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Predicting Land Cover Change Transition in Ho Municipality of Volta Region, Ghana.

by

Selase Kofi Adanu

A Thesis Submitted to the Faculty of Science, University of the Witwatersrand, in fulfillment of the Requirements for the degree of Doctor of Philosophy

Supervisors: Dr Emma Archer
Dr Jennifer Lalley

Johannesburg, 2013

Declaration

I declare that this thesis is my own unaided work. It is being submitted for the Degree of Doctor of Philosophy in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

_____
Signature of candidate

_____ day of _____ 20 _____

Acknowledgement

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Dedication

I dedicate this thesis to Mr and Mrs Adanu my parents.

To my wife Akorfa Adanu

To my son Aseye Adanu

To all my siblings for their prayers and support.

Abstract

Deforestation is a growing environmental concern in tropical areas of the world where it is believed that the increase in human population and associated land use practices are the key drivers of this land cover change transition. This research tests these hypotheses in the Ho Municipality of Ghana and aims to predict future land cover change by assessing remote sensing images and considering the complex interrelationships and synergies of multiple driving forces. The study specifically examines how multiple driving forces of land cover change transition have contributed to the accelerating pace of deforestation in the last 25 years based on observed trends in land use and remotely sensed land cover change data. The study looks at the future prospects for Ghana's forests.

The field study was carried out in four settlements of the Ho Municipality namely Wumenu, Agbokofe, Abutia Kloe and Takla. The data collection was done using structured questionnaires administered to 376 households to investigate their opinions regarding the driving forces of deforestation in the area. The analysis of questionnaire data involved the use of descriptive statistics and factor analysis using the Statistical Package for Social Scientists (SPSS) software. Satellite images comprising, Landsat MSS 1975, Landsat TM 1991 and Landsat ETM+ 2001 were classified using the maximum likelihood algorithm supervised classification to determine the extent and nature of vegetation cover change and to assess the potential of using a Markov model to predict the future state of forest cover.

The research concludes that the municipality lost forest cover from 1975 to 2001 based on satellite and questionnaire data analysis which suggests that the following are the key underlying drivers of deforestation: demographic pressure, poverty, institutional factors, policies, technology and attitudes. Proximate drivers of deforestation are agricultural expansion, illegal logging and wood energy exploitation. The Markov models showed that in the next 25 years various probabilities of change are possible, such as no change in forest cover, forest cover loss and some probabilities of increase in forest cover. These predictions illustrate the need to study the complex driving forces of change to interpret models that are solely based on past land use change transition. Based on the results of the household surveys, current drivers are unlikely to change. Land use planners should thus be aware that deforestation in Ghana is most likely going to continue.

On the basis of these findings the following recommendations have been made. There is a need to intensify tree planting activities in the municipality to increase forest cover. Planting of fast maturing trees for woodlots will reduce pressure on the forest for wood energy. Public education on the advantages of family planning should be undertaken by the Municipal Assembly and NGOs working in the area to reduce population pressure on forests. Poverty reduction strategies should focus on alternative livelihood opportunities to divert attention from forest goods while also increasing the protection of remaining forests. Lastly, community participative approaches to forest management could mitigate both underlying and proximate causes of deforestation.

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Chapter One

Introduction

1. 1 General background

Tropical forests are undergoing rapid deforestation due to increasing human population pressure and land use practices such as agricultural production and animal grazing (Mondal and Southworth, 2010). Deforestation is defined as a long-term (10 years) or a permanent loss of forest cover due to human-induced activities or natural occurrences that involve conversion of forest areas to agriculture (including agroforestry), pasture and urban areas (Forest Resource Assessment Project- [FRAP], 2000). The term excludes however, areas where trees have been removed due to logging activities and measures have been put in place to ensure natural regeneration through silvicultural practices (FRAP, 2000). The extent and rate of deforestation varies from one country to the other. For example, in Brazil, Indonesia and Australia, more than 2.5 million hectares of forest were lost between 2005 and 2010 (Global Forest Resource Assessment, 2010) while more than 1.2 million hectares of forest loss occurred in Myanmar, Bolivia, Venezuela, Nigeria, Congo, Tanzania and Zimbabwe, from 2000 to 2010, {Food and Agriculture Organization, (FAO, 2010)}.

A World Bank forest assessment report indicates that the total global forest area continues to decline annually, as documented by the World Resources Institute (1998) including a further loss of approximately 4 million hectares of primary forest in 2000 (Global Forest Resources Assessment, 2010). Deforestation has intensified in parts of the world such as Brazil and Indonesia where large scale agricultural production takes place (Fonseca, *et al*, 2009). In Central Africa, current deforestation estimates, based on coarse and medium resolution satellite imagery, show that the deforestation rate is 0.21% per annum (Duveillur *et al*., 2008).

As a result of the challenge of global deforestation, most tropical forests are in transition. 'Land Cover Change Transition' is a term referring to deforestation resulting from population pressure and economic growth in developing countries. These factors may lead to scarcity of timber and other environmental resources (Zhang, 2010). 'Land cover change transition' has become a global environmental issue describing random or systematic gains and losses from one land cover type to another, such as converting closed woodlands to open woodlands (Braimoh, 2006). In other words, a net increase or decrease of the land cover from one state to another refers to land cover change transition (Tome and Kelly, 2007).

To address complex global 'land cover change transition' challenges, models have been developed to simulate and predict land cover changes (Miguel *et al*, 2007). Studies of 'land cover change transition' based on modeling are useful for developing theories of 'land cover change transition' and the explanation of the driving forces of Land Use and Cover Change, (LUCC) (Rudel *et al*, 2007). Land cover change transition and the assessment of the potential utility of predictive models are central themes of the research undertaken here, with a focus on forest transition.

Specific application of the term 'land cover change transition' to forestry, known as 'forest transition', was coined to explain how forest stocks change in predictable ways from forest lands to deforested lands and sometimes from deforested lands to forests as societies undergo economic development, industrialization and urbanization (Rudel, 2005; Mather, 1990). Global industrialization and economic development have in certain areas, accelerated the clearing of forest lands for crop cultivation, construction of houses and building of roads (Kassas, 2005). Land cover change transition emanating from economic development has been a major environmental challenge, and forest transition, particularly, as mentioned previously, is a global concern (Ostrom, 2005). There is thus a need to improve our understanding of the drivers of forest transition, be they economic or social.

Globally, land cover change transition occurs at various scales such as on individual farms, counties, states and nations (Rudel *et al*, 2007). 'Land cover change transition' is used in this study to mean, changes in the land cover from forest to woodland, then to grassland vegetation and finally to bare areas. These transitions may be studied at the national to regional and from regional to district and local community scales.

The driving forces of land use and cover change are categorized into human-induced driving forces and biophysical driving forces (Land Use and Cover Change-LUCC, 2001). Biophysical driving forces are caused by natural events, including secondary succession, while human -induced driving forces are orchestrated by human beings which, in fact, are the focus of this study. The human-induced driving forces are categorized into proximate and underlying causes of land cover change (LUCC, 2001). Proximate causes of land cover change may, for example, relate to the use of land by mining or logging companies or by local individual farmers, households and communities for purposes such as agriculture (Radonia, 2007). There are also underlying or indirect causes of ' land cover change", such as the extent to which the decisions of districts, provinces or countries with certain demographic characteristics and technology trigger social, economic, political and cultural forces to influence 'land cover change' (Radonia, 2007). Cultural values have been identified as possible underlying driving forces of 'land cover change' as they are intimately linked to the philosophy of people living in given spaces, as defined by the concept of place in geography (Callicott *et al*, 2006). Geographic space is defined as the space that encircles the planet through which biological life evolves and the use of this geographic space is influenced by human perceptions and values that either protect or destroy nature (Cresswell, 2005; Kunstler, 1994).

Due to the global problems of land use and cover change, the Stockholm UN Conference on Human Environment held in 1972 discussed land use and development issues. This led to the formulation of global strategies to deal with emerging problems,

such as deforestation identified at the conference (UNEP, 2005). The increasing complexity of land use and cover change problems over time contributed to another conference agenda, notably the World Commission on Environment and Development (WCED) conference (UN, 1997). Key discussions at WCED focused on global environmental problems emanating from poverty in the southern hemisphere (developing countries), and unsustainable patterns of consumption in the northern hemisphere (developed countries).

Another conference known as the World Summit on Sustainable Development brought together one hundred and eighteen countries to discuss strategies for environmental restoration, reservation and social development (World Summit on Sustainable Development, 2002).

The Convention on Biological Diversity (CBD) was adopted in 1992 with the aim to promote conservation of biological diversity of ecosystems, habitat, species, genetic diversity and biomes (Convention on Biological Diversity, 2010). Ghana, a party to the convention has produced its fourth national report which contains information on the status of biodiversity, trends, threats, strategies and action plans for biodiversity conservation (Convention on Biological Diversity, 2010).

The United Nations Framework Convention on Climate Change (UNFCCC) was adopted in 1997 with the aim of finding solutions to climate change problems such as global warming (UNFCCC, 1997). Ghana has shown its commitment to UNFCCC by submitting its readiness preparation proposal to the Forest Carbon Partnership Facility for funding to implement Reduction of Emissions from Deforestation and Degradations plus (REDD+) project (Ghana Readiness Preparation Proposal, 2010).

As a result of these initiatives, social and physical scientists from diverse academic backgrounds came together to develop a scientific research plan to investigate

global environmental change problems such as land use and land cover change through joint projects (Global Land Project - GLP, 2005). The joint project initiative was to undertake empirical assessment of the patterns of 'land cover change' through comparative case studies. These case studies were expected to help improve understanding of how processes of land use and land cover change vary across spatial and temporal scales. The joint project initiative was also expected to develop comprehensive models to deal effectively with land cover change problems.

Bringing together local, regional and global case studies from diverse sources under the joint project was to provide a comprehensive solution to land cover change problems. In relation to the above joint project initiative, this study embarked on a comparative study into the nature of land cover transition (deforestation) in the Ho Municipality in the Volta Region of Ghana for the past 25 years, focusing on four towns. The comparative study was carried out to find out how increases in the district population density contributed to deforestation over nearly three decades. The study result is expected to contribute to the understanding of the extent to which various socio-economic factors contribute to deforestation. Further analysis of socio-cultural variables, such as land tenure systems and cultural values connected to land use, explain the extent to which such variables contribute to deforestation. In addition, one economic variable analysed in the study is how demand and supply for forest products has influenced deforestation. A case study of this nature helps to explain local and regional 'land cover change transition' problems such as the deforestation processes in Ghana.

