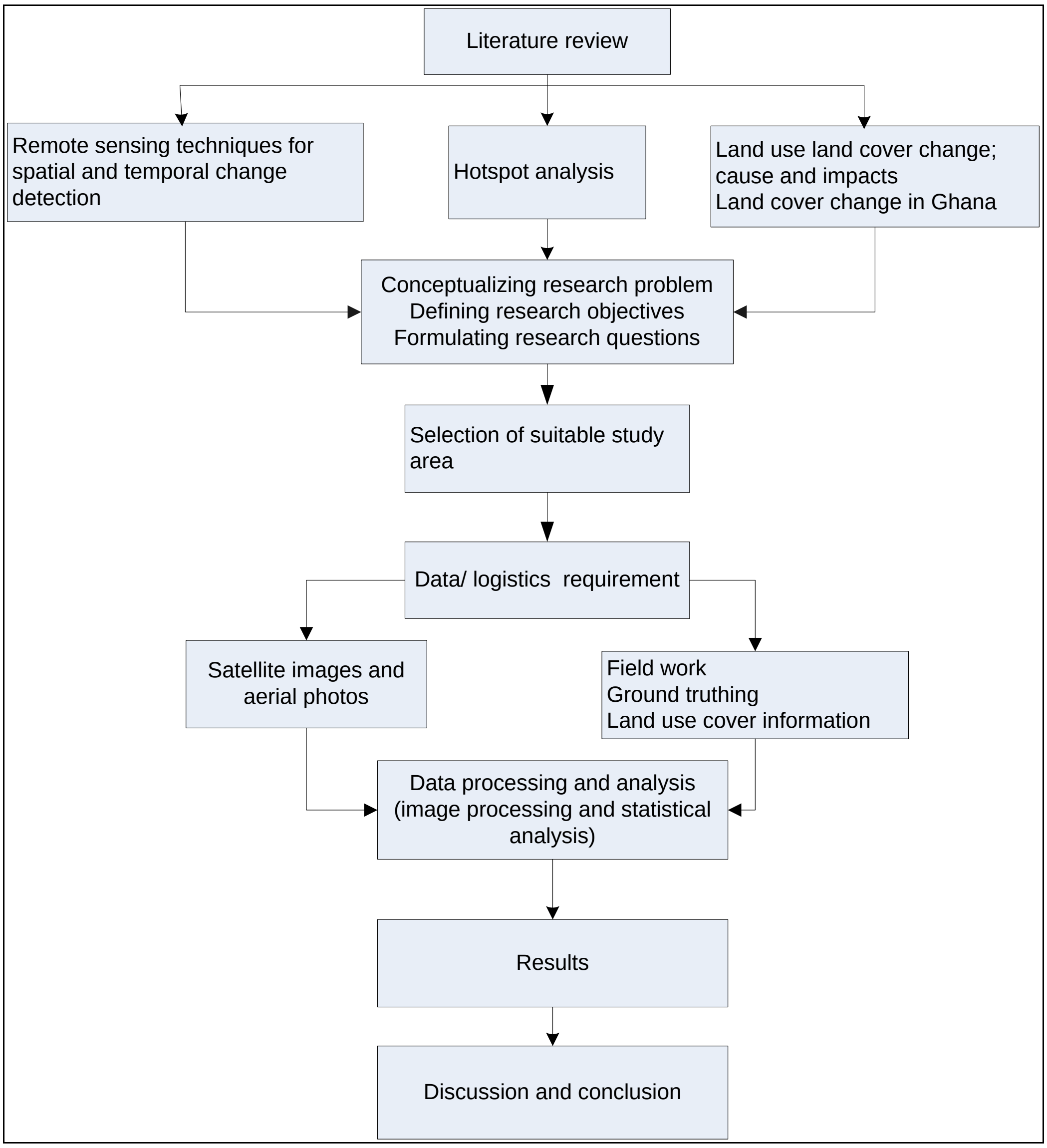

Figure 1: Conceptual framework of the study

2. Concepts and definitions

2.1. Land use and land cover changes

Land use refers to the function of land to humans which usually emphasis the importance of land in an economic activity. It includes all the arrangements, activities, and inputs undertaken in a certain land cover type in other to reap social, cultural and economic benefits whereas land cover is the physical appearance of land surface which provide visible prove of land use (Campbell, 2002; Meyer and Turner II, 1992). In essence land cover is more obvious on the field than land use which is usually inferred from the cover. These two words are closely linked such that in mapping they are treated together to avoid ambiguity (Lillesand and Kiefer, 1994). Nagendra *et al* (2004) highlighted the difficulty in splitting the two terms due to the complex feedback loop that exist between them, making it difficult to distinguish effect from cause. According to (Meyer and Turner II, 1992) land use and land cover share a common source of change in the form of human activities that directly alter the physical environment.

Over the years humans have strived to extract higher value from land by converting or modifying the natural cover types through diverse uses. In trying to get benefits from land, a series of transfers is triggered in the use of land which usually subsequently causes a transfer of the cover to another state. Transfers are used as a synonym to change. Land use has been changing since people first began to manage their environment (Metzger *et al.*, 2006). Braissoulis (2000) defines land use and land cover change as the quantitative change in the areal extent of a given type of land use or land cover, respectively. Dye (2003) limits land cover change to alteration or removal of the vegetation in a landscape. Land cover change is a complex process and deserves a careful study to understand. Land use change is pervasive and spatially heterogeneous; its global significance results primarily from the accumulation of many local changes in many local landscapes (Lambin et al., 2001; Vitousek, 1994). Changes exist as a complex between subtle modification and total conversion as seen in a change in forest density and from forest to agriculture land (Geist and Lambin, 2001; Meyer and Turner II, 1992; Veldkamp and Lambin, 2001). Meyer and Turner II (1992) observed that landscape conversion is easily monitored and documented due to ease in measuring compared to modifications. For example it is easier to monitor total transfers of forest to agriculture than a change in tree density. However over emphasis on conversion will divert attention from land cover modification which has gained frequency in recent past. The complexity of land cover change is illustrated by the functional differences within types of land cover, structural variance between types of land cover change with regards to spatial arrangement and temporal patterns of change (Geist and Lambin, 2001). The high spatial variability in land cover type, biophysical and socio-economic drivers of land use change around the world result in the variability in the causes and processes of land use change (Serneels and Lambin, 2001).

2.1.1. Nature and effects

Land use/cover changes have been in the lime light for reasons of importance attached to its impact on the earth and its occupants (Meyer and Turner II, 1992; Verburg *et al.*, 2006). On the whole, these changes have significant short and long term impacts on the functions of the physical, chemical and biological components of earth (Lambin *et al.*, 2003). Change in land cover and land use and subsequent impacts may be positive or negative spatially and temporally. However the balance is mostly tilted to the negative in tropical forest areas (Ingram and Dawson, 2005). These negative changes in the long term reduce the continuous ability of the earth to produce goods and services on which humans survive (Dale *et al.*, 2000). Most land cover changes cause a net loss of vegetation from the landscape and disturb the underlying soil resulting in a net release of carbon stored in vegetation and soils to the atmosphere adding up to atmospheric concentrations and potentially leading to global warming (Dye, 2003). For example Wright (2005) asserts that approximately half of the potential tropical closed-canopy forest has already been removed and the land converted to other uses and a minimum loss of about 28% biodiversity was recorded in Singapore as result of habitat conversions (Brook *et al.*, 2003). Lambin *et al* (2003) cautions that not all impact are negative since many forms of land-use/cover changes are associated with continuing increases in food and fibre production which contribute to the survival humans.

The diverse effects of land use/cover change may be permanent or reversible depending on the type and cause of the change. Analysis by Rudel *et al* (2005) shown that 38% of the world appreciated in forest cover after a period of decline in the 1990s. Turner *et al* (2003) observed a recovery of forest after small scale farms were abandoned in the Southern Appalachian Mountains in the 1900s. The effects of changes are not restricted to the location of the change and combine directly and indirectly in unexpected manner. Land cover alterations in up slopes, such as those brought about by clear-cutting, can result in short-term increases in stream discharge and sedimentation down stream (Baron *et al.*, 1998).

2.1.2. Driving forces of land use/cover change

Land cover change is a natural and / or anthropogenic phenomenon. However it results more often from human activities than naturally occurring. Studies by Turner (1989) showed that landscapes influenced by natural rather than anthropogenic disturbances may respond differently, with natural disturbances increasing landscape complexity. The natural causes include storms, landslide, and diseases and pest of existing vegetation as well as fire which is the most prominent one in most areas. Land use/cover change is the response of the increased use of nature to meet the numerous diverse human survival and developmental needs. Meyer and Turner II (1992) categorized the main driving force of land cover change into technology capacity, socioeconomic organisation, level of development and culture. In addition Heilig (1994) mentioned unprecedented increase of population; the growing affluence in Europe, North America, and parts of Asia and Latin America; the worldwide changes in lifestyles, which are partly explained by rising per capita income; and the growing influence of geopolitical, economic, and military structures and strategies as important drivers most are which are usually ignored in discussions. According to Veldkamp and Lambin (2001) most spatial focus on proximate cause like distance to roads and towns rather than underlying drivers for the sake measuring convenience. The negative contribution of the rapid human population growth to the large pressure on land resources has been noted by most literature on land use/cover change (Lambin and Ehrlich, 1997; Meyer and Turner II, 1992; Verburg et al., 2006; Verburg et al., 1999; Wright, 2005). Contrary Turner *et al* (2003) found that land use may intensify without associated change in land cover if development occurs under natural conditions. E.g. Under the forest canopy. Essentially the driving forces are usually remote in space and time from the observed changes, and often involve macro-economic transformations, technological effects, socio-political factors and policy changes which are difficult to expect (Geist and Lambin, 2001; Serneels and Lambin, 2001). This is true for deforestation which stands out among land cover change process in most countries due to the sharp contrast in the transition from forest to cleared land.

2.1.3. Monitoring land use/cover change

Understanding the dynamics and trends in land use and land cover change is a first step in decision making to combat the negative effects of the process. In the light of the quest for understanding, frequent monitoring becomes a tool to obtain such understanding. According to Lambin (1994) deforestation monitoring calls for the application of remote sensing and GIS in collection, processing and interpretation of data in assessing the nature, magnitude and rates of change. The earliest assessments aimed at providing reliable information on the process of on-going change in response to shortages of forest products. Identifying areas of current and potential deforested areas, quantifying and where possible establish a link with the driving forces at play (Achard *et al.*, 1998; Lambin and Ehrlich, 1997; Van Laake and Sanchez-Azofeifa, 2004). However Lambin and Ehrlich (1997) argued that broad scale assessment provides less information on the complexity social relationships, adaptations to specific ecological conditions and the local socioeconomic context.

2.2. Image processing

2.2.1. Image pre-processing and classification

Image pre-processing are essential in addressing sensor and platform geometric and radiometric distortions present in image data in order to ensure that information derived from the images are a true representation of real world situation.

Geometric distortions are inherently present in remotely sensed images. Geometric correction compensates for distortions due to numerous factors such as perspective of sensor optics; motion of the screening system, motion of the platform, altitude of platform, altitude and velocity; terrain relief; and curvature and rotation of the earth (Canada Centre for Remote Sensing, 2003; Lillesand and Kiefer, 1994). Systematic or predictable variations in nature can be dealt with by accurate modelling of the sensor and platform motion and geometric relationship between platform and earth however random errors can not be modelled rather geometric registration to known ground coordinate system is performed using ground control points (Canada Centre for Remote Sensing, 2003).

Radiometric correction is a process used to remove undesired influence of system noise, and atmosphere interference on image brightness values (Lillesand and Kiefer, 1994). The process is necessary due to variations in scene illumination and viewing geometry, atmospheric conditions and sensor noise and response. The variations are sensor, platform and day specific(Canada Centre for Remote Sensing, 2003).

2.2.2. Land cover mapping

The objective of land cover mapping is to mimic the earth surface as much as possible by delineating the different features as they exit in nature. Remote sensing have continued to play a key role in providing information from satellite images and/or aerial photograph for characterising spatial variation in land cover and monitoring temporal changes in land resources at various scales through classification procedures (Gholz *et al.*, 1996). Aerial photography had been the main source of land cover and use information, but high acquisition, processing and interpretation costs have reduced its use. Professionals in the field have resorted to the utilisation of multispectral satellite imagery for reasons of cost reduction, large areal coverage and availability in digital format (Bauer *et al.*, 2005). Multispectral image classification is the procedure used to automatically categorise all pixels in an image into land cover classes or themes based on the spectral patterns in the image data. The classification type described above is known as Spectral pattern recognition (Lillesand and Kiefer, 1994) Categorisation is numerically based on the different combinations of spectral reflectance and/or emittance from the different land cover features which is represented as DN values.. According to Hayes and Cohen (2006) associating individual pixel in an image with a single, discrete category assumes that each pixel represents a homogenous area on the ground however this becomes a matter of concern when the feature of interest is at a lower spatial resolution than that of the image. Classification methods broadly exist in two forms namely supervised and unsupervised. Supervised classification procedure relies largely on the analyst's familiarity with the area of interest and availability of adequate data in order to spectrally characterise the classes by selecting pre-determined cover types known as training areas (Kerle *et al.*, 2004). Unsupervised classification unlike former makes less demand on the analyst's knowledge in partitioning the image data. Cluster algorithms iteratively partition the image spectrally by determining statistical groups based on the numerical information (DN values) present in the image. However the analyst is required to specify the desired number of classes in the data set and merge and or split some groups in the output of the classifier. Hence unsupervised classification is not entirely independent of human intervention (Canada Centre for Remote Sensing, 2003).