1. 2 Problem statement

Ghana is a West African country situated between latitude 5º 36´ N and 11º 0´0´´N and longitude 0º 10´ E and 3º 0´0´´W and comprises two main ecological zones; the closed forest zone, occupying 8.2 million hectares of the country's land area, and the savannah land covering 15.6 million hectares (Nsiah- Gyabaah, 1994).

Deforestation and environmental degradation have been considered critical issues in Ghana since the 1930s due to diverse driving forces (Benneh, *et al*, 1990). The colonial forest policies of the past, for example, forcefully took forest lands from individual land owners and families for forest reserves and people affected by such colonial land policies resorted to exploiting the forest cover indiscriminately, regardless of the negative effects on forest cover (Agbosu, 1983). In addition, during the 1960s and 1970s, cultivation of cocoa as an export commodity has contributed to forest cover change during this period (Dei, 1990).

From 1981 to 1985 Ghana's annual deforestation rate was estimated at 1.3%. At this time, timber was the third largest export commodity contributing between 5% and 7% of Ghana's Gross Domestic Product (GDP), (International Institute for Environment and Development-IIED, 1987).

There is awareness among Ghanaian policy makers that the driving forces for deforestation have become diverse and interrelated in increasingly complex ways. The government of Ghana thus, formulated a policy framework for sustainable land management to protect the ecosystem and improve rural livelihoods (EPA, 2007). Despite such efforts by the state, however, deforestation continues to be a major environmental concern in Ghana. Anthropogenic causes of deforestation contributed to a reduction of forest cover from 8.2 million hectares to an estimated 0.836 million hectares of forest in 2000 indicating an annual deforestation rate of 2.8% (EPA, 2004). The clearing of forest lands using the slash-and-burn agricultural method has contributed to large-scale deforestation and a loss of soil nutrients (EPA, 2005). Soil nutrient deficiencies compel farmers to clear new forest lands that are rich in soil nutrients for crop cultivation, which resulted in further loss of forest lands (EPA, 2005). It was estimated that in 2003 approximately 64.97% (165,00 km_2) of Ghana's land area was prone to desertification especially in the Upper East and Northern regions due to shifting cultivation and wildfires (EPA, 2004).

In the Volta Region, land cover can be categorised into forest, savannah and coastal areas and key land uses are farming, woodfuel extraction, logging and fishing. From a historical point of view, the central part of the Volta Region was densely forested 40 years ago. Large areas were however, destroyed through conversion to agricultural lands (Forum, 2000). Assessments show that 65% of forests in the Volta Region are heavily degraded and only 10% can be classified as dense forests (Forum, 2000). Although forest cover is important for human survival in the Volta Region, there have been few published studies on forest land use and cover change (Titriku and Anku, 1989).

Proximate driving forces of deforestation in the Ho Municipality of the Volta Region include land tenure problems, logging, charcoal production, occurrence of wildfires and the expansion of agricultural lands (Adanu, 2005; FRIDEC, 2007).

As far as the underlying driving forces of deforestation are concerned, population pressure is often a key contributing factor to deforestation (Lambin *et al*, 2003). To characterize the linkages among the multiple driving forces of deforestation, this study investigates as the main drivers of forest cover change transition the following: the role of population growth; people's attitudes; cultural values; land tenure systems; the use of fire; farming activities; woodfuel extraction; and cattle raising. To understand how these multiple driving forces contribute to deforestation, three hypotheses were formulated (section 1.3) and the test results of the hypotheses are explained (section 8.2).

1. 3 Hypotheses

The following hypotheses were tested.

- Demographic pressure is the key underlying cause of land cover change transition
- The existing forest cover will decrease further by half of its existing size in the next 25 years due to the effects of underlying and proximate driving forces
- Land use in the Ho Municipality is determined by local economic demand and not by central government economic policy.

Based on the hypotheses above, the following research questions have been addressed in chapters Seven, Eight, Nine and Ten.

1. 4 Research questions

1. How is the nature and extent of accelerated land cover transition (deforestation) from 1975 to 2001 determined by classification of satellite images and variability in underlying and proximate driving forces?
2. Do population growth and density play any significant role in deforestation compared to the other proximate driving forces of deforestation?
3. Can we determine implications for future forest areas by assessing the potential utility of Markov modeling in land cover transition modeling?

1. 5 Aim of research

The aim of this research was to detect past land cover change transition scenarios and the drivers of deforestation in the Ho Municipality from 1975 to 2001 and use this information to predict land cover change transition for the next 25 years.

1. 6 Objectives

This research was aimed at achieving the following objectives:

- Examine how multiple driving forces of land cover change transition have contributed to the accelerating pace of deforestation in the last 25 years through the interview of households at the study sites.

- Examine the complex interrelationships among the multiple driving forces of deforestation and the extent to which such multiple driving forces contribute to the accelerating pace of land cover change transition.
- Predict land cover changes transition for the study area using satellite data and Markov modeling approaches.

1. 7 Justification of study

As stated earlier, forest land use and cover change transition is a crucial environmental issue globally and in developing countries such as Ghana, where the forest resource is a major livelihood for the people. Forests are used for farming maize, cassava and yams; hunting of antelopes, deers and grass-cutters; and the extraction of medicinal plants. Apart from the direct benefits derived from the forest cover, the forest is, of course, important in maintaining the local climate of the area and in enhancing its biodiversity. Although, as mentioned earlier, Ghana is a signatory to the Convention on Biological Diversity, the country has not put in adequate measures to protect the environment, leading to habitat loss and the subsequent loss of species (Agyemang, 2007). Furthermore, any change in climate due to land use and cover change may cause variations in rainfall and temperature on temporal and spatial scales at the district level. Climatic variations such as unreliable rainfall, rises in temperature, flooding and drought could potentially lead to further biodiversity loss and limit agricultural productivity. The implication is that failure of agriculture due to climate variability could have serious consequences for human survival since agriculture employs approximately 60% of the labour force in Ghana (EPA, 2005).

Out of the ten regions of Ghana, the Volta Region was chosen for this study as the researcher has worked with a range of stakeholders in the region for four years, focusing on sustainable livelihood issues. Such issues include agricultural land use change, which is linked to deforestation. Deforestation was identified by the people in the Volta Region

as a major challenge to sustainable agriculture, biodiversity preservation and water resource use. Locally, the majority are of the opinion that human-induced deforestation has contributed to rainfall variability, which affects agriculture negatively. In an attempt to address these concerns, a requirement has arisen for a scientific study of the nature of past and present forest cover change transitions and the underlying and proximate factors responsible for deforestation in the Municipality. It is expected that the study results will contribute towards combating deforestation in the municipality as the application of remote sensing is appropriate for more accurate quantitative data analysis of forest cover change to explain deforestation problems (as opposed to previous studies in the municipality that were mostly qualitative descriptions of deforestation).

This dissertation is structured as follows: Chapter Two provides a literature review for the study area. This includes global land use and cover change issues and references to country specific land use and cover change in Ghana. Chapter Three reviews related literature on the underlying driving forces of deforestation such as population, economic driving forces, environmental policies, trade regulation, land distribution and property systems. The literature review on proximate driving forces of deforestation includes woodfuel extraction and agricultural expansion. Chapter Four focuses on the application of remote sensing surveys and models to land cover change assessment such as detection of change in land cover, assessment of image classification accuracy, general applications, and modelling of land cover change transition. Chapter Five focuses on the study country and study area describing the geographic terrain, demography, land use and cover, and economic activities. Chapter Six describes the methods used during the research. Chapter Seven presents the results for satellite image analysis regarding detection of change in vegetation cover from 1975 to 2001. Chapter Eight presents results for the underlying driving forces of deforestation, such as demographic driving forces, indicators of deforestation, institutional factors, and policies. Chapter Nine provides the results for proximate driving forces of deforestation, such as how the following driving forces have contributed to deforestation: preparation of agricultural lands for crop cultivation, illegal logging, wood energy exploitation and the contribution of multiple driving forces to deforestation. Chapter Ten explores the results

for assessing the potential utility of Markov model in predicting land cover change for the study area. Finally, Chapter Eleven provides the summary, recommendations and conclusion of the study.

Chapter Two

Deforestation Processes and Effects

2. 1 Introduction

This chapter provides a literature review of global and local deforestation processes and the effects of deforestation on the biophysical environment and the socio-economic lives of people living in such areas. Issues discussed under deforestation processes include the definition of deforestation, forest degradation and analysis of factors of deforestation. Factors examined that enhance deforestation include: socio-economic factors such as population pressure, poverty and agriculture expansion. Forest fragmentation, bio-physical effects and socio-economic effects are reviewed as part of the discussion on the effects of deforestation.

2. 2 Deforestation processes

Deforestation, as mentioned in chapter one, is defined as a progressive process that results in the conversion of forest areas to pasture and degraded habitats (Panta, *et al*, 2008). Removal of trees in the forests per se does not constitute deforestation since removal of such trees is part of normal forest management activities (Martin, 2008). Deforestation, however, takes place when people clear trees from the land and neither natural succession nor replanting of the cut trees occurs (Rudel, 2005). Besides deforestation, forest degradation that involves reduction in the capacity of the forest to produce goods and services also contributes to land cover changes (FAO, 2002).

Deforestation is, as mentioned in chapter one, globally recognized as one of the world's leading environmental problems affecting productivity of the forest environment and the loss of biodiversity (Brook *et al*., 2003; Sodhi *et al*., 2004). Global environmental change attributable to deforestation occurs at dramatic rates and involves changes in land use, vegetation cover change and species translocations (Sutherst, 2006). Human

activities are central to the phenomenon of global deforestation, since population growth, land policy, cultural values, science and technology are key factors contributing to global deforestation (Seabrook, *et al*, 2006). Global statistics show that deforestation accounts for the loss of 70% to 90% of the world's tree species and 50 to 100 animal species (Myers, 1994). The loss of such tree and animal species may result in the loss of genetic resources with a risk of tree and animal species extinctions (Myers, 1994).

Data gaps regarding deforestation processes in the past have been attributed to unreliable statistics on deforestation situations, creating uncertainty regarding data accuracy for forest clearings. Efforts to bridge the data gaps were pursued by, for example, examining archaeological and paleo-botanical evidence on forest clearings during the late Mesolithic and Neolithic European periods (Williams, 2008). Deforestation data in Europe during the post-1950s was equally limited as far as the extent of deforestation, forest loss pathways and processes of forest cover change were concerned (Williams, 2008). Improvement in data reliability and accuracy began with the application of aerial photography since the 1930s and remote sensing technology for earth observation in early 1970s to capture data on land use and cover change (Clawson and Stewart, 1965; USGS, 2010).