Where there exists complex variability in the spectral response patterns for individual cover types as a result of variation within cover types (species) and site conditions, both classification methods are combined for better land cover categorisation. The combined method is termed as hybrid classification (Lillesand and Kiefer, 1994).

2.2.3. Change detection

Monitoring land cover and land use change are increasingly reliant on land use/land cover maps produced from multi temporal remotely sensed data. The goal of change detection is to discern those areas on digital images that depict change features between two or more imaging dates (Sader and Hayes, 2001). It exhibit the ability to quantify temporal effects from multitemporal data sets (Singh, 1989). Change detection has been an important tool in monitoring land use/cover change and deforestation in many studies (Bauer et al., 2005 ; Hayes and Cohen, 2006; Mertens and Lambin, 2000). Change detection procedures involve the use of multitemporal data set to distinguish areas that experienced a change in land cover: short or long term (Lillesand and Kiefer, 1994). The underlying principle of change detection is that a change in land use/cover must result in a change in surface reflectance; however the perceived change must be substantial than those cause by differences in sensor properties, atmospheric conditions and seasonal change effects. Change detection procedures require data set with accurate spatial registration and recorded on the same day of the year for the change detection to be effective. Although the list of change detection approaches is a non exhaustive one Singh (1989) has reduced them to two basic approaches namely;

- Simultaneous analysis of multitemporal data
- Comparative analysis of independently produced classifications from different dates

However strong these approaches are in detecting changes, there are some weaknesses. The first approach is made up of techniques such as univariate image differencing, image ratioing, vegetation index differencing, principal component analysis, change vector analysis and direct multidate classification. The output of the above change detection techniques are pixel values usually indicating qualitatively "change or no change. The weakness include unclear way of setting threshold between change and no change (Sader and Hayes, 2001); high sensitivity to inter-image misregistration and provision of little or no information on the nature of change (Singh, 1989).

The second approach requires two or more independent classifications of satellite images (Campbell, 2002). Post classification change detection prominently stands out in this category. It is the most commonly used quantitative method of change detection (Chen, 2002). It operates on two or more independently classified images as inputs and results in change map and change matrix. The reality of detected change is dependant upon the classification accuracy of the maps compared (Mertens and Lambin, 2000) However the post-classification approach provides ''from–to'' change information and the kind of landscape transformations that have occurred can easily be calculated and mapped (Bauer *et al.*, 2005) Food and Agriculture Organisation of the United Nations successfully applied post classification change detection technique in a survey of forest cover and change process in 1990 (FAO, 1996).

The technique employed in any change detection analysis is of crucial importance. The type of method implemented can profoundly affect the qualitative and quantitative estimates of the change (Muttitanon and Tripathi, 2005) and the type of image processing methods to adopt.

2.3. Fragmentation

Land use/cover change is a well-known phenomena that greatly affect natural landscapes. It is especially true in rapidly developing and urbanizing areas of most developing countries (Rainis, 2003). Landscapes respond to multiple disturbances, and the interactive effects of disturbances are important but difficult to predict (Turner, 1989).The complex interaction of social and environmental factors gives rise to a dynamic mosaic of human settlements, farmland and scattered fragments of both reforestation and deforestation in diverse forms within landscapes.

Bennett (1998, 2003) defines 'fragmentation' as a dynamic process of change that occur when large blocks of vegetation are incompletely cleared leaving multiple smaller blocks that are separated from each other. Changes to landscape patterns arising from fragmentation can be readily identified and described by measuring attributes. In dealing with fragmentation the most pressing issue is the transfer of forest to agricultural land use usually driven by traditional shifting cultivation and urban growth and development in smaller cities or peri-urban communities (Nagendra *et al.*, 2004). According to Zipperer (1993) forest fragment is an isolated patch of forest cover resulting patchy or disconnected deforestation a contiguous forest. The process of forest fragmentation has had three components: an overall loss of forest, a progressive fragmentation of surviving forest stands into smaller blocks, and an increasing spatial isolation of fragments through time (Bennett, 1998, 2003). Fragmentation emanates from the pressure increasing population and its associated high demand for goods and services exert on ecological systems. Where driving and conditioning factors exhibit a high degree of spatial variation, such as in the cases of soil conditions and market access, this spatial variation gives rise to spatially distinct land use patterns related to the variations in social, economic and environmental context.

Landscape fragmentation impact largely biodiversity and wildlife and sustainability of landscape (Nagendra *et al.*, 2004). Bennett (1998, 2003) identified loss of species in fragments; changes to the composition of faunal assemblages; and changes to ecological processes that involve animal species as the major impacts of fragmentation process on the fauna of remnant habitats.

Land cover fragmentation analyses are used frequently to help interpret the impact of land cover changes within a landscape, by calculating for each land cover class a range of metrics to describe fragmentation and spatial distribution, often from satellite-based land cover classifications (Southworth *et al.*, 2004). The advent of landscape fragmentation analysis techniques provided a new thrust to remote sensing science, greatly expanding the inferential capabilities of such research (Nagendra *et al.*, 2004). According to Herold *et al* (2003) such spatial metrics provide quantitative and aggregate measurement from thematic maps and shows the heterogeneity and dynamicity of a landscape at a specific scale.

2.4. Hotspot analysis

Land use/cover change and its various dimensions have been an issue of great concern politically and scientifically. This is due to the eminent role global aggregate these play in global change. Measurements and analysis of land use/cover change have often been done at the global level. Geist and Lambin (2001) acclaimed this trend to the need for data as input for carbon cycle analysis and global change modelling. FAO conducted a global forest survey using remotely sensed data in 1990 (FAO, 1996). Global studies have the tendency to generalize issues resulting in the masking of national and local level characteristics. According to Etter et al (2006) even regions and landscape levels show contrasting biophysical and socioeconomic characteristics which differentially affect the potential land use/cover change. Patterns of land cover change in most tropical developing countries relate significantly to anthropogenic impacts and are extremely complex, with changes occurring across multiple spatial and temporal scales (Southworth *et al.*, 2004). Van Laake and Sanchez-Azofeifa (2004) also agued that global statistics derived from administrative regions and ecological zones fall shot in incorporating spatial heterogeneity found in deforestation. Data on land-cover change are relevant for local decision-makers, and those data need to be linked with ground data on human activities (Geist and Lambin, 2001). Hence it is capital that studies in land cover changes are done in local areas where they are concentrated in order to establish a link with drivers. Areas with high concentration of land use/cover changes processes are herein termed as hotspots.

Hotspot analysis generally allows the identification of local areas with high concentration of a phenomenon within a landscape. According to Lambin and Ehrlich (1997) land cover change hotspot can be perceived at three levels: high rates of land cover change which are observed at present, or have been observed in the recent past; areas where land cover changes are likely to occur in the near future; and severity of the impact of the change. This study shall adopt the first definition but with respect to change in area extent over the period of the time frame of the images. This is because of its applicability to the study (changes in an area over two different dates). Achard *et al* (1998) categorised methodologies for identifying areas of fast forest transfers into four; report based information, direct and indirect indicators of forest change, change detection from remotely sensed data and logistic or explanatory models. All the method had limitations with regards to consistency, validation, data quality and scale. The method used to develop hotspot map of land cover change via eliciting information about deforested areas from forestry experts during the TREES hotspot experts meeting, though somewhat successful, has been criticized for its dependency on the quality of experts' knowledge, not replicable and difficult to link to drivers of change knowledge (Van Laake and Sanchez-Azofeifa, 2004). In the light of the above (Van Laake and Sanchez-Azofeifa, 2004) developed an objective satellite imagery based procedure for delineating deforestation hotspots in Costa Rica.

3. Materials and methods

3.1. Study area

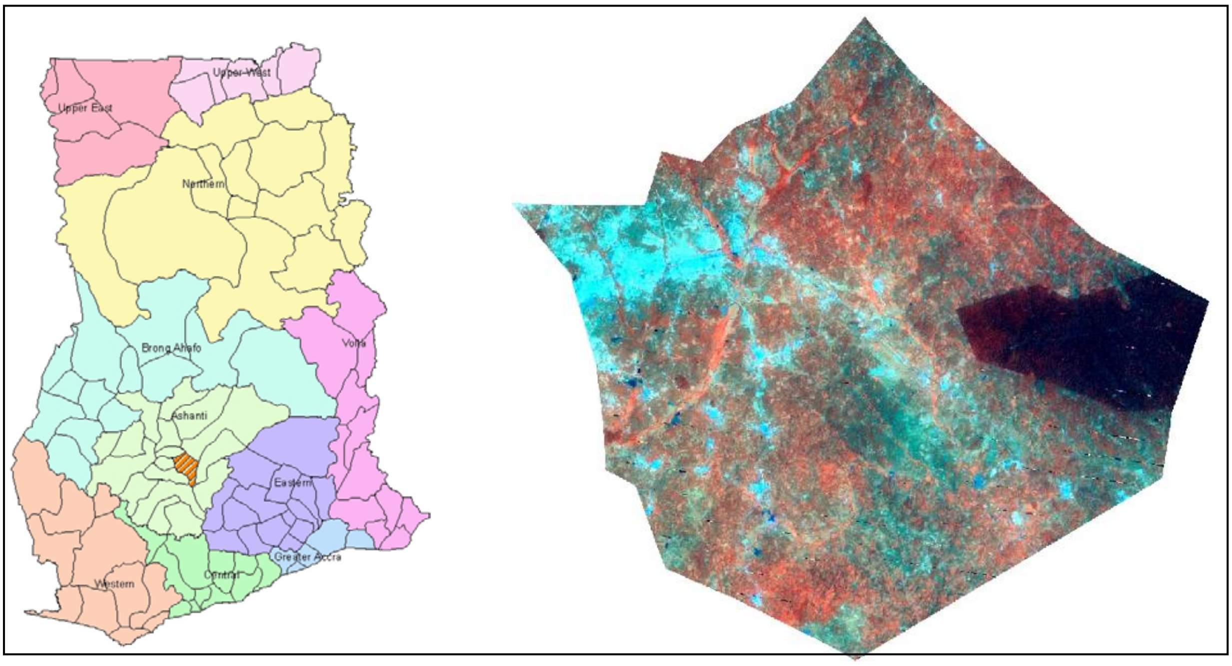

Figure 2: Regional map of Ghana showing the location of Ejisu-Juabeng Districts and unclassified Landsat ETM image (2004) of the northern part of the district

3.1.1. Location and demography

The study area is located in the Ejisu-Juabeng District. Politically the administrative district is positioned in the centre of the Ashanti region sharing boundaries with Kumasi and Kwabre districts in the east, Afigya Sekyere and Asante Akim North districts in the west and Bosumtwe Kwanwoma and Akim south Districts in south. It lies between latitudes 1°15' N and 1°45' N and longitude 6°15' W and 7°00' W with its capital Ejisu, located 20m away from Kumasi. The district covers an area of 637.4 square kilometres. The population of the district stood at 124176 as of 2000 (Ghana Statistical Service, 2003).

The northern portion of the district is going through rapid landscape transformation because of the proximity to a more densely populated and expanding Kumasi Metropolis. The study focus on the northern portions of the Ejisu-Juabeng District (figure 2)

3.1.2. Topography and drainage

The district is topographically situated in the Forest Dissected Physiographic region of Ghana which is underlined by pre-Cambrian rocks of Birimian and Tarkwaian formations. The area is generally undulating, ranging between 240 – 300 metres above sea level. The area is well drained with a number of different rivers and streams running through it, some of which are perennial where as others are seasonal. Prominent among them include Oda, Anum, Waropong, Bankro, Hwere, Bediwaa and Baffoe rivers. Occasional flooding is experienced in the inland valleys along river basins.

3.1.3. Climate

The rainfall pattern in the district is bimodal in nature with wet semi-equatorial climate. It is characterised by double maxima rainfall lasting from March to July and from September to late November. Mean annual rainfall recorded stands at 1200 mm. Relative humidity is usually fairly moderate but high during the rainy season and early mornings. Lying entirely within the tropical high forest zone of southern Ghana; it experiences annual temperatures ranging from 20°C in August and 32°C in March.