Global deforestation research done since the middle 20th century has largely focused on tropical deforestation due to the rapid rate and spatial extent of deforestation in the tropics and the associated effects of deforestation on climate change and biodiversity (Etter, *et al*, 2006). Surveys on deforestation in 103 countries have revealed that high income countries with low forest cover have the highest rates of afforestation. Low-income countries with limited forest cover, on the other hand, are more likely to consume the remaining portion of forests at a faster rate than high income countries (Ewers, 2006). As mentioned in Chapter 1, Ghana is an example of a country experiencing global deforestation problems. For example, approximately 1.9 million hectares of Ghana's forest cover was lost between 1990 and 2005 (Rainforest mongabay, www.rainforests.mongabay.com). As a further example, between 30 - 40 percent of

Ghana's total land area is estimated to be experiencing desertification due to deforestation (Bonsu, *et al*, 2008).

2.2.1 Forest Fragmentation

Assessment of forest cover loss in many countries focus on the extent of forest loss while pay less attention to issues of fragmentation due to uncertainty of the ecological effects of fragmentation on biodiversity (Kupfer, 2005). Since the late 1990s and 2000, profound land cover changes documented show evidence of forest conversions and modifications that resulted in forest fragmentation (Geist and Lambin, 2001). Forest fragmentation refers to the entire process of forest loss, isolation or change in the spatial configuration of forest remnants due to deforestation (Fahrig, 2003). Fragmented forest landscapes are complex and heterogeneous systems that are influenced by factors such as size of the landscape, degree of forest remnant isolation and habitat changes induced by forest edge effects (Pardini, 2004). These changes in forest landscapes often lead to fragmentation and isolation of habitat patches which affect both the structure and function of forest ecosystems (Fahrig, 1997; Kleinn, 2002).

Tropical dry forests which constitute 42% of forests in the tropics have been severely fragmented and disturbed hence disappearing rapidly (Hartter, *et al*., 2008). The rate of tropical forest fragmentation in Chiapas, Mexico, for example, shows that for 15 years (1975 to 1990) the annual rate of deforestation had been 1.3%; while deforestation rates have stood at 4.8% for the 1990 – 2000 period. This has resulted in an increase in the number of forest fragments by 1.0 – 3.2 patches occupying 100 hectares of land with total edge length of 24,781 – 38,400 km resulting in habitat loss (Cayuela *et al*., 2006).

The use of metrics to quantify the spatial attributes of landscapes such as the pattern and structure of forests are effective ways by which the effects of forest fragmentation can be analyzed, interpreted and reported (Herzog *et al*., 2001). Landscape fragmentation caused by transportation infrastructure, urban development and

agricultural expansion have threatened the environment through reduction in the size and viability of wildlife populations and facilitating the spread of invasive species that impair scenic recreational qualities of landscapes (Jueger *et al*., 2007).

Assessment of forest fragmentation in Western Oregon, for example, reveals that human land use accounts for 20% fragmentation and total forest edge effects (Butler, *et al*, 2003). The composition and configuration of forest pattern in the Cantabian range in North-west Spain shows that fragmentation is very severe in forests being used for agriculture (Garcia *et al*., 2004). In Selangor, Malaysia, forest fragmentation has increased between 1966 and 1995 due to the establishment of oil palm and rubber plantations (Abdullan and Nakagoshi, 2007). In the Chitwan District of Nepal, 15% of the forest cover was lost from 1976 to 2000 resulting in fragmentation of forest areas, pasture fields and degradation of animal habitats (Panta, *et al*, 2008).

2.3 Biophysical effects of deforestation

Anthropogenic causes of deforestation are associated, as mentioned earlier, with varying degrees of environmental threats that adversely affect the biophysical components of the earth surface (Blowers *et al*, 2008). In the tropics, interactions between human beings and their environment such as exploitation of two thirds of the world's biomass in least developed countries has contributed to deforestation and desertification problems (Johnson, 2007; Mosus, 2007). Degradation of the forest ecosystem in the past decades has been a major source of concern due to the significant decay of the forest ecosystem partly as a result of population growth, consumption behavior, leisure patterns and changing land use (Paulo, *et al*, 2008). Scientists working on sustainable land use have identified human induced land degradation and deforestation as major factors that limit sustainable production and food security in semi-arid East Africa (Slegers and Stroosnijder, 2008).

2.3.1 Biodiversity and habitat loss

Biodiversity is the sum total of all plants, animals, fungi and micro-organisms on the earth and their genetic and phenotypic variation in communities and ecosystems (Rozensweig, 1995). From a functional and evolutionary point of view, biodiversity constitutes diversity of functional groups of plants and life forms of organisms responding to selective pressure from the environment (Raunkiaer, 1934). As over exploitation of the forest for economic development intensifies, deforestation decreases the biological diversity of the forest cover (Jacobberger – Jellison, 1994).

Habitat loss negatively contributes to variation in geographical patterns of richness of species such that places of high elevations normally have higher tree species richness than lower elevations that are easily accessible and easy to cultivate, (hence more vulnerable to forest cover loss) (Chiba *et al*., 2009). Negative changes in habitats lead to species loss by stochastic fluctuation of reduced populations with consequences. For example, studies in Lago Guri island of Venezuela show how habitat loss has altered the abundance of nest predators and generalist herbivores (Feeley and Terborgh, 2008). A mammal survey at Hood Canal District in Washington reveals a close causal relationship between anthropogenic causes of habitat loss and ecological loss of mammalian communities (Lomolino and Perault, 2004). The study notes that tree species extinction crisis may arise when modifications and transformations intensify in forests. As a further example, harvesting of the coastal redwood forest for over 100 years has reduced the richness and the dominance of valuable tree species in the forest of Saskatchewan in Canada (Hageseth, 2008).

Extensive clearing of forests is not the only factor responsible for destroying forest lands. Human trampling of the understory vegetation on and off paths in sub-urban forests that are located at the forest edges towards the interior of the forest contribute to the loss of tree species. Trampling of the Boreal forest, for instance, suggests a decrease of between 10% and 30% of forest on paths trampled 35 times and a decrease of 50% of tree seedlings trampled 70 – 270 times (Hamber *et al*., 2010). Extensive path networks

created through intensive recreational use of forests influence the distribution and abundance of understory vegetation in urban forest fragments (Malmivaaru-Lamsa *et al*., 2008b). Disturbance of the forest often results, as mentioned earlier, in habitat quality changes and destruction (Kupfer *et al*, 2006).

Fragmentation of forest landscapes have consequences for ecosystem services and biodiversity conservation as shown above. Evaluation of the pattern and distribution of forest areas from 1957 - 2003 in Fragado Eume Natural Park in Spain suggest an increase in fragmentation due to decrease in forest patch size and core areas over time (Teixido, *et al*., 2009). Spatial analysis of the Camili biosphere reserve in Turkey shows that the total number of forest fragments has increased from 172 hectares to 608 hectares and the mean size of the forest patch has decreased from 147.7 hectares to 41.8 hectares from 1972 to 2005 (Sivrikaya *et al*., 2006). Forest fragmentation also affects the population and community dynamics of woody plants such as juvenile stem morphology of *Acer saccharum* Marsh. The differences in stem morphology between forest interior and forest edges indicated that, stem length to stem basal diameters were greater in forest interiors than near forest edges (Albro *et al*, 2007). Edge effect also influences stand transpiration whereby transpiration increases towards the edge of forests (Herbst *et al*, 2007).

Effects of nine forest fragments greater than 10 hectares and nine continuous forest sites greater than 1000 hectares on four ″Ctenus spiders ″ (C. Amphora, C. Crulsi, C. Manavara and C.Villasboasi) populations belonging to the genus Ctenus in central Amazonia indicate that fragmentation has resulted in much smaller populations of (C. amphora and C.Villasboasi) than the (C. Crulsi, C. manavara) populations. The study concluded that, isolation and forest reduction increases the chance of local extinction and threatens the diversity of ″C. Amphora and C.Villasboasi) spiders ″ (Felipe, *et al*., 2007). A study by Puttker, *et al*, (2008) showed that there is a strong positive correlation between secondary forest fragments and the highly endangered ″Akodon montensis ″ rodent species in the coastal Atlantic rainforest and a negative correlation at the edge density.

Rates of edge erosion and composition of edge ages in the Amazon forest and the distances from edges are important factors for determining the magnitude of forest degradation such as biomass collapse and carbon flux (Numata *et al*., 2009). More than 50% of forest edges were eliminated in the first four years after edge creation and only 20% of the edges survived for more than ten years in the Amazon (Numata *et al*., 2009).

A study conducted to investigate ecological consequences of human induced forest edges on non forest species, secondary forest species and primary forest species in Yunna, China, concludes that the dominance of each ecological group did not change significantly along the edge to the interior gradients. Dominance of secondary forest species decreased with distance from the edge, while dominance of primary forest species increased with distance from the edge (Lin and Cao, 2009). Edge structure affects the spatial extent of edge effects on the forest such that at open edges, the edge effect penetrates at least up to 30m into the forest patches whereas closed edges may prevent such penetration effects (Hamberg, *et al*, 2008).

2.3.2 Greenhouse gas emissions

Greenhouse gas emissions occur from two main terrestrial cover related sources; trees and soil that account for approximately 2 billion tons of annual global CO_2 released into the atmosphere due to deforestation (FAO, 2005). Beside these two sources, cities are considered as sources of high CO_2 emissions and heat islands due to industrial production, increased energy demands for transportation, heating, cooking and use of air conditioners especially in densely populated urban areas (GEO 4, 2007).

Trees are considered to provide carbon sinks and clearing of trees and woody vegetation contributes to the release of carbon dioxide (stored in trees) into the atmosphere with consequences of global warming (Searchinger *et al*, 2008). The release or loss of carbon stocks as a result of logging is usually estimated by calculating biomass from tree census data on forest plots, using alometric equations and extrapolations

(Gibbs, *et al*., 2007). It is estimated that, on average, 1.8 million hectares of forest disappear annually, hence, the release of carbon dioxide into the atmosphere has implications for human health and the biophysical environment (UNECE/FAO, 2007). Approximately 25% of $C0_2$ emissions during the 1990s occurred due to deforestation (Heat and Conrad, 2006).

Recent studies have improved policy makers and researchers' understanding of how deforestation contributes to greenhouse emissions. Some of these studies are briefly reviewed here.