3.1.4. Vegetation and soil

The Ejisu-Juabeng Districts is endowed with a large tract of Moist semi-deciduous forest vegetation as categorised by Hall and Swaine (1976). The Bobiri Forest Reserve has a total area of 54.6 km^2 serving both production and conservation functions. It is one of the richest in terms of biodiversity in the country. The reserve is floristically diverse and endowed with large quantities of economic timber species which include *Triplochiton screloxylon, Terminalia superba, Nesogodonia papaverifera, Aningeria robusta, Chrysophyllum albidum* and various species of *Entandrophragma* (Bureau of Integrated Rural Development, 2001). Also present is the endangered species *Pericopsis elata* trade in which has been banned.

The off reserve areas mainly consist of annual crops, cash crops, fallow lands forest patches and riparian vegetation along the rivers and streams. It is important to note that forests outside the reserves are unsustainably logged by illegal and legal loggers. The most predominant plant is mainly *Chromolena ordorata*.

There are eight soil types in the district namely granite based Kumasi-Offin Compound, Bomso-Offin Compound and Swedru-Nsaba Simple Associations; Birrimian rock based Bekwai-Oda Compound, Kobeda-Eschiem-Sobenso-Oda Complex and Atunkrom-Asikuma Association; Tarkwaian based Juaso-Mawso association and lastly the superficial deposites based Boamang-Suko Simple Association (Gaespenu and Associates, 1996). All these soil types can support some form of agriculture ranging from annual crops to cash crops.

3.2. Materials

3.2.1. Data

The study was based on time series of two Landsat satellite imageries. These consisted of Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper plus (ETM) acquired in the first weeks of January 1986 and February 2004 respectively. The images were selected from the ITC database based on availability and suitability in reducing seasonal changes which are problematic in detecting change. Ideally one or more images between these periods would have aided a better understanding of trends however available images covering the 1990s have cloud cover more than the acceptable 10 %. A 1:25000 topographic map (hardcopy), river and road maps were also used as guide for field navigation to pick ground control points for geo-referencing, classification and accuracy assessment. Informal interactions and personal observations formed an important component of the data for the study.

3.2.2. Software

Software used in the study include ArcGIS 9.1, ERDAS imagine 8.7, Fragstats 3.0 and DNR Garmin.

3.3. Methods

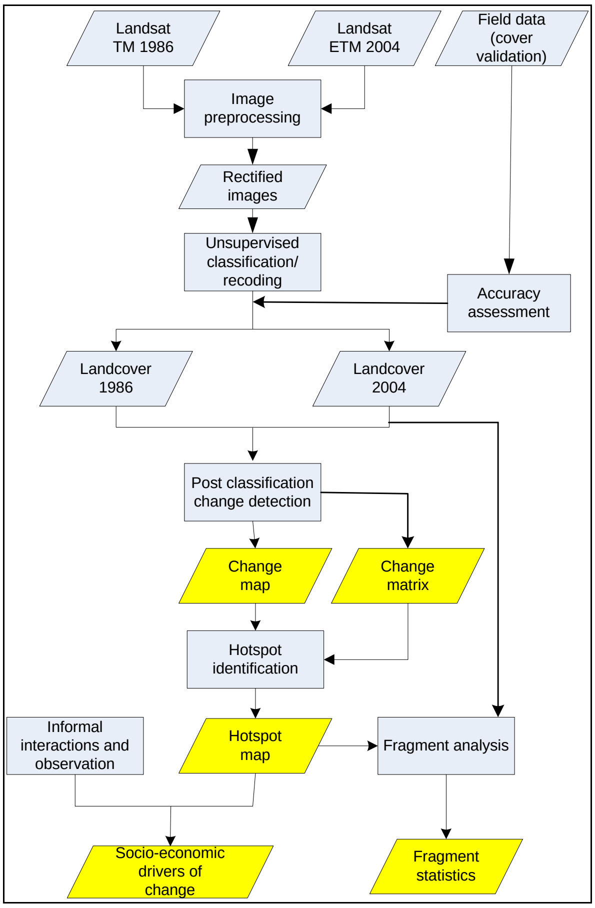

Figure 3: Methodological approach flow chart

3.3.1. Data pre-processing

The two remotely sensed Landsat images were subjected to image pre-processing procedures using ERDAS Imagine 8.7 version. As part of pre-processing, both Landsat images were resampled to 28.5*28.5 meter pixel size using the nearest neighbour resampling method to preserve the original image radiometry (Serra *et al.*, 2003). The nearest neighbour resampling method assigns the DN value of the closest original pixel to the new pixel without being changed and retains all spectral information, which makes the resampled image efficient in classification (Kerle et al., 2004). The two Landsat images which originally were in global coordinates, UTM Zone 30/WGS 84 were geo-referenced to the local coordinate system, Traverse Mercator projection in the Legion datum (appendix 8.1 table A). A maximum of 20 pairs of GCPs were picked at road intersections and river confluence from the road and river digital maps respectively and the TM 1986 image to determine the transformation coefficients using 2nd order polynomial transformation. Afterwards the ETM 2004 was also co-registered to the geo-referenced TM 1986. Changes that have taken place between road junctions on images and roads make it difficult to picking more GCPs to increase accuracy. The geo-referencing processes successfully yielded a total root mean square error for positional accuracy of 7.21 m each which is 0.2 of a pixel. The error margin was acceptable for the study because it is within a pixel (Bauer et al., 2005 ; Leica Geosystems GIS and Mapping, 2003)

Radiometrically, much could not be done to the ETM 2004 although hazy. The correlation between the visible regions was less than 0.8. Conversely the TM 1986 was corrected for haze using the haze reduction module in ERDAS 8.7. For multi-spectral images, the method is based on the Tasseled Cap transformation which yields a component that correlates with haze and removes it. The image is then transformed back into RGB space (Leica Geosystems GIS and Mapping, 2003).

On the field, a Garmin 12XL GPS was used to collect 300 GCPs (polygons and points) from the different land cover types by purposive sampling based on accessibility since most areas were waterlogged. DNR Garmin software was used to extract field points from the GPS and converted into a shapefile. Additional six points were picked on survey pillars of known true coordinates and used in least square computations to correct the inherent errors in the GPS and transformation shifts in moving from global Lat/Lon WGS 84 to local coordinate system. Below is the transformation equation:

$X = Ax + By + C$ ………. (1)
$Y = -Bx + Ay + D$……….. (2)

Where X Y are the corrected coordinates, x y are the error inherent coordinates and their coefficients are: A = 1.002699091, B = 0.000504208, C = -3281.618524, D = -1608.329102

3.3.2. Image classification

Mas *et al* (2004) observed that the presence of frequent thick cloud cover is a critical problem in tropical countries and limits the amount of available useful images. The study area is not an exception to this. Clouds and shadows on the TM1986 were selected as areas of interest and filled with constant values of 1 to avoid them taking part in the mapping. Land use mapping may be defined as a process of segmenting images into a mosaic of parcels with each parcel assigned to a class (Campbell, 2002). Considering the size of the different land cover types which mostly were less than the spatial

resolution of the image available and complex variability in the spectral response patterns for individual cover types, unsupervised classification would be the unbiased method to apply (Lillesand and Kiefer, 1994).
However, the ideal situation which is a one to one exclusive relation between spectral classes and land use/cover type could hardly be achieved for reasons explained above. A land use/cover type derived from multi-spectral data using appropriate classification techniques such as unsupervised classification can be problematic with an individual spectral class representing more than one land use/cover type. This situation result when spectral classes too broad and may be distinguished if a larger number of narrower spectral classes are sought (Serra et al., 2003).

In the light of the above relations the strengths of both unsupervised and supervised classification techniques were exploited in the study. In avoidance of having relatively broad clusters which may produce false results or a large number of very pure clusters which is costly in terms of time required for cluster labelling and high computational resources demand, Mundia and Aniya (2006) used 40 optimum spectral classes to capture the necessary variation in land cover.

In this study, both images were classified into 50 spectral classes each using the ISODATA algorithm of ERDAS imagine 8.7 to perform unsupervised classification. The TM 1986 and ETM 2004 images were aggregated into 7 (clouds and shadows inclusive) and 6 major land cover types of the study area respectively. The corrected field points and their respective cover types were used for class identification and validation during the aggregation procedure for the ETM 2004. The TM 1986, unlike the former lacked reference points hence its aggregation was based on cover types in 2004 which are likely to have not changed and farmers views. The use of field points in class identification introduced elements of supervised classification. Simple forest and non forest classification leads to information loss on forest fragments and change density (FAO, 1996). The main land use/cover classes considered include forest, fallow land, agriculture land, Bamboo-raffia complex, grasses and build-up areas. The “salt and pepper” appearance of classified images resulting from per pixel classification were then smoothen out in both images. Smoothening of both classified images was achieved by applying a 3*3 majority filter (Lillesand and Kiefer, 1994).

The accuracy of the classified ETM 2004 image was assessed using 60 reference points to obtain error matrix and Kappa statistics.

Table 1: Description of the main land use/cover classes in the study area

Land use/cover	Description
Forest	Includes the moist semi-deciduous forest (Bobiri reserve) and other areas high tree cover density (both open and closed canopy) reaching above 15m
Fallow	Land which have been logged or farmed in the past and now left to recover. It is made up of thickets of shrubs and tree ranging from 2m to about 15m
Agriculture	Consist of land put under any form of cultivational use such as annual cropping, cocoa and oil palm plantations.
Bamboo-raffia	Predominantly *Bambusa vulgaris* and raffia palm mixture usually found along water ways and marshy areas. Such areas harbour non-tree vegetation like ferns and water cocoyam
Grass	Includes all forms of grasses, ranging from creeping species up to tall elephant grass. Sparsely distributed trees
Build-up/bare	Areas with high intensity of infrastructure and land areas of exposed soil surface resulting from human activities or natural causes. Usually contains sparse vegetation cover and relicts of secondary forest.
clouds	Consist of areas in the image that was covered by clouds and its associated shadows

3.3.3. Change detection

Change detection has different meanings to different users. However it invariably involves detection of change in the form of location and extent, and sometimes the identification (Muttitanon and Tripathi, 2005). In order to identify changes in LULC in terms of areal extent, spots of change and the path of change post classification change detection technique was used. As explained above this method required two independently classified images as inputs resulting in a thematic map and a change matrix as outputs. The classified and smoothened thematic maps TM 1986 and ETM 2004 were loaded in the matrix dialogue of ERDAS 8.7 to indicate changes between both images in the form of change map. The change matrix derived from raster attributes of the change map revealed the class-to-class transitions observed between 1986 and 2004 (Mas *et al*., 2004). As discussed above the over all accuracy of the change detection is dependent on the individual accuracies of the two classified maps used. This is determined from the multiplication of the classification accuracies. The major limitation of the change detection conducted in the study is that the accuracy of the change detection can not be accounted for due to lack of reference data to assess the accuracy of the TM 1986.

3.3.4. Hotspot identification

Hotspot analysis was applied to statistically identify forest areas undergoing prevalent transfers to other land use/cover types. This was done by comparing forest between 1986 and 2004. Areas that have recorded land use/cover transfers between 1986 and 2004 were detected from land use/cover maps derived from TM1986 and 2004ETM Landsat images respectively. Both thematic land use/cover maps were taken through a series of initial steps in ERDAS to ensure their suitability for the process. The individual land use/cover classes in the 1986 were clumped to uniquely numbered discrete patches in order to set thresholds with regards to conditions pertaining in the area. Small patches covering less then 5 pixels (0.406125ha) were initially removed to reduce computational time cost (Imbernon and

Branthomme, 2001). Forest patches with areas less than 78 ha were also removed from the TM1986 thematic map used in the analysis. This step was in avoidance of recording 100% deforestation in areas when relatively small patches of forest below this threshold in 1986 are cleared by 2004. Situations where such patches are spread across the entire image, almost the entire area becomes hotspot. Van Laake and Sanchez-Azofeifa (2004) considers such local spikes in deforestation as incidental and not structurally related to major land use/cover changes process of the area.

Binary raster maps of “forest and others” were made from both ETM 2004 and TM86 (with threshold) and both crossed to identify deforested areas within the northern part of the district in ArcGis 9.1 environment. The “others” consist of agriculture, bamboo-raffia, grass, fallow and build-up/bare. The grid systems of the binary deforested and TM86 maps are resampled to a coarser resolution using mean aggregate function with a cell factor of 5. The cell factor was chosen taking into consideration the configuration of forest cover in the area, however the output raster should contain enough input points to produce sensible statistics. Lastly forest transfer rate was calculated using the aggregated outputs as follows:

Forest transfer rate = (Transferred forest/ForestTM86)*100

For better understanding, the forest transfer rate is express as contours for presentation. Those areas with more than 25% transfer and 300m buffer zone around them are herein referred to as hotspots. The 300m buffer zone around the deforestation contour is considered as next possible area to be cleared of forest. The 300m buffer was chosen base on the nature of the human activities pertaining to the area. The identified hotspots were manually digitised and labelled with names of near by towns for easy identification and in-depth analysis.

3.3.5. Statistical analysis

The statistical analysis was mainly fragmentation analysis. Fragmentation analysis were applied to interpret the impact of land use/cover transfers within the landscape, by calculating for some elements of the land use/cover class of interest (forest) a range of spatial metrics to describe fragmentation and spatial distribution pattern in the study area (Southworth et al., 2004). FRAGSTATS 3.3 is a spatial pattern analysis program for thematic maps which quantifies the areal extent and spatial distribution of patches (i.e., polygons on map coverage) within a landscape (McGarigal and Marks, 1994). FRAGSTATS computes many different metrics like density, area, shape, core area, diversity, connectivity and distance to nearest neighbour; on each patch in a thematic map, each class in a thematic map and the entire landscape (McGarigal *et al.*, 2001).

Fragment analysis was achieved at two levels namely; whole study area level for both 1986 and 2004 to compare assess changes in fragmentation due to land use/cover transfers, and also in hotspot level to assess dynamics of forest transfers. At the whole study area level metrics like number of patches, largest patch index, patch density and mean patch size were computed whiles total core area, mean core area, and total core area index were added at the hotspot level. Table 2 below describes these metrics. Maps in ERDAS imagine formats were exported to generic binary, 8 bits signed formats to make them acceptable as inputs in spatial computations.

Table 2: Spatial metrics used in the hotspots of the Ejisu Juabeng District

Metric	Description
Number of patches	Number of patches in a particular class in the landscape
Largest patch index	The percentage of the total class area occupied by the largest patch
Mean patch size	The sum of all patch areas in a class divided by the number of patches in the class
Patch density	Number of patches of a class per 100 hectares
Total core area	Sum of forest patch interior area. Where depth-of-edge from the perimeter is arbitrary set at 100m
Mean core area	The sum of all forest core areas divided by the number of patches present.
Total core area index	Quantifies the total core area of forest as percentage of the total forest area

4. Results

4.1. Land use/cover classification

The unsupervised classification approach yielded two land use/cover maps from both TM1986 and ETM 2004 Landsat images of the study area. The maps categorised the area into six main land use/cover classes as elaborated in Table 1. The classified land use/cover maps of the Ejisu-Juabeng District are shown in figures 4 and 5 below respectively.

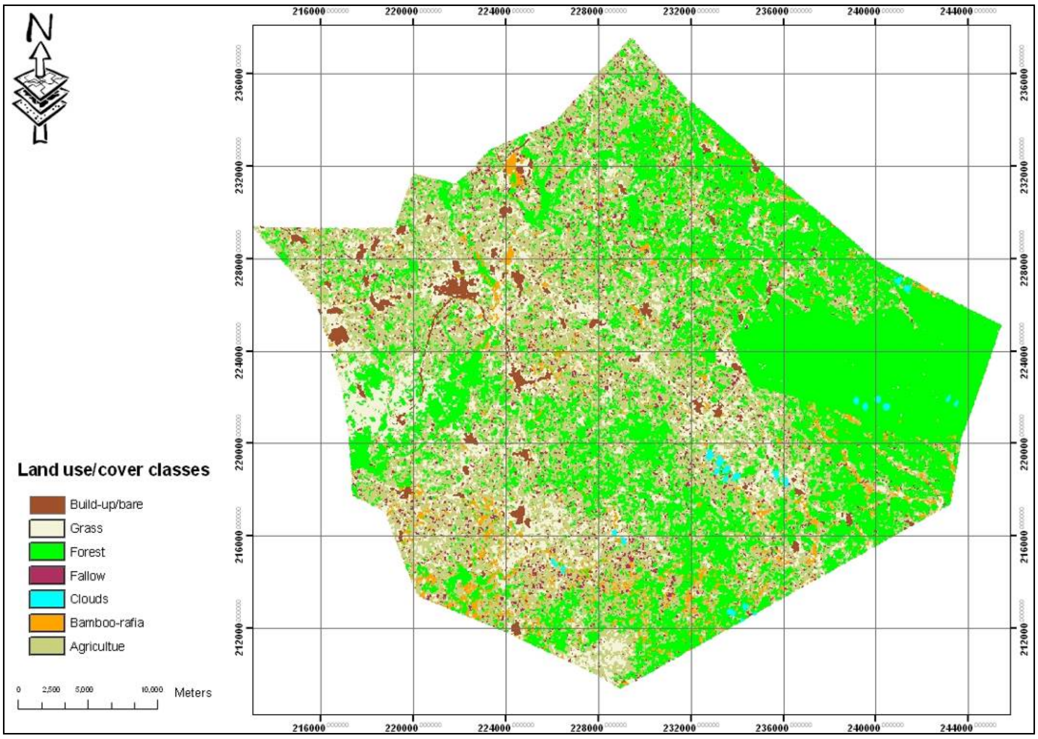

Figure 4: Classified land use/cover map of the Ejisu_Juabeng District in 1986

In the 1986 land use/cover map above, forest is mainly found in the north-eastern and south-eastern portions of the area with a few patches scattered across the entire area. Agriculture and grass are predominant in western part and around towns while the others are scattered across the landscape with bamboo-raffia restricted to marshy areas along river courses. Table 3 revealed that forest, agriculture and grass form the major land use/cover in the study area occupying 40.05%, 36.02%and 13.99% of the area respectively in 1986. It is followed by bamboo-raffia (3.86%), fallow (3.73%), and lastly build-up/bare (2.35%).

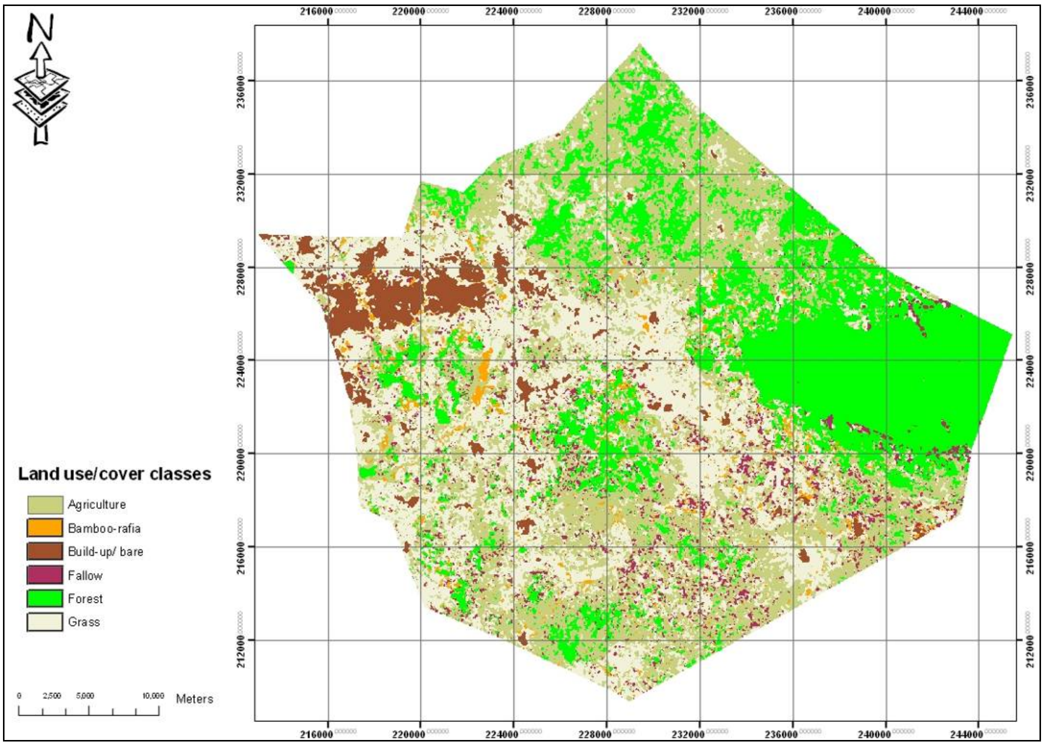

Figure 5: Classified land use/cover map of the Ejisu-Juabeng Distict in 2004

Forest is found in patches mainly in the northern and central portions, however the forest reserve in the north-east exist a large homogenous patch. Agriculture spreads across the entire landscape but the middle and partly southern portions, which have been taken over by grass. Whiles fallow is scattered among agriculture, build-up/bare is predominant in the north-western corner. Bamboo-raffia exists as strips along water ways. In 2004 the area experienced a redistribution of class areas as shown in table 3. Agriculture, grass and forest form the major land use/cover in the study area occupying 33.75%, 29.29%and 25.19% of the area respectively. Following are build-up/bare (4.82%), fallow (4.49%) and bamboo-raffia (2.46%) in that order.

Table 3: Land use/cover classes and their areas for 1986 and 2004

Land use/cover	1986		2004	
	Area (ha)	%	Area (ha)	%
Forest	20385.04	40.05%	12824.62	25.19%
Fallow	1900.096	3.73%	2285.996	4.49%
Agric	18337.44	36.02%	17180.31	33.75%
Bamboo-raffia	1964.183	3.86%	1251.515	2.46%
Grass	7121.158	13.99%	14908.44	29.29%
Build-up	1196.688	2.35%	2453.726	4.82%
Total	50904.6	100.00%	50904.6	100.00%

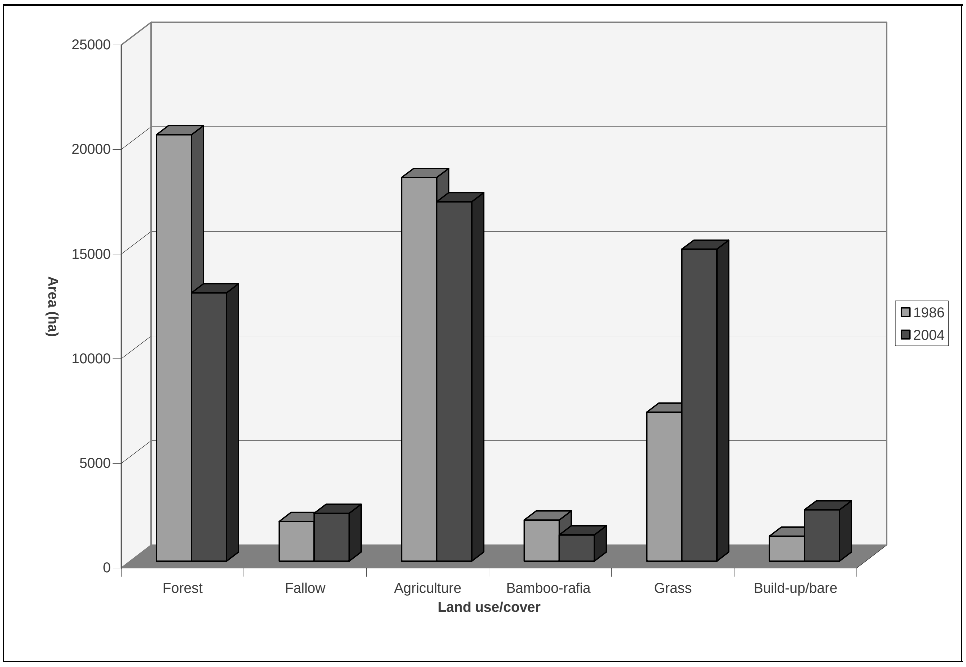

Figure 6: Land use/cover proportions in the Ejisu-Juabeng Distict from 1986 to 2004.

4.1.1. Classification accuracy

The land use/cover map of 2004 yielded an overall accuracy of 76.67% when the classified image was compared on a class-by-class basis with 60 transformed ground control points from the field in a confusion matrix. For reason of obtaining the level of significance further evaluation with Kappa statistics was conducted and yielded 0.71 as the overall (appendix 8.1, table B). However nothing can be reported on the accuracy of the TM 1986 image.

4.2. Land use/cover transfers

The comparison between the 1986 and 2004 land use/cover maps above revealed various degrees of changes in the area resulting from multiple transfers of land use/cover classes. The graph in figure 6 depicts the extent transfers among the land use/cover classes. Generally all six land use/cover classes experienced change in size from 1986 to 2004. Figures 6 and 7 show that forest, agriculture and bamboo-raffia decreased in areal extent while build-up/bare, fallow and grass increased over the 18 year period under study. Forest and grass experienced the most negative and positive changes respectively in the Ejisu-Juabeng District. Whiles forest lost a substantial area of 7560.42 ha which is about a third of the previous forest extent and 40% of total area change, grass conversely increase by gaining 7787.28 ha contributing 41% of the total change. In order of reducing size, agriculture and bamboo-raffia follow with 1157.13 ha and 712.67 ha losses respectively. However the decrease bamboo-raffia and agriculture formed 6.66 % and 3.78% the total area change

On the other hand, like grass, build-up/bare increased to more than double the size in 1986 from 1196.69 ha to 2453.73 ha in 2004. Also fallow appreciated in area with 2286 ha in 2004 compared with an initial area of 1900.1 ha in 1986.