Increase in greenhouse gas emissions resulting from the clearance of forests for agriculture, mainly in South America and Southeast Asia contribute approximately 6% of tropical greenhouse gas emissions (Verburg, *et al*., 2009). The Brazilian Amazonia soils contain up to 136GT of carbon to a depth of 8m of which 47GT are in the top soil. Rapid conversion of the Amazonian forest to cattle pasture has disturbed the soil carbon stock leading to changes in the global carbon balance and net greenhouse gas emissions into the atmosphere (Fearnside and Barbosa, 1999). Soil carbon stock declines of approximately 0 – 63% have been reported in Asia due to agriculture related deforestation (Girmay, *et al*., 2007). Production of agricultural crops for export due to liberal agricultural trade policies have contributed to greenhouse gas emissions as liberal policies serve as incentive to farmers to clear fertile forest lands to produce crops for export (Eickhout *et al*., 2009).

As shown above human land use for sustenance has been partly responsible for deforestation and consequently emission of CO_2 gases in developing countries leading to global warming (Salam and Noguch, 2005). In Sub-Saharan Africa for example, destruction of forests have the potential of increasing soil carbon in the atmosphere to cause global warming (Vagen, *et al*, 2005). At country level, Papua New Guinea, being one of the world's largest existing tropical forests in Sub-Saharan Africa experienced declines in forest size from 1972 to 2002 as a result of logging which resulted in carbon emissions into the atmosphere (Bryan *et al*. 2009).

The agricultural sector accounts for approximately 15% of total global anthropogenic emissions (Popp, *et al*, 2010). Conversion of forest lands to pasture fields has contributed to greenhouse gas emissions in that, fermentation of cattle droppings release greenhouse gases such as methane and nitrous oxide into the atmosphere (Freibauer *et al*., 2004). Methane fermentation and the amount of CO_2 emissions can be calculated using the parameter of total feed requirements and feed composition (IPCC, 2006).

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) has estimated that the forest sector contributes 17.4% of greenhouse gases due to anthropogenic deforestation and forest degradation (IPCC, 2007). Anthropogenic causes of land cover change such as deforestation accounts for the second largest human induced carbon dioxide flux into the atmosphere (Canadell *et al*, 2007). As a result of carbon emissions into the atmosphere, 37% of the world's population is likely to face climate change related stresses in developing countries due to their vulnerability to the adverse effects of climate change (Reynolds *et al*, 2007).

2.3.2.1 Benefits and human responses to climate change

There are opposing views to the negative effects of greenhouse gas emissions into the atmosphere caused by deforestation. This includes the view that greenhouse gases are beneficial for plant growth; hence, the effects of climate change should not only be seen as negative. One estimate, for example, indicates that agricultural yields will increase by 30% in the future due to the presence of greenhouse emissions, which may cause the ecosystem to become more resilient (Fajer and Bazzaz, 2002).

Another view proposes that regardless of the adverse effects of climate change man cannot be overwhelmed by climate change as there are opportunities for adaptation. A case to consider here comprises the Sahelian people who have been socially resilient to climate change related stresses for many years (Mortimore, 2005). Sustainable adaptation

to climate change can be addressed using policy frameworks based on local household participation in developing the policy for effective adaptation to climate change (Eriksen and Brown, 2011). In Ghana, adaptation strategies to climate change by farmers in the Kassena Nankana District of the Upper East Region include intensification of crop production using shallow ground irrigation methods, which is a water saving approach to farm irrigation (Laube *et al*., 2011). Another study investigated gender responses to climate change adaptation in the Afram plains of Ghana. The results showed that female farmers opted for construction of wells, bore holes and rain harvesting as the three most preferred adaptation strategies to climate change for domestic and farming uses. Male farmers, on the other hand, considered irrigation, construction of wells and bore holes in addition to planting drought tolerant crops to be the most preferred adaptation strategies to climate change (Codjoe *et al*, 2011).

2.3.3 Soil erosion and fertility loss

It has been suggested that population growth and accelerated deforestation are the main causes of soil erosion in many developing countries (Krschke, *et al*, 1994). Farmers' perceptions of soil erosion and degradation include reduced yield, change in the appearance of the soil and soil becoming stonier when the fine top layers are washed away (Moges and Holden, 2006).

Forest loss contributes to the removal of vegetation cover that protects the top soil resulting in the loss of soil nutrients. Soil nutrient loss occurs when the soil temperature exceeds 25°C, leading to the loss of volatile nutrients such as nitrogen through nutrient evaporation into the atmosphere (Mayer, 1994). Other effects of deforestation are soil erosion, sedimentation of major waterways and increased frequency and severity of floods (Sweeney *et al*., 2004). Clearing of the Amazonia forest using bulldozers has ,for example, contributed to compaction and distortion of the physical properties of the soil such as decreases in organic matter (nitrogen and phosphorus), soil porosity, base saturation and increase in the cation exchange capacity (Woodward, 1999; Allaby, 2000).

Effects of deforestation on the physical and chemical properties of soils in the Mediterranean region of north western Jordan show that soil organic matter decreases in cultivated soils compared to forest soils. The decline in the physical and chemical properties of the soil contributes to soil erosion and reduced fertility (Khresat, *et al*, 2008). Soil health and productivity studies using microbial bio-indicators for physical, chemical and biological soil fertility investigations show rapid loss of organic matter on cultivated forest lands compared to uncultivated lands (Regueira *et al*, 2005). Decline in the clay texture of tropical deforested barren soils is an indication that bulk density and soil porosity which are necessary for plant growth are limited in such soils (Sahan and Behera, 2000).

Conversion of natural vegetation to cropland or grazing fields has brought about changes in soil proprieties such as loss of water holding capacity, structure, stability and compactness necessary for efficient plant growth (Rasiah, *et al*., 2004). The concentration of domestic animals on woody lands contributes to the over utilization of woodland vegetation resources hence, the problem of degradation of the woody vegetation cover with attendant soil erosion problems (Röder *et al*, 2007).

Household surveys in Sidama, southern Ethiopia, identified soil erosion and fertility loss as problems faced by farmers due to deforestation and over-cultivation of the same land for many years (Moges and Holden, 2006). Another study in Ethiopia showed evidence of erosion of between 24 and 16 Mg ha^{-1} per year due to clearing of forest and woody vegetation over steep slopes (Tefera and Sterk, 2010). In the montane zone of Ethiopia, soil nutrient quality is very low due to severe deforestation, with accordant challenges in supporting efficient plant growth (McPeak and Barret, 2001). Improper cultivation practices have seriously degraded forest ecosystems in the Bale mountain of Ethiopia such that soil organic carbon and nitrogen have decreased during the past 15 years by 1m of the soil layer (Yimer, *et al*, 2007).

Analysis of the driving forces of environmental change in the eastern Senegal town of Saloum showed that conversion of forest and savannah areas to agricultural lands during the past 20 - 30 years has resulted in decline of precipitation and increased soil erosion (Mbow, *et al*, 2008). Similarly, soil analysis in Cote d' Voire shows that phosphorous decline occurred during the past 10 - 25 years of land cultivation (Negassa and Leinweber, 2009).

It is thus clear that significant changes in soil organic carbon, following conversion of natural vegetation to cultivated areas has adversely affected soil fertility in most developing Africa and Asian countries (Doming *et al*., 2002). In Mali, soil analysis in 19 villages showed that farmlands used for intensive commercial cotton production have poor soil fertility while sacred groves that were protected had higher soil fertility (Benjaminsen, *et al*, 2010). Again soil organic carbon assessment over large cultivated lands at Bondoukui in the western parts of Burkina Faso proved that over-cultivation of cotton resulted in an annual loss of $31.5gm^{-2}$ of organic carbon during the first 20 years of cotton cultivation (Ouattara *et al*, 2007).

Loss of soil fertility through deforestation affects not only the biophysical environment, but also the socio-economic lives of the people. For example, in the Awussa watershed of Ethiopia, deforestation led to soil fertility loss through erosion which negatively affected the social, economic and political lives of the people for over 100 years (Dessie and Christiansson, 2008).

2.3.4 Effects of deforestation on hydrology

The degradation of forests or woodlands impacts watershed processes and bio-geochemical cycles (Helmer, *et al*, 2000). Disturbance of forest cover can push ecosystems beyond their resilient points resulting in adverse hydrological and surface energy imbalances (Garcia, 2008). Tree canopy removal affects the hydrology of forest ecosystems by, for example, causing the water table to rise in areas receiving high annual

rainfall (Roy, 1998). Rain water runoff and soil erosion occur in semi arid areas where the woody vegetation cover is removed any time there is heavy rainfall (Ruprecht and Schofield, 1991). Also, forest clearing impacts water resources by increasing infiltration rates, speeding up dissolved organic carbon in water and increasing nutrient transfer from the top soil to underground water (Weatherhead and Howden, 2009).

The frequent wetting of tree canopies in addition to an average wind speed of 0.74m has resulted in 30% interception loss from cleared forests compared with 1% of annual precipitation loss from the shrub cover (Daiz, *et al*, 2007). The difference in canopy interception loss accounts for a rise in the water table by an average of between 10 and 45 cm and this prevents normal tree regeneration when the water table rises high (Daiz *et al*, 2007). Transpiration from tree canopies and evaporation from surface water are the path ways for loss of water from forest ecosystems, as trees are considered as 'ecosystem engineers' (Jones *et al*, 1994).

Empirical investigations have confirmed these theoretical possibilities. For example, clearing and burning of the Chiloe Island forest in Chile has resulted in a sparse forest which affected the total annual precipitation (Daiz *et al*, 2007). Furthermore, observations in Ghana show significant adverse effects of the removal of the forest and woodland cover which has led to the drying up of some springs and waterfalls or a reduction in the speed and volume of such waterfalls. For instance, the waterfall near Asesewa has become seasonal and flows only during the rainy season (Duadze, 2004).

2.4 Socio-economic effects of deforestation

Deforestation has disrupted the livelihoods of millions of people as activities such as hunting and gathering, and also harvesting of forest products such as rubber are becoming difficult, leading, on occasion, to violent conflicts (World Wide Fund, 2007). Small scale production and trading in forest products which constitute a large part of rural enterprises that offer livelihood opportunities to people may, in certain areas, be phasing

out due to unsustainable harvesting of the forest, hence depriving some rural households of their livelihood options (Liedholm and Mead, 1993). The loss of forest cover through deforestation also deprives people of forest ecosystem services such as fresh air, recreation and bio-geochemical cycle services, (Freer- smith and Carmmes, 2008).