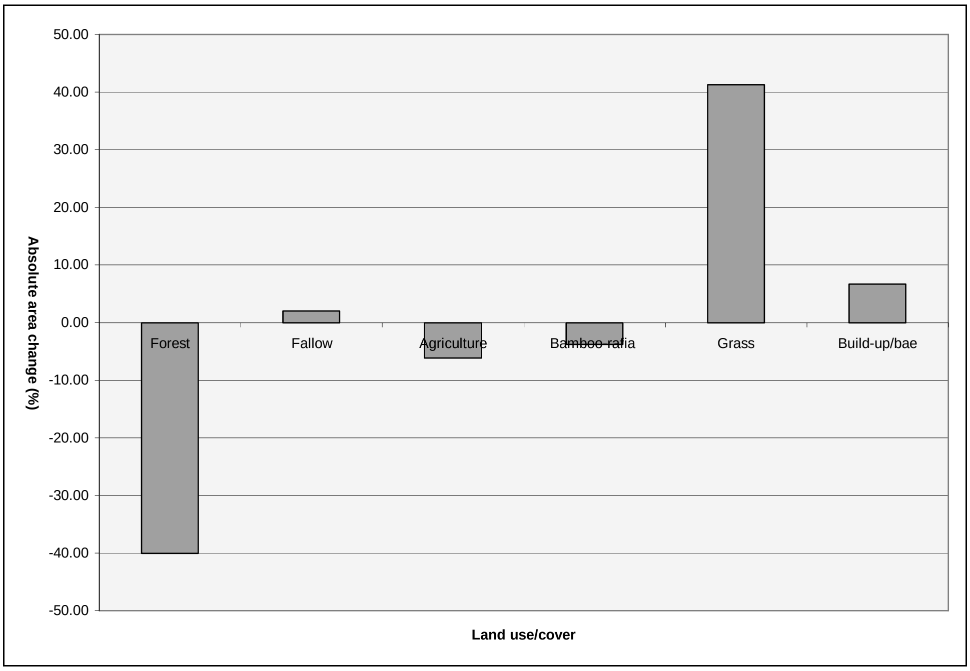

Figure 7: Percentage contribution of individual land use/cover to total change at district level

4.2.1. Land use/cover transfer Map

The landscape of the Ejisu-Juabeng District has been transformed through complex transfer of areas under a particular land use/cover in 1986 to another in 2004 as depicted on the change map in figure 8. The diagonal of table 3 shows that the proportion of the landscape that remained stable is 40.89%. Build-up/bare experienced the highest persistence whereas agriculture had least among man made classes. Grass emerged highly persistent and bamboo-raffia the least when compared with other natural vegetation classes.

Table 4: Land use/cover transfer matrix of theEjisu-Juabeng District between 1986 and 2004

	Land use/cover 2004						
Land use/cover 1986	Forest	Fallow	Agric	Bamboo-raffia	Grass	Build-up/bare	Total area 86
Forest	9540.2823	817.9357	6591.4087	392.9665	2855.0587	187.386	20385.0379
Fallow	227.43	105.9174	775.2926	49.7097	676.1169	65.6298	1900.0964
Agric	2338.7926	947.5708	6945.306	491.2488	6813.2342	801.2846	18337.437
Bamboo-raffia	190.2289	115.0146	862.5282	87.8042	682.4524	26.1544	1964.1827
Grass	509.4432	285.1809	1924.0578	206.7176	3478.9479	716.8106	7121.158
Build-up/bare	18.438	14.3768	81.7123	23.0679	402.6323	656.4604	1196.6877
Total area 2004	12824.615	2285.996	17180.3056	1251.515	14908.442	2453.726	50904.5997*

*Shaded box is the total area of the study area.

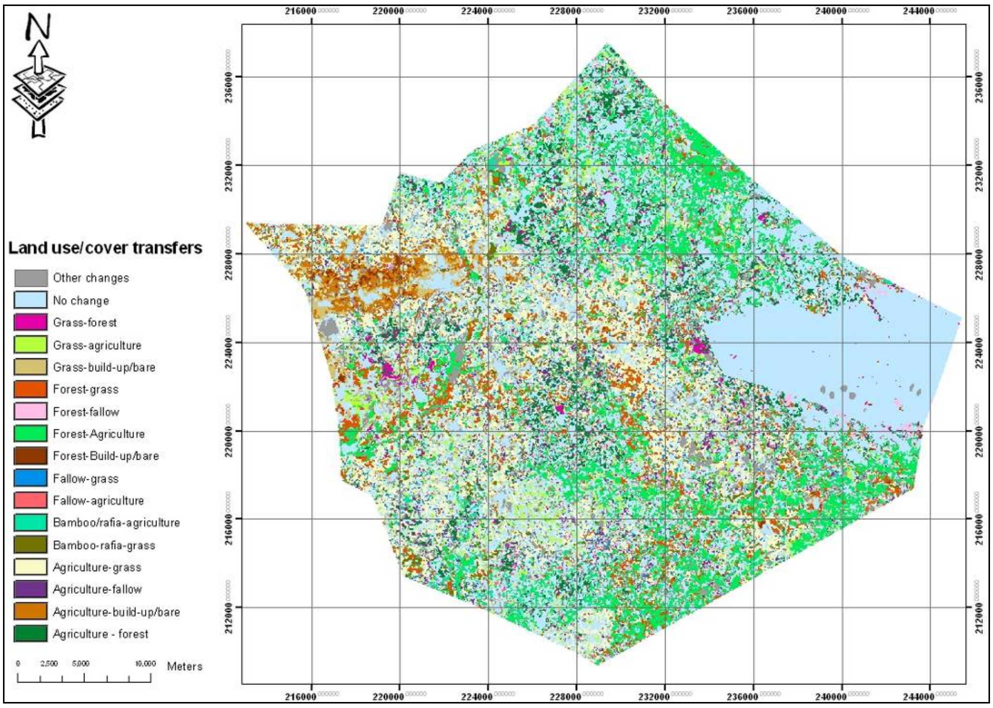

Figure 8: Major land use/cover transfers in the Ejisu-Juabeng District from 1986 to 2004.

With a transfer of 6813.23 ha, agriculture made the single highest transfer to grass. However the reverse transfer for the period was about two-thirds lower though substantial in the order of transfers. This large transfer to grass almost paid by transfer from forest to agriculture constituting 6591.41 ha. Nevertheless grass is also receiving immensely from forest. The reverse transfer to forest from both agriculture and grass are not enough to equate the loss. Transfers from agriculture to fallow and the reverse are marginally different. Apart from grass which received 402.63 ha from build-up/bare all transfers from this class are the least in all classes however it is making substantial gains from grass (716.81 ha) and agriculture (801.28 ha). Bamboo-raffia transfer to agriculture is 862.53 ha yet receives unsubstantial amount of 491.25 ha in return.

4.3. Fragmentation at study area level

Table 5: Patch statistics at the study area level for 1986 and 2004

Patch indicators	1986	2004
Number of patches (NP)		
Forest patches	4421	2115
Other land use/cover	1859	696
Largest patch index (LPI) (%)		
Forest	9.82	7.49
Other land use/cover	30.58	40.55
Mean patch size (MN) (ha)		
Forest	4.62	6.06
Other land use/cover	16.43	54.76
Patch density (PD)		
Forest	4.82	2.30
Other land use/cover	2.02	0.76

The study area has undergone changes in pattern attributes over the 18 year period. There has been a general reduction in the number of patches of forest and other land use/cover from 1986 to 2004.

However from 4421 to 2115 patches, forest had more fragments in both years than other land use/cover patches. The distribution patch area in figure 9 a and b is skewed to right for both forest and other land use/cover in both years. About 90% of the patches have sizes below 16 ha for both forest and other land use/cover in both 1986 and 2004.

Forest recorded lower largest patch index compared with other land use/cover for both years. Largest patch index of forests declined by 2.33% between the two years whiles that of other land use/cover appreciated by 9.97%. Patch density of forest follows a similar trend like forest LPI but other land use/cover was different from its largest patch index. Mean patch size shown increasing trends between both years however forest size was least in both year when compared with other use/cover.

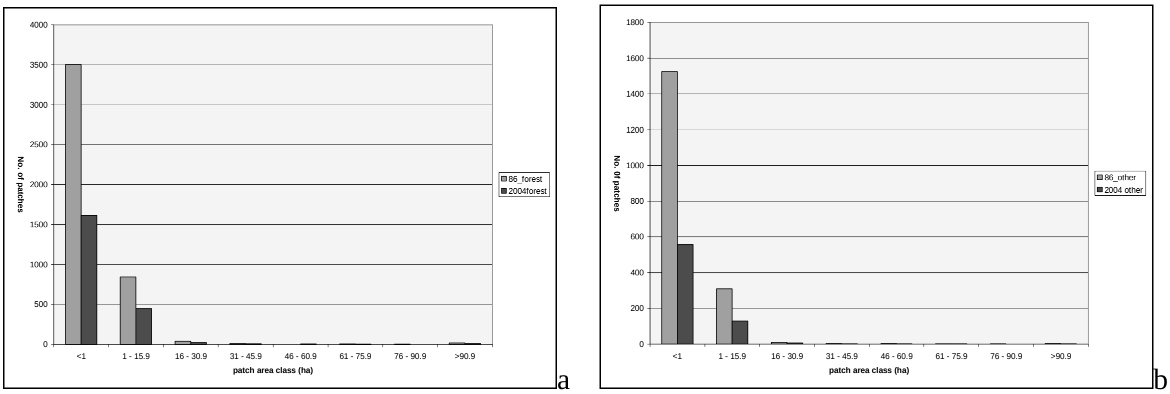

Figure 9: Patch area distribution for (a) forest and (b) other land use/cover

4.4. Hotspot analysis

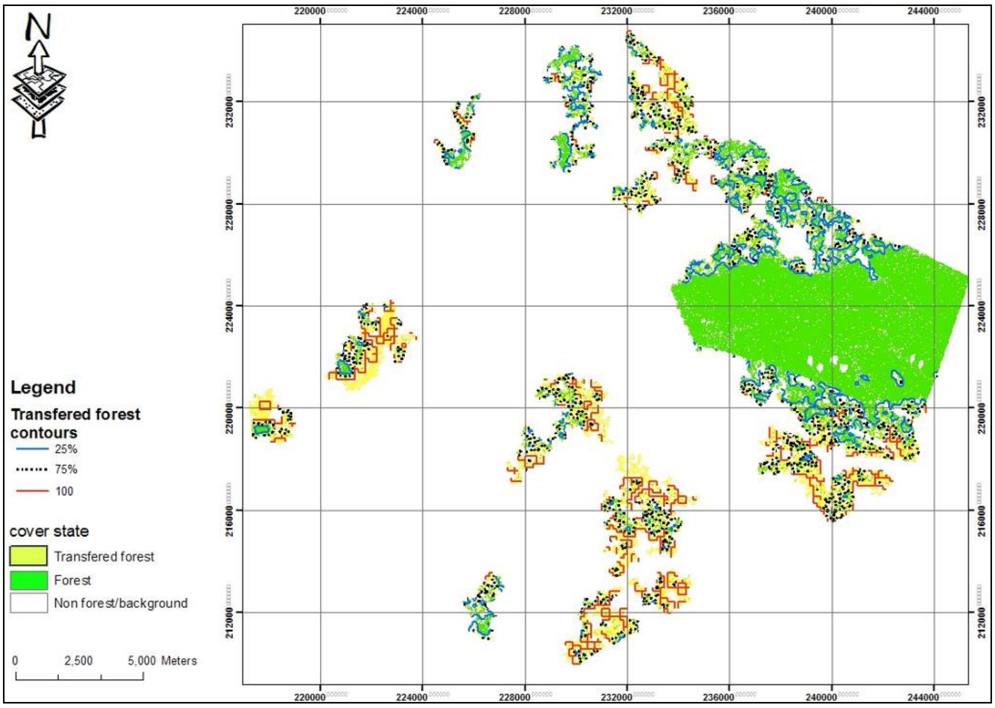

Figure 10: Forest transfer contours

The deforestation contours show areas which have undergone substantial forest transfer by 2004 in detail. The transfers at every point is graded into percentages and presented in contours. Blue, black dash and red contours represent 25%, 75% and 100% forest transfer isolines respectively. The 25% isoline constitutes the basis for hotspot delineation.

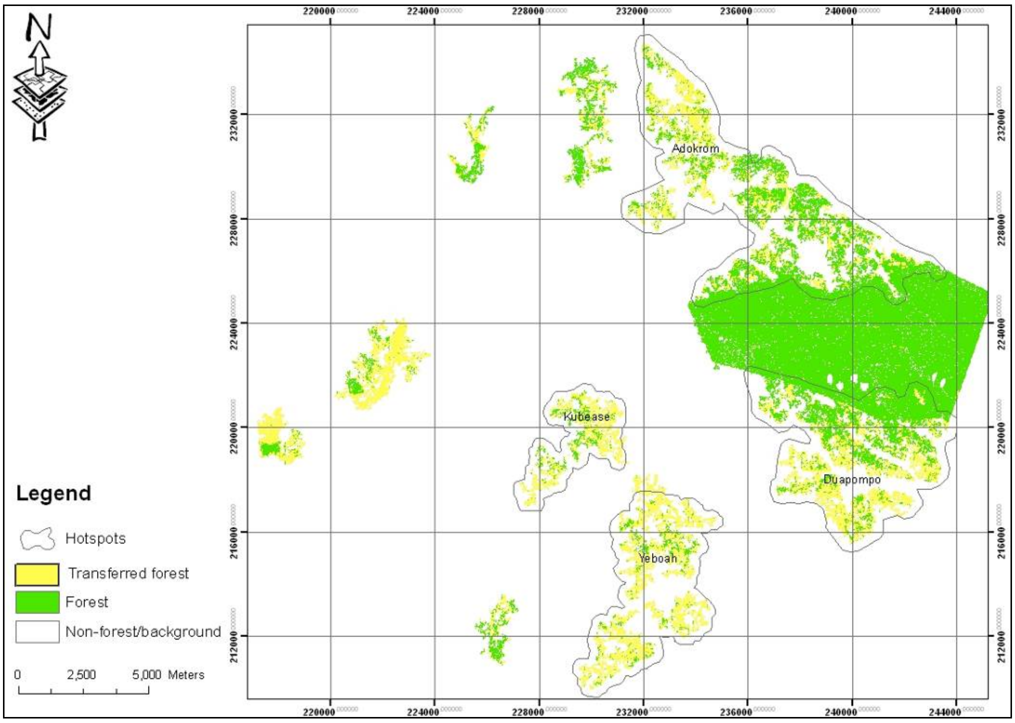

Figure 11: Identified forest transfer hotspots within the Ejisu-Juabeng District

In total 9 hotspots (figure 11) were derived from the forest transfer contours. However four major ones were buffered for further analysis (table 6). These include Adokrom, Duapompo, Kubease, and Yeboah.

Table 6: Patch analysis of six selected forest transfer hotspots and Ejisu-Juabeng District in 2004

Indicator unit	**Hotspots**				**other lands**	**District**
	Adokrom	**Duapompo**	**Kubease**	**Yeboah**		
Land area (ha)	4600.83	3327.14	1135.53	2373.48	39646.57	50956.10
Forest(ha)	1853.72	1229.18	170.41	159.36	6115.59	9537.36
Forest (%)	40.29%	36.94%	15.01%	6.71%	15.43%	18.72%
Transferred forest (1986-2004)(ha)	1305.61	1143.89	455.35	1208.22	6767.91	10874.32
Transferred forest (1986-2004) (%)	41.33%	48.20%	72.77%	88.35%	52..53%	53.27%
Other land use/cover(ha)	1441.50	954.07	509.77	1005.89	26763.0	30544.42
Other use/cover (%)	31.33%	28.68%	44.89%	42.38%	67.50%	59.94%
Reforestation (1986-2004) (ha)	407.83	158.63	97.71	51.25	2624.30	3289.04
Reforestation (1986-2004) (%)	18.03%	11.43%	36.44%	24.33%	30.03	25.64%
Patch indicators						
Forest patches	325.00	203.00	124.00	167.00	1897.00	2651.00
Largest patch index (%)						
Forest	9.43	16.88	0.99	0.34	4.1323	6.59
Other land use/cover	1.58	4.12	5.22	6.14	27.8724	30.61
Mean patch size (ha)						
Forest	5.70	6.06	1.37	0.95	3.2238	3.60
Transferred forest	1.81	3.62	2.60	5.89	1.2916	1.70
Other land use/cover	3.03	3.77	4.81	4.74	26.8706	16.43
Reforestation	0.59	0.53	0.78	0.35	0.9655	0.86
Patch density (#/100ha)						
Forest	2.46	3.44	5.77	3.61	2.0691	2.89
Transferred forest	5.48	5.36	8.14	4.43	5.7154	0.75
Other land use/cover	3.61	4.29	4.93	4.59	1.0864	2.03
Reforestation	5.28	5.04	5.86	3.18	2.9646	4.17
Core area indicators (forest edge depth 100m)						
Total core area (ha)	314.18	367.46	0.57	0.24	3406.008	4472.82
Total core area (%)	6.83	11.04	0.05	0.01	8.59	8.78
Mean core area / patch (ha)	0.97	1.81	0.00	0.00	1.7955	1.69
Total core area index (%)	16.95	29.89	0.33	0.15	55.69	46.90

4.4.1. Adokrom

Overlapping the northern boundary of the Bobri Forest Reserve, Adokrom has experienced forest transfers at a rate of 41.33% with the northern portion transferring more than the south which is close to the protected area. However it still has a substantial 40.29% of forest cover remaining. Although low, regenerated forest constitutes 18.3% of the total forest in the area in 2004. As the largest hotspot, it has 325 forest patches which is the highest in the hotspot level but substantially lower when compared with that of the district. However the largest patch index of forest is fairly bigger with reference to the district. The mean size of the patches of forest is 5.70 ha which is the second largest among the hotspots and almost twice the size that of both other land use/cover of the hotspot and the entire district. However the patch density of forest is higher than other lands by a small margin though it is the least among the hotspots.

About 80% of the change in land use/cover in this hotpot occurs in forest and agriculture (figure 12). Of this value the proportional decrease in forest area is about 43% and the remaining is for increasing agriculture. Next in the order of significance is grass which made an increase of 8.7% which is relatively low compared to the two former cover types. The least change in the hotpot is in fallow (below 1%). Bamboo and raffia decreased by two-thirds of initial size making 5% of the total change areas

4.4.2. Duapompo

As the second largest hotspot in term of area, the landscape of Duapompo mainly consist of agriculture lands with a few hamlets and some marshy grasslands low lying areas. Agriculture is mainly annual cropping and two main types cocoa plantation (with and without trees). Like Adokrom this hotspot also overlap the forest reserve but in the south. In spite of the significant forest transfers of 48.20% remaining forest forms 36.94% of the landscape area (table 6). However regeneration is the lowest so far constituting only 11.43 % of the total forest available in 2004. Notable is the high values of largest patch index (16.88%) which is more than double the district value (6.59%) and core area (11.04%) higher than those recorded in other hotspot and the district.

Duapompo unlike Adokrom had four land use/cover types making positive changes in by 2004 (figure 12). This constitute about 50% of the total change with agriculture recording highest followed by grass and fallow in a decreasing order. Forest and bamboo-raffia share the remaining 45% and 5% proportions respectively.

4.4.3. Kubease

With 36.44% Kubease recorded the highest regeneration relative to the existing total forest cover. The forest transfer rate stands at 72.77% which is the second highest in the hotspots leaving 15.01% of the remnant forest. The amount of forest transferred over the 18 years is 40.07% of the total landscape of the hotspot. The remaining forest has a patch density 5.77 and a commensurate high transferred forest patch density of 8.14 all higher than the values recorded for the district.

In figure 12 Kubease differs from the fist two hotspots in terms of the nature of proportions of change in land use/cover. Forest contributes about half the total change in the hotspot but in the negative direction whiles the remaining 50% is contributed by other land use/cover. Agriculture and grass are almost at par with about 20% and fallow and bamboo-raffia with 4% contributions to the total change in Kubease.

4.4.4. Yeboah

This hotspot is mainly agriculture constituting scattered few plantations of palm, orange and cocoa. The majority of the farming activities are annual cropping. In the marshy valleys exist a mixture of sugar cane, sugar beets and grass forming the minority cover in the landscape. The highest rate of forest transfers occurred in Yeboah with rate exceeding the district rate by 35.08%. Supporting this is the relatively large mean patch area of other land use/cover (4.74 ha), transferred forest (5.89 ha) and the significant 2.24 growth rate of other lands. The recovery of forest is 24.33% and highly comparable with regeneration at the district level. This largest patch index at hotspot is the lowest 0.34%.

The distribution of individual proportions of change in Yeboah looks similar to that of Duapompo. Although negative, forest had the largest proportion of change in the hotspot. On the positive side the largest contribution to the change is from agriculture followed by grass, fallow and build-bare which had least proportion of change irrespective of the direction. Bamboo-raffia lost by 4.7%

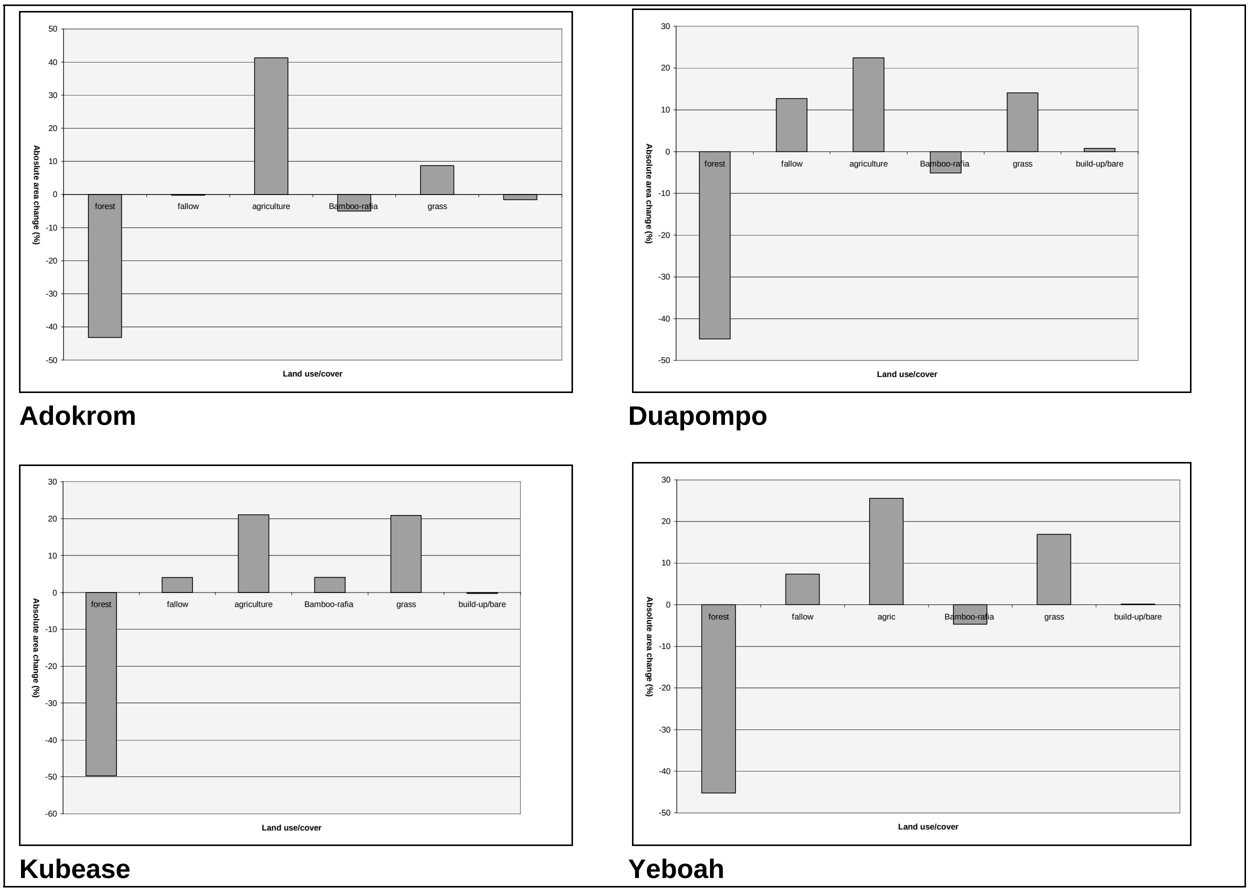

Figure 12: Percentage contribution of individual land use/cover to total change at each hotspot (sign indicate the type of change: negative- loss otherwise a gain)

5. Discussion

5.1. land use/cover classification and accuracy

The classified images of 1986 and 2004 were key tools in the monitoring of land use/cover transfers in the Ejisu-Juabeng District and also within the identified hotspots. Image classification is never a complete process when the accuracy of the output land use/cover map is unknown. The quality of classification is judged by its accuracy. The 76.67% overall accuracy recorded for classification of the 2004 ETM image into six major classes of the study area was lower than the 85% standard noted in Campbell (2002). Further analysis with kappa statistic revealed that only 71% of the whole classification was in agreement with the reference data used for the assessment leaving the remaining 29% to chance. Kappa at this level is considered moderate. However the lower accuracy is due to inherent errors in the field points collected in 2006 to assess the classification of an image taken in 2004. It is worth noting that a good accuracy result is as good as the training area and reference data (Lillesand and Kiefer, 1994). As well, the difficulty in removing haze from the image may be a contributing factor. This difficulty was due to the low correlation between the visible bands of the 2004 ETM image. Nothing could be reported on the accuracy of the 1986 image due to the unavailability of validated map or aerial photo of the study area for that period.. Its classification is as good as the 2004 image since the reference data used to assign class on the 1986 image are invariant areas on the 2004 image.

Significant seasonal differences and its subsequent effect on the nature of vegetation in the tropics could have little or no role in this since both images were taken in the dry season. Yet the similar nature of the reflectance of teak plantations and grasslands in the dry season makes it difficult to separate them. This was also true for immediately harvested agricultural fields (still with agricultural use but without much vegetation at the time of capture) and bare lands.