Again, there is some empirical evidence in support of the above observations. For example, accelerated deforestation in Asia such as Java, has depleted forest resources that used to be exploited for income, farmers are thus impoverished (Sunderlin *et al*, 2001). Reduction of income opportunities from exploitation of forest resources in forest fringe communities in the Periya Tiger forest of India is contributing to worsening socio-economic conditions as income obtained from non-timber forest products are inadequate in meeting daily living costs (Gubbi and Macmillan, 2008). A study by Wildlife Alliance, (2009) showed that a major effect of deforestation on Cambodian rural communities is acute poverty. In China, land degradation is a developmental and environmental issue that afflicts people when biodiversity is lost (Bai and Dent, 2009). Deforestation through agricultural expansion has decreased livelihood opportunities for non-timber forest resource dependent people living in the Himalayan region as these resources become scarce (Vetaas and Knudsen, 2004).

A large area of deforestation in South America from 1991 to 2001 has been responsible for unprecedented loss of livelihoods in the Central American and Caribbean regions (Carr and Lopez, 2009). For example, deforestation in Brazil has badly affected indigenous people who live in the rainforest as livelihood activities such as hunting and collection of non-timber forest resources are becoming increasingly limited (Innes, 1996).

Following Oksanen, *et al*, (2003), forests play key roles in poverty reduction strategies in Africa. But, rapid forest land use changes have resulted in deforestation and biodiversity loss such as in East Africa with serious consequences for people's livelihoods (Olson *et al*., 2007). As a further example, environmental resources such as forests in Zimbabwe which used to contribute 40% of the average rural income of poor households has diminished due to deforestation (Cavendish, 2000).

Building on the above evidence, one can argue that, forest users, industries and institutions that exploit the forest unsustainably have placed those Ghanians who depend on the forest in desperate situations, as their livelihoods are being lost due to loss of the forest (Mayers *et al*, 2008). Additionally, deforestation has adversely affected the livelihoods of forest fringe communities, such as those in the Offin basin of Ghana as the quantity and frequency of rainfall has declined by 22.2% between 1960 and 2000 possibly as a result of forest cover loss. This has negatively affected agriculture, a major source of income in Ghana (Amisah *et al*, 2009). Rural women are being denied access to food and medicinal plants as forest cover is loss, leading to a concomitant disruption of rural household livelihoods and welfare systems (Adedayo *et al*, 2010).

2.5 Discussion

The literature review presented here discusses issues at country, continental and global levels related to deforestation processes and the effects of these processes on the biophysical environment including plant and animal species, soil properties and the associated consequences of the release of carbon dioxide into the atmosphere. Some knowledge gaps in the literature have been identified, and these include effects of deforestation on hydrology as an issue requiring further research.

Published data and information gaps exist on deforestation processes and its effects in Ghana, particularly in the study area. It is difficult to determine the exact extent of deforestation at district and community levels as data on forest cover change at such spatial units are, in fact, either not available or outdated due to the inability of responsible institutions and agencies to update their database annualy (Appia *et al* ,2009). It is therefore common to find data on national deforestation and in some cases, regional deforestation data, but not local and district deforestation data. As a result of the data gap local farmers and pastoralists use local techniques to produce crude (unscientific)

data on degraded forest areas as they farm and manage their livestock in these areas, but such crude data are often ignored by scientists even though they are relevant for studying the physical changes in the forest cover (Robu, 2008). The situation is however, not the same at global, continental and country levels where there is better access to data such as UNEP (2007) published data showing 0.2% global deforestation between 1990 and 2005 and an estimated that 50,000km^2 of primary forest lost in Asia annually. Apart from the limited data on local and district deforestation, literature available on the effects of forest fragmentation and edge effects on plants, animals and insects in Ghana is very limited, which suggests that this area has not been extensively researched hence the very limited literature reviewed in this study. The result of the study is expected to contribute to bridging the knowledge gap.

Global literature on sources of greenhouse gas emissions indicate that soil, trees and cities are among the key sources, with negative effects for the biophysical environment and people. Climate change may, however, also bring opportunity. Much of the Ghanaian literature on climate change includes study results of questionnaire surveys to determine opinions on adaptation strategies to climate change, rather than scientific measurements of for example, carbon emissions from trees due to deforestation at regional and district levels. This gap in Ghanaian literature deserves research attention at a time that climate change is a global issue.

The processes and effects of deforestation on soil degradation and erosion are diverse and crucial for the global environment. The crucial nature of deforestation processes and the effects on people and their livelihood resources, requires further research attention particularly in Ghana. Though literature in this area may exist at departmental and faculty levels of Ghanaian universities, it is not easy to access the information due to the inability of universities to place the study reports online.

In conclusion, the processes and effects of deforestation on the physical environment such as soil degradation, loss of habitat, forest fragmentation and edge

effects, carbon emissions, and effects of deforestation on hydrology are diverse and crucial for sustainable use of the environment. The critical nature of deforestation processes and effects on the biophysical environment in Ghana requires further research attention.

Chapter Three
Driving Forces of Deforestation

3.1 Introduction

Understanding the causes of tropical deforestation remains one of the key contentious issues in global environmental change. This comprises the major causes of forest cover change in different geographical and historical contexts (Lambin *et al*, 1999). Some tropical deforestation reports indicate that deforestation occurs under diverse circumstances with obscured underlying patterns (FAO, 2000). Causative factors responsible for deforestation, as stated earlir, are many and varied and reveal no distinct patterns (Rudel and Roper, 1996). Even though there are multiple driving forces of deforestation, human beings are the key actors that drive deforestation in view of population growth, cultural values, policy, science and technology that are considered human causes of land cover change (Seabrook, *et al*, 2006).

The literature review on driving forces of deforestation in this chapter has been divided into two main sections, namely; underlying driving forces and proximate driving forces of deforestation. The underlying driving forces of deforestation examined are the indirect causes of deforestation such as issues relating to population and deforestation, economic causes of deforestation, environmental policies and trade regulations and property systems (sections 3.2). The literature review on proximate driving forces of deforestation focuses on how human activities such as woodfuel exploitation and farming result in deforestation (section 3.3).

3.2 Underlying driving forces

Underlying driving forces of deforestation may occur as a result of structural factors, domestic policies, economic and institutional factors that contribute to deforestation (Motel *et al*, 2009). Studies in Chiradzulu in Malawi, for example, show

that poverty has contributed much to the country's deforestation, as 97% of the country's population earn less than $US 1 a day. The low income in Malawi compelled the poorest people to exploit the forest for income to meet their basic needs (Kamanga, *et al*, 2010). Widespread rural poverty and environmental degradation have brought about the development of green governance ideas aimed at halting environmental degradation. These ideas do not, however, adequately address the environmental problems (Hein-Anton van der Heijden, 2008). Wide spread poverty and high unemployment stimulate the demand for land and forest resources which contribute to deforestation (Kenya National, Bureau of Statistics, 2007). Forest fires, increase in human population, conflicts of interest and political interferences have further deepened the underlying driving forces of deforestation (Mwavu and Witkowski, 2008).

3.2.1 Population and deforestation

It is generally acknowledge that population growth by itself can speed up the process of deforestation in all countries**.** Between 1960 and 2010 the world's population rose from 3 billion to 6.8 billion with a population growth of 83 million people per year (Population Media Centre, 2009). The growth in world population has implications for increasing demand for housing, food and forest products which drives deforestation (Doos, 2002). In poor countries of Sub - Saharan Africa and south Asia, rapid increase in population has been responsible for loss of forest and woody vegetations such that households that need wood for house construction have limited access to it (Wells, 2000). In Mopti, Mali, for example, population growth has led to deforestation with consequences of deterioration on the quantity and quality of wood available for housing (Wells *et al*., 1999).

Population pressure is often associated with forest depletion and degradation in developing countries as stated earlier (Gulati and Sharma, 1991). This association underlies many proximate causes of deforestation, however the linkages are complex. Despite the numerous publications that make this linkage, one must keep in mind that population growth has its own proximate and underlying causes.

World Bank reports affirm that rapid population growth is a cause of environmental degradation in many developing countries (World Bank, 1993). For example, rapid population growth is identified as a contributer to deforestation in south central African Miombo woodlands (Walker and Desanker, 2004). Although population growth is a key driver of deforestation other driving forces as reviewed in the literature are equally important driving forces of deforestation that deserve to be investigated in this study.

Studies in tropical deforestation dwelt on the Malthusian concerns that rapid population growth in developing countries would soon destroy natural resources such as forest cover (Myers, 1980). The role of population as a driving force of deforestation is often elucidated by citing factors such as consumption patterns, urban and rural demand for forest resources, affluence and technology as factors that operate in tandem with population (Carr, and Barbieri, 2006). In the 1980s and 1990s, many studies were done to consider the effects of population on forest decline (Walker, 2004). Between 1970 and 1991, population pressure contributed significantly to deforestation as several case studies have shown connections between population growth and environmental degradation (Walsh and McGinnis, 2008; Uusivuori *et al*, 2002).

Due to a rise in the population of Nang Rong district in North East Thailand, for example, forest lands around villages have been converted to agricultural lands in order to produce food crops (Entwisle *et al*., 2006). In Africa, population growth in Kenya has contributed to deterioration in the balance between the number of people and the forest resource base, resulting in deforestation. To determine the magnitude and extent of population pressure on resources in Kenya, a rural population pressure study was conducted (Anzagi and Bernard, 2002). The study established that deforestation in coastal Kenya can be attributed to demographic pressure resulting in over exploitation of forest resources (Owino and Oyugi, 2009).

The rapidity with which forests are lost can be attributed to rural population increases which push farmers to clear fertile forest lands to meet food demands in non

agricultural urban centres (Marcoux, 2000). Increase in rural population occurred for example, due to rural to rural migration to forest frontiers in Latin America for farming purposes which resulted in deforestation (Carr, 2009). Increased population pressure in Java led to expansion in agricultural lands when there was increased demand for fertile forest lands for agriculture (Verburg, *et al*, 1999). While there is a great deal of consensus on deforestation from the global perspective, it appears there was a reduction in deforestation during the 1990s in some developing countries due to low population growth in rural areas as a result of rural to urban migration in search of factory jobs when agriculture in the rural areas became less profitable (World Bank, 2008). Although rural to rural migration plays a key role in deforestation this area of research has been ignored in most studies (Zimmerer, 2004).

In Sub-Saharan Africa, rapid population growth and poverty constitute the main driving forces of change in forest land use (Lambin, *et al*., 2003). The southern region of Burkina Faso has, for example, experienced population increase since the 1980s not only as a result of natural growth in population but also immigration of farmers from drought affected areas of the north and central regions of the country (Quendraogo *et al*., 2008). Rapid population growth coupled with poverty has driven the conversion of woodland and forest areas to cropland and pasture fields in southern Burkina Faso (Ouendraogo *et al*., 2010). The study in Burkina Faso made use of satellite image analysis to measure changes in land cover types while national population census data was used to examine the population dynamics and deforestation (Quendrago, *et al*., 2010).

Analysis of population and satellite data from 1960 – 2008 also suggests that population pressure has contributed to a steady increase in the size of croplands in West Africa (Ruelland, *et al*, 2009). A study of the drivers of deforestation in Bauea-Limbe in Cameroon from 1984 – 2000 using census data, suggests that population is a key factor of deforestation given the extensive forest areas that have been lost (Mbatu, 2009). Analysis of demographic data in Ghana shows severe degradation of the natural vegetation due to population increase (Leblanc *et al*., 2008).

Four primary factors by which population dynamics impact deforestation are population density, fertility levels, household demographic composition and migration (Carr, 2004). Population growth coupled with economic development contributes to urbanization, with consequences for forest lands (Rolnik, 2001). A study on the effects of population pressure on agricultural expansion from 1975 to 2000 in Bangladesh indicates that demographic pressure accounts for the clearing of more forest lands for agriculture (Shajaat, 2007).

The amount of forest biomass used per capita can be determined by historical patterns of land use and population density instead of affluence and the economic status of resource users (Krausmann *et al*, 2008). Studies of historical deforestation processes in British Columbia show, for example, that forest disturbances before and after the 1950s were caused by human exploitation of the forest for agriculture (Klenner, *et al*, 2008).

Changes in the population growth rate and density of Sahelian countries have contributed to the loss of woody vegetation cover (Mortimore, and Turner, 2005). For example, in Kenya high population density of 578 persons per square kilometer has resulted in decrease of the national forest cover (World Bank, 2008). Furthermore, global expansion of urban centers has resulted in increased urban population by 15 times since the last millennium (Kumar, 2009). As a result, urban population growth from 1900 – 2000 has aggravated the effects of population growth on the environment as the process of urbanization has compelled farmers and some land owners to convert agricultural lands to residential and other land uses with consequential forest and woody vegetation losses (Kumar, 2009). For example, the Kakamega forest in Kenya is under imminent threat of degradation due to a rapidly growing population close to the forest coupled with high poverty levels in the area which is above the national poverty average (Müller, and Mburu, 2009).

Studies show that households who live close to forests derive approximately 60% of their income from forests (Guthiga *et al*, 2008). Exploitation of the forest and woodland resources therefore contribute to deforestation with implications for the health

of the environment in Ghana as also discussed earlier (Koku, 2001). Deforestation may not, however, always be attributed to poverty given that households with high levels of assets also contribute to deforestation in pursuit of different livelihood activities (Stringer, 2009).

3. 2. 2 *Economic causes of land cover change*

A nation's economic growth strategies may contribute to deforestation. This is particularly true for countries that depend heavily on the agricultural sector to stimulate growth either through domestic market expansion or increased export or both. The increase in global trade has exerted pressure on the environment as increased profit earning is motivating farmers to expand their farmlands into forests in Latin America and Caribbean (UNEP, 2005b). Economic growth indeed contributes to forest cover change as economic growth is associated with increased consumption of environmental resources such as the forest, frequently resulting in forest cover loss (Nelson and de Jong, 2006). Economic analysis of deforestation shows that, theoretically, countries that are in the process of economic development exploit environmental resources such as trees for large scale industrial use and for construction to spur economic growth (Barbier, 2005 ; Naidoo, 2004). At a point of economic growth and development the risk of environmental degradation such as loss of forest land becomes an issue of the past when the economy of a country is diversified and less reliant on the export of forest products (Tamazian *et al*, 2009).

It has been hypothesised that causes of deforestation are more likely to be determined by economic events outside the forest arena than by what happens within the forest sector. For example, high agricultural prices can stimulate forest clearing when farmers respond to the opportunity of making more profit from farming than from alternative available jobs (Wunder, 2000). The structural adjustment policy of the El Salvador government, for example, which was meant to modernise agro-exports led to the clearing of extensive forested areas for cattle ranching, cultivation of sugarcane and

cotton for industrial exports (Hecht *et al*, 2006). Growth in the agricultural sector was, in fact, facilitated by financial incentives from the El Salvador government. After some time, however, the decline in the world price of agro-exports coupled with the migration of males from conflict farming towns in El Salvador contributed to natural succession of the forest cover (Conroy *et al*, 1996).

Since 1986, Bolivia has witnessed a significant increase in agriculture especially with regards to soybean production which was mainly due to the promulgation of a government policy aimed at expanding soybean production as the world soybean prices continued to increase. To boost expansion of soybean farms, foreign farmers from Mexico and Canada were invited to farm in Bolivia. The foreign farmers had access to heavy farm machines that contributed rather more to the clearing of more forests than more basic equipment used by the local Bolivians who are primarily subsistent farmers (Hecht, 2005). Fluctuating market prices associated with price attractions go along with the desire to increase income; hence, can be considered a driving force for deforestation (Mbow *et al*, 2008).

Most African economies are heavily reliant on agriculture and natural resources for their GDP, national food needs, employment and export revenues that require clearing forest lands (Mutangadura, 2007). For instance, post independent African forest land use policies in Kenya and Tanzania promoted clearing of forest lands to grow export crops. The governments of Kenya and Tanzania, created National Food Corporations such as the National Food Corporation of Tanzania and Nyayo Tea Plantation of Kenya (Olson *et al*, 2004). These corporations contributed to commercial cultivation of export crops which consequently contributed to deforestation in these two countries. Furthermore, macro economic change in other African countries such as Cameroon played a fundamental role in forest cover change. Such macro economic change occurs whenever there is an expanded market for food crops and the modification of farming systems that involve the use of high machine technology in remote forest zones (Mertens and Lambin, 2000). Further studies on forest loss in Cameroon show that market and policy failures,

institutional weakness, debt crisis and population growth are driving forces of deforestation in Cameroon (Mbatu, 2009).

In an attempt to implement programmes to reduce poverty, developing countries have often concentrated on the easiest ways to solve their poverty problems such as logging forest trees for export to earn income (Norman and Myers, 1991). High global demand for wood products has contributed to the creation of a situation whereby chronic wood supply difficulties are being faced by wood and paper processing industries which results in the degradation of natural wooded areas (Barrand and Sayer, 2001). Apart from the high global demand for wood products, empirical studies in Mfyome village of Tanzania show, for example, that taxation of households that produce forest products has created income deficits on poor households compelling families to exploit more resources to earn more income thereby worsening deforestation problems in the country (Anthon *et al*, 2008). In addition, timber exports from developing countries, unlike exported timber sold in developed countries, attract very low prices. For example, in Papua New Guinea, local communities receive between US$ 5 and US$ 20 per m^3 of logged wood while the price of the dock wood in the US sells for approximately US$ 700 per m^3. At the retail level, the price goes up to US$ 2000 and more. In situations of this kind, much of the profit goes to dock companies and retailers in the US and not to local logging companies. Due to poverty, local logging companies in Papua New Guinea continue to log more forest trees to make up for the low payments received from their exports thus, facilitating deforestation (Heat and Conrad, 2006).

Conversion of forest lands to livestock grazing fields became necessary, as a further example, when the price of beef rose on the international market (Night and Nation, 1980). The attractive market price for beef stimulated, for example, the conversion of parts of the Amazonian forest to livestock grazing fields (Night and Nation, 1980; Browder *et al*, 2008). Subsidies for cattle production further encouraged more people to clear forest lands for cattle production in the Amazonia basin, leading to the rapid loss of forest cover (Rapetto and Gillis, 1988).

3. 2. 3. *Environmental policies and governance*

Government policy failures and misdirected policies have in certain cases indirectly resulted in deforestation in developing countries (Norman and Myers, 1991). The loss of the Amazonia forest is an example of global scale deforestation that started in the 1960s due to a government policy that allowed construction of roads in the Amazon forest region such as the Belem-Brasilia highway. The highway constructed increased the population of the area from 3 million to almost 23 million people. The increase in population around the Brazilian basin contributed to the loss of large tracts of forest (Walker *et al*, 2007). The nature of government structures in existence also determines the effect of governance on the environment. For example, and linked to the previous section's discussion, a rise in trade openness reduces deforestation under autocratic governments and increases deforestation under democratic governments in both developed and developing countries (Li and Reuveny, 2009). Reduction in deforestation under dictatorial governments occurs due to the exercise of martial laws concerning forest use. Under democratic governments, however, the principle of freedom of speech may make it easier for laws to be defaulted (Guiang and Castillo, 2008).

Poor enforcement of forest protection policies has resulted in extensive illegal logging in Costa Rica (Ibarra and Hirakuri, 2006). For instance, government forestry officials in certain cases in Africa and Asia come around only to collect occasional bribes instead of focusing on technical issues concerning forest loss and preventing unauthorized tree felling (Silva *et al*., 2002). The effect of poor law enforcement includes deforestation and loss of habitat for animals and other organisms (Defries *et al*, 2007). Excessive timber harvesting has been responsible for most forest cover losses that negatively affected forest stand, structure and composition (McDonald *et al*, 2008). The unprecedented loss of tropical forest cover has brought to the fore a new thinking aimed at developing socially optimal policies for biodiversity conservation in the United States of America with a focus on identifying best forest conservation policy practices and the adoption rate of such policies (Matta, *et al*, 2006).

Uncertainty surrounding global trade policies has proved to be an imminent threat to forest survival in Lao, South East Asia (Lestrelin, 2009). In Africa, for example, macro-economic policies such as the structural adjustment programme implemented in Zimbabwe encouraged export of tropical wood to European markets resulting in deforestation (Kowero and Mabugu, 2004). The implementation of a similar policy in Cameroon comprising a structural adjustment and market policy reform from the 1980s to 1990s has equally contributed to deforestation in Cameroon (Pokam and Sunderlin, 1999; Bhagwati, 1995).

Global and regional decline of tropical forests result from adverse forest policies in places such as in Zanzibar, Tanzania, where the state alone may decide on lands to be gazetted as forest without consulting land owners. In such situations, land owners do not cooperate in conserving such forests. They may instead over exploit the forest since they are denied their source of basic livelihood (Kayhko, *et al*, 2010). In a developing European country such as Greece, as a further example, regional economic development policies on forest ownership have contributed to the loss of forest resources (Minetos and Polyzos, 2010).