5.2. Land use/cover tranfers and fragmentation at the Ejisu-Juabeng District

Detail information on classes making transfers, by how much and the proportion gained in return is the main advantage of the post classification change detection method used in the study. The change detection yielded a land use/cover map showing the spatial distribution of transfer in the classes (figure 8) and a change matrix (table 4) indicating the proportions of specific land use/covers taking part in the transfers. The Ejisu-Juabeng District landscape has experienced complex land use/cover transfers resulting from increased human activities over the 18-year period under study. Land use/cover transfers have compositional and structural implications on the landscape. Structurally, the general reduction in number of patches in forest and other lands between both years indicate a reduction in fragmentation in the study area. The reverse indication suggested by higher largest patch index of 1986 is likely due to the large patch size portrayed by Bobiri Forest Reserve and the adjoining off-reserve forest areas, which in 2004 had lost some connections and areas with and in the off-reserves respectively. However the smaller mean patch size and higher percentage in patch density of 1986 forest than 2004 forest is a clear indication of reduced fragmentation of forests in 2004

(McGarigal and Marks, 1994). All the indexes point to the fact that other lands 1986 is more fragmented than 2004.

The high mean patch size of both forest and other lands in 2004 indicates that most of the patches were getting bigger due to aggregation. Critically the higher level of aggregation experienced by other lands in comparison with forest clearly indicates that small patches of forests usually bordering agricultural fields are being replaced by other lands in 2004. The unusual indication of increased forest size suggested by mean patch size index could be due to large patch size contributed by Bobiri Forest Reserve in the computation of the index. Land use/cover transfers impacting the landscape structure have resulted in more than 100% increase in both grasslands and build-up/bare areas and a decrease in forest and agriculture. Forests are significantly transferred to agriculture and grass while agriculture is interestingly losing a little more than the gains from forest to grass. The inference drawn from the nature of transfers is that though forest transfers to agriculture is substantial, agriculture is only acting as a transit point to grass. This may be so because agriculture decreased and forests are not cleared to favour grass since ranching is not a land use option in the area. It explains why generally agricultural lands have reduced irrespective of gains made from bamboo and raffia and forest. Also agriculture and grasslands formerly surrounding towns contribute the majority of the transfers to build-up/bare with a gain exceeding 100%. Underlying these trends is an important socio-economic factor or issue. Urban to peri-urban migration which is a prominent factor in the study is claiming agriculture lands close to urbanised areas and dislocated farmers seek new agriculture lands at the expense of forest lands in areas beyond urbanisation (Serneels and Lambin, 2001). The increase in build-up area is concentrated at the boundary between the district and Kumasi (bigger centre) radiating from the sides of the Kumasi-Accra road. This is due to the spilling effects from the rapid expansion of Kumasi. An informal interview with opinion leaders in the highly urbanised portion of the district, in confirmation linked it to increased purchase of lands for building by people from Kumasi and its surroundings due to relatively cheaper prices of land compared to Kumasi. Lands are preferably sold to outsiders than natives because of the good money they offer. Nairobi experienced concentric urban expansion along transportation routes emanating from city centres (Mundia and Aniya, 2006). The nature of urban expansion along the Kumasi –Accra road is rather relatively linear in nature. Although the economy is gradually changing to commensurate the urbanisation, farmers who have lost farm lands to the urbanisation process seek new lands further away from Kumasi on “abunu/abusa” (meaning farming and sharing with land owner on equal/ one third-two third basis) or lease (Gaespenu and Associates, 1996). Consequently, pressure is mounted on land resource in these new areas, resulting in additional forest clearance and continuous cropping. The subsequent reduction of fallow periods and lands and the indiscriminate application of inorganic fertilizer all together do not just lead to soil degradation but also decreases in crop yield and subsequent farmer relocation. . Such abandoned degraded lands are taken over by grass hence the observed large increase in grassland. In essence the trends discussed above confirms the earlier observation by Gaespenu and Associates (1996). Conversely the increase in fallow observed from change detection emanate from the short period between dissertation of farmlands by farmers for reasons of land purchased for building and the time of actual construction.

Another reason for the large transfers of forest is the gradual replacement of old cocoa (require trees shade) with the high yielding hybrid (no shade requirement) and the shift to non traditional crops like citrus plantations that grows best without trees. In addition illegal logging by both farmers and commercial groups play key roles in reducing the forest cover of the Ejisu-Juabeng District. Lambin et al (2001) described causes of land use/cover transfers as complex network factors resulting from peoples' response to economic opportunities. Also the reduction in bamboo-raffia is immediately clear from the increased farming activities along water ways where this cover is usually found. Such marshy areas provide readily available water supply for farm and suitable conditions for rice cultivation.

In linking patch statistics to forest transfers in the study area, fragmentation is decreased whiles forest transfer was high. This is contrary to the linkages observed in other studies (Zipperer, 1993).

5.3. Hotspot analysis

Monitoring dynamic processes of land use/cover transfers in tropical regions are better understood at localised scales (Lambin and Ehrlich, 1997). Forest cover transfers within the Ejisu –Juabeng District has been dynamic spatially and temporally over the 18 years under study. The hotspot analysis facilitated the identification of areas within the district that have under gone high levels of forest transfers. The thresholds set at various stages of the identification procedure resulted in nine hotspots. The satellite image and spatial analysis based method adopted for the identification of hotspots in the Ejisu-Juabeng District proved to have more advantages. The method allowed the reduction of large satellite data set for easy computation and zooming into specific areas for detailed analysis and comparison. The orderly and objective manner in which they were delineated as a result of reduced human interference (Achard et al., 1998) and elimination of the use of assumption of presence or absence of variables like fire and proximity to towns in the actual identification makes it repetitive. This capability facilitate regular monitoring of hotspots in order to develop specific measures for specific hotspots (Van Laake and Sanchez-Azofeifa, 2004). However care should be taken in setting cell factors which to some extent affect possible areas to select as hotspots. Another issue is that the method after identification treats hotspots as individual landscapes in the computation of the fragment indexes.

In terms of composition, Adokrom and Duapompo roughly have 38% of their landscapes covered with forest than Kubease, which is also significantly higher than Yeboah. Hence ecological process is significantly different for the hotspots depending on the areal extent available for interaction. This is an indication that animal populations with a high affinity for forest cover may reside more in Adokrom and Duapompo. Their individual over laps with the forest is a strong support of the argument. However the two other hotspots which are mostly agriculture and grass will support different set of populations.

The forest transfer contributed about 50% of total change in all the four hotspots (figure 12). This suggests reduction in forest area. Since the area of the hotspot remains constant, a transfer from one land use /cover means an increase in others and vice versa. Hence an increase in forest transfers result in increased gains in other land use/cover types. In figure 12 the gains in other land use/cover types are eminent in agriculture and grass with their contribution to changes in the positive zone of the graphs. Although forest transfers form a major proportion of the total change in all hotspots, it occurs at different rates (table 6) with Yeboah having the highest rate or the most prevalent forest transfers. It is followed by Kubease, Duapompo and Adokrom in order in decreasing transfers in forest. Yeboah and Kubease are mianly agricultural landscapes with few standing trees indicating the presence of forest formerly. Adokrom and Duapompo on the other hand are also mainly agriculture but their location and the nature of agriculture support more trees. These two hotspots overlap with Bobiri Forest Reserve which is under protection (figure 11). Hence forest which lay in the overlapped areas of Bobiri and the hotspots are some what preserved while lands far from the reserved area experience higher transfers (figure 10). Adokrom's 3.35% high rate may be due to the shape which is elongated further away from reserve. Also inaccessibility to some areas due to swamps especially in Duapompo is a factor for undergoing less transfer. Another important factor is presence of large amount of cocoa plantations of which some are still "Tete Quashie" breed that require trees for proper growth.

At the district level the Ejisu-Juabeng District lost 10874.32 ha of forest between 1986 and 2004 at rate of 53.27%. However in-depth analysis within the hotspots show forest transfers significantly different from that of the district rates. With 35.08% higher forest transfer rate than the entire study area transfers in Yeboah constitute only 11.11% of the total forest transfers in the district. The nature of agricultural practice in Yeboah is subsistence annual cropping. Usually subsistence farming is done at the family level with simple farm tools and fire as an important tool hence relatively smaller areas are cultivated. The land tenure system of the area allow almost every family to own lands which is shared among individual family members for cultivation resulting in fragmentation (Gaespenu and Associates, 1996). Unlike the deforestation hotspot identified in Province Limon of Costa Rica (Van Laake and Sanchez-Azofeifa, 2004) forest transfers in the Ejisu-Juabeng area are not concentrated in the hotspots. Total forest transfer in all the four hotspots accounted for just 37.8% of the transfers in the whole study area. The small contribution to the total study area forest transfers from all the four hotspot indicate that forest clearing in the study area occur in smaller scattered fragments. The smaller mean patch size of transferred forest of the district (1.7 ha) confirms the above argument. Generally both hotspots and district had regenerated marginally. In spite of the high levels of deforestation and fragmentation at Kubease and they recorded the highest regeneration of forest in the hotspots and this was higher than the amount regenerated at the district level. These are found in far areas which been left untouched after the 1983 bushfires because of inability to support cocoa at that time. Zipperer (1993) also observed forest regeneration from idle agriculture lands.

Structurally all the hotpots as well as the entire study area highly fragment due a relative low largest patch index (0.34%- 16.88%). Duapompo which had the highest largest patch index had only 16.88% of the landscape occupied by the largest patch. The District is more fragmented than Adokrom and Duapompo with its low largest patch index. On a scale of hundred as shown by the largest patch index, Yeboah is the most fragmented hotspot with 0.34% of its landscape covered with forest. Following is Kubease, Adokrom and Duapompo in the order of decreasing fragmentation. The values recorded for mean patch size and total core area index follow a similar trend but the total core area index of the district (46.90) and other areas of the district, which lay outside hotspots (55.69) are higher than Duapompo. The anomaly is because the forest reserve which is fully represented in both landscapes contributes immensely to their large core areas when only 100m is considered edge width. The entirely different ranking order of fragmentation suggested by patch density is due to the fact that forest areas are not the same across hotspots, the district and areas outside the hotspots (McGarigal and Marks, 1994).

Invariably the forces at play in the dynamic process of forest transfer within the area are different in terms of combination and degree of operation due to diverse culture and response patterns to economic and policy opportunities at every scale of study (Lambin et al., 2001). The landscape observation and informal conversation suggested that forest transfers in both Adokrom and Duapompo have similar drivers. The unmistakable sound of the chainsaw that runs sporadically in both area and the stumps of felled tress is an indication that commercial logging is a cause of forest transfers in the area. The general farmers' perception that hybrid cocoa (new breed) does not survive and yield less under tree canopies is a contribution factor to high rates transfers. Also farmers are gradually shifting focus from cocoa to citrus plantations, which do not support tree. In essence the under lying factors are economic, technology and market preference.

Similarly, Kubease and Yeboah both experience bushfires resulting farm practise and there is persistence clearing lands of for agriculture. The factor pushing this clearing at the current rates is partly due to the influx of new farmers who need land to farm. in addition soil infertility problems emanating from continuous cropping due to limited land resource is a contributing factor.

6. Conclusion

This study has used remote sensing and GIS techniques to monitor lands use/cover transfers especially for forest in the study area. In Ghana forest transfer monitoring are conducted at the national or administrative level and the general results used as reference to prescribe counter measures. Remote sensing observations revealed that the landscape of Ejisu –Juabeng District has significantly been transformed through large amounts of forest transfers between 1986 and 2004. The application of hotspot identification procedure enabled the identification of nine hotspots of forest transfers between the years under study. It provides an easy way to zoom in specific areas in a landscape that need critical attention. Statistical analysis on the fragments in the four largest hotspots and the entire study area differs. Yeboah was found to be the hotspot with the highest forest transfers and most fragmented. Adokrom and Duapompo on the other hand remained the hotspot with the least forest transfers and least fragmented respectively. This piece of information generated by the study is beneficial for forest and land managers for better planning.

The availability of ground data for both 1986 and 2004 could have improved the accuracy testing for the land use/cover maps produced from the TM 1986 and ETM 2004 images as well as the change detection. It would have been interesting to study general temporal trends of changes but lack of cloud free images between the two years did not permit this. The underlying factors suggested were not statistically tested due to the unwillingness of respondents to talk and future research into underlying factors of forest is required.

7. References

Achard, F., Eva, H., Glinni, A., Mayaux, P., Richards, T. and Stibig, H.J., 1998. Identification of deforestation hotspot areas in the Humid Topics TREES series B.research report

4. European Commission Brussels, 104 pp.

Affum-Baffoe, K., 2001. Modified procedures for tree resource assessment in off-reserve areas in the high forest zone of Ghana, Forest, Biometry, modelling and information system Conference. IUFRO, Greenwich University.