Change in the environment such as deforestation has contributed to the formation of political coalitions that have generated dynamic environmental and political networks aimed at building broad based social environmental collaborations to monitor global environmental change (Dichiro, 2008). The formation of international groupings such as the 'North American Agreement on Environment Cooperation' was to strengthen international laws to protect the environment. Even though the agreement was signed, inadequate enforcement of the environmental law made the agreement ineffective, however, in reducing the pressure on the environment (Blair, 2008). The failure of such agreements has led to the emergence of civil society organizations such as the World Rainforest Movement (WRM) to campaign against deforestation by writing articles and holding meetings to brainstorm to find solutions to deforestation (World Rainforest Movement, www.org.uy/). The WRM has been involved in cases such as that of Ecuador where BOTROSA a foreign company in Rio Pitzara replaced natural forest with exotic

monoculture plantations resulting in substantive ecosystem damage (Ramos and Bonilla, 2008).

Deforestation is also attributed to factors such as insufficient environmental awareness campaigns due to budgetary limitations on the part of governments in developing countries who find it difficult to make financial resources available for grassroots level educational programs on the need to be responsible with exploitation of the forest (Espindola, 2007). Bilateral cooperations among governments of developed and developing countries that focus on reducing emission from deforestation emphasis creation of large tracts of forests to sequester carbon. However, there is a challenge to this large scale afforestation as indigenous people who own such lands depend on it for their livelihoods, hence, are not willing to use such lands for forestry projects unless they are provided altenative livelihood opportunites (World Rainforest Movement, 2002).

3.2.4 Trade regulations

Neo-liberal trade policies are associated with free trade and reduced government involvement in directing trade based on the idea that the free market may provide social and environmental solutions to forest degradation. This is argued to be possible when forest property rights are assigned to private individual owners instead of government (Liverman and Vilas, 2006). It has been argued that state policies impede market functioning; restraining the market problem solving potential and inhibiting the development of technologies that could improve environmental degradation hence the need for a neo-liberal policy (Obach and Ozler, 2009). Critics of neo-liberal policies contend, however, that predictions of environmental improvement have not necessarily come about. Instead, greater environmental degradation and health risks have occurred in cases such as Mexico and the United States of America (Cooney, 2001). In Chile, for example, state forests and plantations were sold off in 1975 as part of neo-liberal trade reforms resulting in extensive forest cover loss (UN-FAO, 2000).

Global capitalism, social reproduction, neo-liberal policies of privatization and deregulation have, in a number of cases, eroded the assurance of living wages, affordable health care and clean water in developing countries, possibly resulting in the need for excessive exploitation of forest resources (Alves, 2007). Estimates in 2004 show, for example, that 4 million km^2 of closed moist forest land which constitutes 16.3% of the Brazilian Amazon was lost (Alves, 2007). An effort to conserve the forest in Brazil has been pursued by putting in place policies to compel people cutting the forest to reimburse the government as a way of raising funds to replace felled trees. Such efforts did not, however, pay off as monies collected were not properly accounted for (Calvo- Alvarado *et al,* 2008).

Increase in trade with emerging economies such as China, India, Brazil, Mexico and South Africa has influenced global resource consumption. Such a trend may have environmental consequences as industries in these countries often depend on natural resources such as timber for industrial production (Grunbino, 2007).

Trade restrictions on logging and timber exports encouraged corruption and illegal logging in both Indonesia and Ghana (Richards *et al*, 2003). Furthermore, from the period 1950 to 1970, international commerce favored commercial trading in wood, hence, government policy in Cote d'Ivoire encouraged logging resulting in increased forest cover loss (Verdaux and Alphas, 2004; Gonzalez-Pacheco, 2005; Honey-Roses, 2009)**.**

3.2.5 Land Distribution and Property systems

Land tenure and resource availability plays a critical role in land use decision making processes resulting in different types of land use changes (Wanna-Sai, and Shrestha, 2007). Land tenure is the legal or customary relationship that exists among individual groups with respect to land and the associated natural resources. In other words, the terms and conditions under which land is held, used and translated, determines who can use what land, for how long and under what conditions (FAO, 2002).

Essentially, land use rights refer to property entitlement and land ownership without which access to land becomes problematic (Rodgers, 2010). Land tenure therefore defines the relationship between people, land and other natural resources regarding the conditions of access, rights and obligations related to how land can be used and controlled (Grover *et al*, 2006). Changes in land tenure rules are sometimes necessary to enhance people's rights to tenure security for proper land use management (Amanor, 2008).

Ethnographic evidence from Tigray shows, for example, that land transfer rights could be informal short tenure arrangements that do not ensure secure titles to land, thus farmers working on such lands destroy potential forest cover (Segers *et al*, 2010). In other parts of the world, common property regimes have encouraged multipurpose management options for mountain forest management as in Austria and Switzerland (Gluck, 2002).

Some experts of land cover change studies attribute deforestation to agrarian reforms such as inequitable land distribution policies (Alston *et al*, 2000). Inequitable land distribution policies may compel land users to exploit the land to the maximum during their tenure which leads to deforestation. Land insecurity on common property such as cattle grazing fields, for example, encourages extensive degradation of grazing fields (Hardin, 1968). Implementation of restrictive and strictly segregated forest resource allocation policies, whereby the government acted as the sole guarantor and controller of natural forest resources contributed, for example, to deforestation in Cote d'Ivoire (Verdeaux and Alphas, 2004). In situations where state forest policies exclude owners of forest resources from decision making there may tend to be a disincentive on the part of stakeholder communities to protect forests (Verdeaux and Alphas, 2004).

Facts concerning land tenure histories in indigenous territories of Nicaragua suggest, as a further example, that a key challenge to forest resource administration aimed at curbing deforestation is how to address tenure insecurity issues (Finley-Brook, 2007). Land tenure insecurity was a major factor that contributed to deforestation in

Maramhao in the Eastern Amazon where people cultivating the land considered themselves as people who only have temporary title to the land. They therefore removed needs to satisfy own objectives and not those of land owners (Oliveira, 2008). In a number of cases, land tenure insecurity is found to be associated with deforestation and forest encroachment as unsecured land title holders' clear forest lands considered fertile for growing perennial crops for profit making (Wannasai and Shrestha, 2007). However, people with more secure land tenure arrangements have better control over resources on their lands. As a result, they may think in terms of long term gains on the land, and may therefore be willing to protect trees of economic value to them (Nareeluck, and Rajendra, 2007). Studies carried out at Prasae watershed in Thailand showed, for example, that land tenure insecurity is associated with deforestation and forest encroachment since settler farmers are only interested in exploiting trees on the land to support livelihoods regardless of the consequences (Wannasai *et al*, 2008).

Prioritizing national and colonial forest policies over the interest of rural populations who have been depending on the forests for centuries has, in a number of cases, further resulted in extensive loss of forest in many countries. The negative effect of such policies has contributed to the debate for land tenure reforms in Africa, Asia and Latin America (Larson, *et al*, 2010). In China for example, extensive loss of forests due to insecure tenancy rights in the year 2000 led to land reforms on an experimental basis by the government in provinces in favor of individual ownership where collective forest ownership is dominant (Shen *et al*., 2009).

Barnes (2008) investigated the Ejido land tenure system in Mexico and found that rules relating to land acquisition, transfer and extinction of land resource rights show that community based tenure contributes to forest conservation. Establishing property rights over pasture fields for instance, will ensure seasonal pasture movement for sustained pasture land management (Robinson *et al*., 2009). In effect, as mentioned earlier, people or institutions that have control over land can determine how land resources such as forests should be used (Turner, 1990).

Colonialism and post independence land reforms frequently removed land title rights from local land owners. Land redistribution has thus been a feature of more recent policy in a number of southern African countries. Land redistributed to the native land owners was, in certain cases over-exploited, resulting in the loss of woody savannah vegetation in Botswana, Mozambique, South Africa and Zimbabwe (Eriksen and Watson, 2009). In Botswana, for example, 6% of the country's land offered to white commercial livestock farmers is freehold tenure while in other parts of Botswana land allocations are done by chiefs (Molomo, 2008).

Post independence land reforms largely failed to address fundamental issues that constituted threats to social, economic and environmental sustainability in the southern African region. The persistent problem of deforestation can thus be attributed to the exploitation of forest and woodland resources for food and other socio-economic needs (Clover and Eriksen, 2008). Land tenure and environmental change are issues of concern in rural arid and moist areas that comprise southern African savannah lands (O'Brien *et al*, 2009). Land tenure and land policies may, as mentioned earlier, create conflicts of interest that lead to land use problems (Amanor, 2008a). For example, in Senegal, rapid agriculture expansion took place between 1960 and 1970, associated with controversial land policies that led to the clearing of more forest and woody areas. In 1964, a new land tenure law facilitated land acquisition easier for large scale groundnut production contributing to forest cover loss (Mbow *et al*, 2008).

Indigenous land use rights in Ghana involve acquiring land for farming by virtue of belonging to a land owning community or family. In such a case, acquisition of land title by a farmer requires continuous occupation of the land but does not confer absolute ownership rights (Odoom, 1999). The cultivator of a field under the indigenous land use rights has no discretionary land transfer right because the land belongs to a corporate body such as the community or family (Benneh, 1989). Long undisturbed possession of land by migrants or trespassers with limited interest cannot be considered as title to land either (Kasanga, 1989). In the north eastern part of Ghana, studies revealed that the main cause of environmental degradation and poor agriculture production is land tenure

insecurity (Bugri, 2007). It has been suggested that land market reforms in terms of providing financial aid to farmers to own the land they cultivate can provide the needed security to address the rapid deforestation problems in Ghana (Zhang and Owiredu, 2006).

In situations where land tenure systems are associated with problems, fundamental political and technical reforms are required to bring about changes in the land tenure agreements (Amanor, 2008b). Land reforms aimed at addressing inequalities created by colonial regulations have to safeguard social and environmental interests rather than commercial sector colonial interests (Kanyongolo, 2008). Land reforms in the past were in certain cases driven by macro- economic growth motives at the expense of social stability of land use systems (AU/ADB/ECA, 2006). The interaction of social, political and economic factors determine issues of access, distribution, security of tenure and management of land (Clover and Eriksen, 2008).

3.3 Discussion of underlying driving forces in Ghana.

Leaning on the literature review above, it can be argued that population increase coupled with poverty are key driving forces of deforestation in Ghana as was the case in Malawi where poverty compelled Malawians to cut forest trees for survival resulting in deforestation (Kamanga *et al,* 2010) ; Mwavu and Witkowski, 2008). Further, the quest for economic development involves the exploitation of wood from the forest to provide housing and road infrastructure in most parts of Ghana a situation similar to the study of Nelson *et al*, 2006.