Agyarko, T., 2001. Country Report - Ghana Ministry of Lands and Forestry.

Baron, J.S., Hartman, M.D., Kittel, T.G.F., Band, L.E., Ojima, D.S. and Lammers, R.B., 1998. Effects of Land Cover, Water Redistribution, and Temperature on Ecosystem Processes in the South Platte Basin. Ecological Applications, 8(4): 1037-1051.

Bauer, M.E., Yuan, F., Sawaya, K.E. and Loeffelholz, B.C., 2005 Land cover classification and change analysis of the Twin Cities (Minnesota) Metropolitan Area by multitemporal Landsat remote sensing. Remote Sensing of Environment, 98 317 - 328.

Bennett, A.F., 1998, 2003. Linkages in the landscapes: the role of corridors and conectivity in wildlife conservation. Conserving Forest Ecosystems Series

1. IUCN, Gland, Switzerland and Cambridge, UK, xiv + 254 pp. pp.

Boletta, P.E., Ravelo, A.C., Planchuelo, A.M. and Grilli, M., 2006. Assessing deforestation in the Argentine Chaco. Forest Ecology and Management 228: 108-114.

Briassoulis, H., 2000. Analysis of Land Use Change: Theoretical and Modeling Approaches. In: S. Loveridge (Editor), The Web Book of Regional Science Regional Research Institute, West Virginia University, Morgantown, West Virginia.

Brook, B.W., Sodhi, N.S. and Ng, P.K.L., 2003 Catastrophic extinctions follow deforestation in Singapore. NATURE, VOL 424: 420-423.

Bureau of Integrated Rural Development, 2001. Tropenbos Ghana Programme research site community survey (final report), KNUST,Kumasi.

Campbell, J.B., 2002. Introduction to Remote Sensing. Taylor and Francis, London 621 pp.

Canada Centre for Remote Sensing, 2003. Fundamentals of Remote Sensing.

Chen, X., 2002. Using remote sensing and GIS to analyse land cover change and its impacts on regional sustainable development. int. j. remote sensing,, 23(1): 107-124.

Dale, V.H., Brown, S., A., H.R., Hobbs, N.T., Huntly, N., Naiman, R.J., Riebsame, W.E., Turner, M.G. and Valone, T.J., 2000. Ecological Principles and Guidelines for Managing the Use of Land. Ecological Applications, 10(3): 639-670.

Dye, D., 2003. Effects of Land Cover Change on the Carbon Cycle in Southern China, Frontier Newsletter.

Etter, A., McAlpine, C., Wilson, K., Phinn, S. and Possingham, H., 2006. Regional patterns of agriculture landuse and deforestation in Colombia. Agriculture, Ecosystems and Environment, 114: 369-386.

FAO, 1996. Forest resource assessment 1990: survey of tropical forest cover and study of change processes, 130. FAO, Rome.

FAO, 2001. Global forest resources assessment 2000: main report, FAO, Rome.

Friends of the Earth International, 1999. Cut and run:illegal logging and timber trade in the tropics. International Development Research Centre, Ottawa.

Gaespenu and Associates, 1996. A medium term development plan for Ejisu-Juabeng Distict (1996-2000).

Geist, H.J. and Lambin, E.F., 2001. Global land-use and land-cover change: what have we learned so far?, Global Change news letter, pp. 27-30.

Ghana Statistical Service, 2003. 2000 Population and housing census, Accra.

Gholz, H.L., Nakane, K. and Shiwode (Editors), 1996. The use of remote sensing in modelling of forest productivity
Detecting structural and growth change in woodlands and forest: the chanllenge to remote sensing and the role of geometric-optical modelling
Kluwer Acad. Dordmeoh, Netherlands 75-108 pp.
Hawthorne, W.D. and Abu-Juam, M., 1995. Forest protection in Ghana. IUCN, Gland, Switzerland and Cambridge, UK xvii+203 pp.
Hayes, D.J. and Cohen, W.B., 2006. Spatial, spectral and temporal patterns of tropical forest cover change as observed with multiple scales of optical satellite data. Remote Sensing of Environment, doi:10.1016/j.rse.2006.07.002.
Heilig, G.K., 1994. Neglected Dimensions of Global Land-Use Change: Reflections and Data. Population and Development Review, Vol. 20, (No. 4.): pp. 831-859.
Herold, M., Goldstein, N.C. and Clarke, K.C., 2003. The spatiotemporal form of urban growth: measurement, analysis and modeling. Remote Sensing of Environment, 86: 286-302.
Imbernon, J. and Branthomme, A., 2001. Characterization of landscape patterns of deforestation in tropical rain forests. Int. J. Remote Sensing, 22(9): 1753-1765.
Ingram, J.C. and Dawson, T.P., 2005. Inter-annual analysis of deforestation hotspots in Madagascar from high temporal resolution satellite observations. International Journal of Remote Sensing, 26(7): 1447-1461.
Islam, K.R. and Weil, R.R., 2000. Land use effects on soil quality in a tropical forest ecosystem of Bangladesh. Ecosystems & Environment, 79(1): 9-16.
ITTO, 2006. Status of Tropical Forest Management 2005

Kerle, N., Janssen, L.L.F. and Huurneman, G.C. (Editors), 2004. Principles of Remote sensing ITC Educational Textbook Series, 2. ITC, Enschede.
Kotey, N.A., Francois, J., Owusu, J., Yeboah, R., Amanor, K.S. and Antwi, L., 1998. Falling into place. Policy that works for forests and people, 4. International Institute for Environment and Development, London, 138 pp.
Kufuor, K.O., 2000. Forest Management in Ghana: Towards a Sustainable Approach. Journal of African Law, 44(1): 52-64.
Lambin, E.F., 1994. Modelling deforestation processes : a review. TREES series B. research report 1. European Commission, Brussels.
Lambin, E.F. and Ehrlich, D., 1997. The identification of tropical deforestation fronts at broad spatial scales. int. j. remote sensing,, 18(17): 3551± 3568.
Lambin, E.F., Geist, H.J. and Lepers, E., 2003. Dynamics of landuse and land cover change in tropical regions Annual Reviews Environmental Resource, 28: 205-41.
Lambin, E.F., Turner, B.L., Geist, H.J., Agbola, S.B., Angelsen, A., Bruce, J.W., Coomes, O.T., Dirzo, R., Fischer, G.u., Folke, C., George, P.S., Homewood, K., Imbernon, J., Leemans, R., Li, X., Moran, E.F., Mortimore, M., Ramakrishnan, P.S., Richards, J.F., Skanes, H., Steffen, W., Stone, G.D., Svedin, U., Veldkamp, T.A., Vogel, C. and Xu, J., 2001. The causes of land-use and land-cover change:moving beyond the myths. Global Environmental Change 11: 261–269.
Leica Geosystems GIS and Mapping, 2003. ERDAS Imagine tour guide.
Lillesand, T.M. and Kiefer, R.W., 1994. Remote sensing and image interpretation. John Wiley and sons Inc., New York, 750 pp.
Mas, J.-F.o., Vela´zquez, A., Dı´az-Gallegos, J.R., Mayorga-Saucedo, R., Alca´ntara, C., Boccob, G., Castro, R., Ferna´ndez, T. and Pe´rez-Vega, A., 2004. Assessing land use/cover changes: a nationwide multidate spatial database for Mexico
International Journal of Applied Earth Observation and Geoinformation, 5: 249-261.
McGarigal, K. and Marks, B., 1994. FRAGSTATS. Spatial Pattern Analysis Program For Quantifying Landscape Structure. Forest Science Department. Oregon State University, Oregon.
McGarigal, K., Marks, B.J., Holmes, C. and Ene, E., 2001. FRAGSTATS USER GUIDELINES Version 3.
Mensah, J., Oppong-Koranteng, R. and Frempah-Yeboah, K., 2002. Understanding reform: the Case of Ghana, pp. 48.

Mertens, B. and Lambin, E.F., 2000. Land-Cover-Change Trajectories in Southern Cameroon. Annals of the Association of American Geographers, 90(3): 467-494.

Metzger, M.J., Rounsevell, M.D.A., Acosta-Michlik, Leemans, R. and Schro¨ter, D., 2006. The vulnerability of ecosystem services to land use change. Agriculture, Ecosystems and Environment, 114 69-85.

Meyer, W.B. and Turner II, B.L., 1992. Human Population Growth and Global Land-Use/Cover Change. Annual Review of Ecology and Systematics, 23: 39-61.

Mundia, C.N. and Aniya, M., 2006. Dynamics of landscape changes and degradation of Nairobi city, Kenya. land degradation & development, 17(97-108).

Muttitanon, W. and Tripathi, K., 2005. Land use/land cover changes in the coastal zone of Ban Don Bay, Thailand using Landsat 5 TM data. International Journal of Remote Sensing, Vol. 26(No. 11): 2311-2323.

Nagendra, H., Munroe, D.K. and Southworth, J., 2004. From pattern to process: landscape fragmentation and the analysis of land use/land cover change. Agriculture, Ecosystems and Environment 101: 111-115.

Rainis, R., 2003. Application of GIS and landscape metrics in monitoring urban landuse change In: N.M. Hashim and R. Rainis (Editors), Urban Ecosystem Studies in Malaysia-A study of change. Universal Publishers.

Rudel, T.K., Coomes, O.T., Moran, E., Achard, F., Angelsen, A., Xu, J. and EricLambin, 2005. Forest transitions: towards a global understanding of land use change. Global Environmental Change 15: 23–31.

Sader, D.S.A. and Hayes, D.J., 2001. Change Detection Techniques for Monitoring Forest Clearing and Regrowth in a Tropical Moist Forest. Photogramm. Eng. Rem. Sens. : 23.

Serneels, S. and Lambin, E.F., 2001. Proximate causes of land-use change in Narok District, Kenya: a spatial statistical model. Agriculture, Ecosystems and Environment 85: 65-81.

Serra, P., Pons, X. and Sauri, D., 2003. Post-classification change detection with data from different sensors: some accuracy considerations. International Journal of Remote Sensing, 24,(16): 3311-3340.

Singh, A., 1989. Digital change detection techniques using remotely sensed data. Int. J. Remote Sensing, 10(6): 989-1003.

Southworth, J., Munroe, D. and Nagendra, H., 2004. Land cover change and landscape fragmentation—comparing the utility of continuous and discrete analyses for a western Honduras region. Agriculture, Ecosystems and Environment, 101: 185-205.

Swaine, M.D. and Hall, J.B., 1976. Classification and ecology of closed-canopy forests in Ghana. The Journal of Ecology, 84(3): 419-428.

Turner, M.G., 1989. Landscape ecology: the effect of pattern on process. Annual Review of Ecology and Systematics, 20: 171-197.

Turner, M.G., Pearson, S.M., Bolstad, P. and Wear", D.N., 2003. Effects of land-cover change on spatial pattern of forest communities in the Southern Appalachian Mountains (USA). Landscape ecology, 18: 449 - 464.

Van Laake, P.E. and Sanchez-Azofeifa, G.A., 2004. Focus on deforestation : zooming in on hot spots in highly fragmented ecosystems in Costa Rica Agriculture, Ecosystems and Environment, 102: 3 -15.

Veldkamp, A. and Lambin, E.F., 2001. Predicting land-use change. Agriculture, Ecosystems and Environment 85: 1-6.

Verburg, P.H., Overmars, K.P., Huigen, M.G.A., Groot, W.T.d. and Veldkamp, A., 2006. Analysis of the effects of land use change on protected areas in the Philippines. Applied Geography, 26: 153–173.

Verburg, P.H., Veldkamp, T.A. and Bouma, J., 1999. Land use change under conditions of high population pressure:the case of Java. Global Environmental Change 9: 303-312.

Vitousek, P.M., 1994. Beyond global warming: ecology global change. Ecology, 75(7): 1861-1876.

Wright, S.J., 2005. Tropical forests in a changing environment. TRENDS in Ecology and Evolution Vol. No. , 20(10).

Zipperer, W.C., 1993. Deforestation patterns and their effects on forest patches. Landscape ecology, 8(3): 177-184.

8. Appendices

8.1. Appendix

A: projection system of Ghana

Projected Coordinate System	Leigon_Transverse_Mercator
Projection	Transverse_Mercator
False_Easting	274320.00000000
False_Northing	0.00000000
Central_Meridian	1.00000000
Scale_Factor	0.99975000
Latitude_Of_Origin	4.66666667
Linear Unit	Meter
Datum	D_Leigon
Prime Meridian	0
Angular Unit:	Degree

B: classification accuracy table

Class name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy	Kappa
Forest	11	11	9	81.82%	81.82%	0.78
Fallow	7	7	4	57.14%	57.14%	0.51
Agriculture	20	16	14	70.00%	87.50%	0.81
Bamboo-rafia	4	3	3	75.00%	100.00%	1
Grass	11	16	9	81.82%	56.25%	0.46
Build-up/bare	7	7	7	100.00%	100.00%	1
Totals	60	60	46			
Overall Accuracy	76.67%					
Overall kappa	0.71					