The colonial Forest Ordinance Act of 1927 in Ghana (Cap.157), which is the basis for the 1927 colonial forest policy, led to the creation of forest reserves with powers of forest control vested in a reserve commissioner without paying compensation to individuals and families (Gyampoh, 2011). The unfavorable terms of the act compelled affected people to exploit trees and other resources in the forest unsustainably just to

survive. The study of Larson *et al*, (2010) confirms how past colonial forest policies negatively affected forest areas in Ghana just as in other parts of the world. At present, colonial policies are no longer strong underlying driving forces of deforestation in Ghana due to policy reforms. Instead, subsistence farming influenced by local demand for food crops and small scale industries are among factors contributing to deforestation in Ghana just as the study result of Olson and Maitima (2006) has indicated. In Ghana, policy failures and the failure of government institutions responsible for monitoring the forest are also responsible for deforestation (Wibow and Byron, 1999).

In summary, the interplay of underlying driving forces of deforestation such as population increase, economic policies, environmental and trade policies have been extensively researched. However, further research is needed to find out how land title reforms have influenced land use and cover change in Ghana.

3.4 Proximate driving forces

Proximate driving forces of deforestation such as agricultural expansion, wood extraction and infrastructure expansion are the direct land use activities that contribute to loss of forest cover, (Geist and Lambin, 2002). As mentioned earlier, the use of land for agriculture is among the most common proximate driving forces of deforestation due to exploitation of the forest for food (Krausmann *et al*, 2008). Fuelwood extraction, selective logging by commercial firms, charcoal production, extraction of construction materials and burning of the forest comprise further causes of deforestation (Backeus *et al*, 2006). In some situations, a combination of proximate driving forces such as the clearing of forest for agriculture, timber exploitation and forest fires are the causes of deforestation. A typical example here is the Monarch Butterfly Biosphere Reserve (MBBR) in Mexico where illegal logging and agricultural clearing are cited as the main drivers of forest loss (Rendon- Salinas *et al*, 2007). Detailed explanations on the proximate driving forces are provided in sections 3.4.1 and 3.4.2.

3.4.1 *Woodfuel extraction and deforestation*

In 2000, 300 million cubic meters of wood were used for woodfuel worldwide, a quantity that is approximately 60 percent of the world's total wood removal from forest and non forest lands for energy production (FAO, 2008). Global studies suggest that the demand for woodfuel will continue to rise for several decades as wood based fuels are the dominant sources of energy for over two billion people, particularly households in developing countries (FAO, 2008). For example, rapid deforestation in Brazil has occurred as a result of large-scale consumption of biomass energy (Ceccon and Miramontes, 2008). The consequence of extensive woodfuel use in Africa, Asia and Latin America is deforestation and widespread woodfuel shortages (Bensel, 2008). In Uganda, for example, forest biomass constitutes 89% of total energy consumption at a time that the hydro-electric power potential of the country is not fully developed. Even when hydro-electric power potential fully developed, it is estimated that 75% of total energy consumption will continue to be met through biomass energy by 2015 (Akankwasa and Tromborg, 2001). In the event of such a shortfall, one energy substitute proposed for developing countries is wood residues from saw mills and crop residues (Tomaselli, 2007; Perley, 2008).

Charcoal and firewood are considered as the basic energy sources in most developing countries yet the inefficient production of charcoal and firewood pose a challenge for forest survival in African countries (Wood Energy and the Environment, 2008). For instance, disturbance to the soil during burying of wood meant to be processed to charcoal contributes to the loss of vital top soil nutrients and young plants that have the potential to develop into trees at the charcoal production sites (Anhi, 1998).

Major uses of woodfuel in Sub-Saharan Africa such as gin distillation, brick manufacturing, tea production and domestic cooking adversely impact the environment in the form of soil erosion, and further degradation as entire trees are cut instead of cutting branches (Liu *et al*, 2007; Naughton- Treves *et al*, 2007).

The demand for urban wood energy has also increased as the urban population keeps increasing with its associated environmental consequences of deforestation (Leach and Mearns, 1998). Urban demand for woodfuel in Sudanian and sahelian West Africa has been assumed to contribute to permanent deforestation in dry land forests and woodland savannah areas. As such, it is difficult for dry forest and woodlands to supply woodfuel to the Sudanian and sahelian city regions (Ribot, 1999). It is important to note that exploitation of fuelwood and charcoal contributes not only to widespread tropical deforestation in developing countries but also to desertification in woodland and shrub land habitats (Arnold, 2006; Bensel, 2008). It is expected that the demand for fuelwood and charcoal in cities may continue to rise while the growth rate of trees and shrubs may decrease in the coming decades (FAO, 1987).

In Zambia, the energy budget is dominated by 70% of biomass energy which amounts to approximately 4.33 million tons of wood energy contributing in part to deforestation in Zambia (Energy Department of Zambia, 1992). Woodfuel deficits in southern and central Malawi, Blantyre, Zomba and Lilongwe cities have been attributed to limited electricity access and reliability coupled with high electricity tariffs. This situation has compelled poor households to deepen their reliance on woodfuel, affecting forest cover offtake (Zulu, 2010).

A country wide study on charcoal and fuelwood consumption in Ghana indicates that the consumption of woodfuel increases annually at a rate of 5.8% contributing to deforestation (Ardayfio-Schandorf, 1986). Another study in Ghana shows that over 500,000 metric tons of charcoal had been consumed annually since the 1980s, as such, an estimated 3.6 million tons of wood was cleared from Ghanaian forests on a yearly basis (Energy Research Group, 1989). A bulk of the charcoal and fuelwood produced in Ghana is obtained directly from the natural forest and 10% is from wood waste derived from logging and sawmill residues. It is expected that by 2020, woodfuel consumption will reach 25 million tons in Ghana (Energy Commission of Ghana, 2002). The major charcoal producing areas in Ghana, such as Donkorkrom, Kintampo, Nkoranza, Wenchi and Damongo show signs of depleted forests and woody vegetation. Consequently, wood

energy producers have to travel longer distances in search of wood for charcoal production, (Energy Commission of Ghana, 2002).

Inefficiency of cooking stoves contributes to deforestation. A study of three cooking stoves in Ghana (the Ahibenso stove, Gyapa stove and the traditional stove) shows that the Ahibenso and Gyapa stoves have better energy efficiency due to their desing, hence save 26% and 37% fuel per day respectively compared to the traditional stove that has poorer energy efficiency (Stosch and Quaye, 2002). The traditional stove which is made up of stone or clay by its design do not allow direct contact of cooking pot to fire as the pot hangs at a distance from the fire. This results in energy loss as such lots of firewood are burnt in a day for less cooking leading to cutting more trees for wood energy.

3.4.2 Agriculture and deforestation

Part of the literature review in this section has been discussed in sections 3.1 and 3.2 as well as in the introductory chapters. However, a detailed discussion is provided in this section. Agriculture expansion is a major driving force of deforestation in Asia, Africa and Latin America (MEA, 2005). Traditional smallholder agriculture in developing countries occupies a central place in the tropical deforestation debate in Africa as shifting cultivators are viewed as the primary agents of deforestation (Jasen *et al*, 2007). Studies in the Maninka province of Mozambique show, for example, a substantial decrease in the forest cover due to the clearing of the forest for crop cultivation and a change from shifting cultivation to permanent cultivation on gentle slopes close to road networks (Jansen, *et al*, 2008).

Intensification of agriculture, mainly due to population pressure, has rendered the practice of shifting cultivation at regional and global levels to short term rotational fallow periods leading to loss of riparian forests as space for subsistence farming is scarce (Wood *et al*, 2004; Eaton and Lawrence, 2008). Intensive cultivation of land for agriculture reduces the length of farming fallow periods within which woody vegetations

in many parts of the Sahel could regenerate leading to negative impacts such as loss of woody vegetation and soil erosion effects (Elmqvist and Khatir, 2008).

Encroachment of agriculture on forest has resulted in the loss of prime forest lands (Jansen *et al*, 2007). For example, clearing the South American forest cover for agriculture since the 1990s has created extensive deforestation estimated at a loss of 45.87% of the forest cover in 2001 (Lui *et al*, 2008). Furthermore, in the past 30 years, the Atlantic forest had been rapidly replaced by commercial cultivation of soybean and the raising of livestock by subsistence settler farmers who operated either legally or illegally (Huang, *et al*, 2007). Presently in the Rondonia state of Brazil, approximately 68,000 km^2 of tropical forest has been cleared from 1970 to 2009 for the purposes of agriculture (Silvio-Frosini *et al*, 2009). Further, cultivation of sugarcane in the Budongo forest reserve increased 17 fold from 690 hectares in 1988 to 12,729 hectares in 2002, resulting in the loss of approximately 4680 hectares of forest and woodlands (Mwavu and Witkowski, 2008).

Agricultural expansion, opening of new roads and the migration of people to unexploited forest areas also contributed to deforestation in the Amazonia area as discussed previously (Azevedo-Ramos, 2008). The Brazilian forest biomass is at present experiencing conversion from natural forest to agricultural land use (Santos *et al*, 2008).

Production of bio-fuel serves as a catalyst for deforestation and the loss of woody vegetation covers as creation of bio-fuel plantations have the potential to destroy forest and woody vegetation. For example, a Jetropha bio-fuel project to be initiated at Lolito in the South Tongu District of the Volta Region has been projected to destroy over 820 hectares of woody vegetation and thickets to the detriment of wildlife habitats in the area (Biofuel Africa, 2008).

3.5 Discussion of proximate driving forces of deforestation in Ghana

In Ghana, as in other parts of the world, an increase in the demand for wood energy due to a lack of cheaper alternative sources of energy has contributed to the loss of forest areas (FAO, 2008). Naughton-Treves *et al*, (2007) noted in a study that the cutting of entire trees instead of tree branches is responsible for deforestation in parts of Ghana. Loss of woody plants and vital soil nutrients required for supporting the growth of trees had been lost by digging the surface soil to cover piles of wood burnt to produce charcoal in Ghana and the study area as demonstrated by Anhi (1998). In some parts of the world trees are cut to produce firewood to cure tobacco (Moyo *et al,* 1993). In Ghana, however, fuelwood is used for small scale industrial activities such as oil palm processing, commercial culinary activities and brewing of local alcoholic drinks. While wood energy obtained from dried wood and shrubs do not contribute to deforestation, they remain insufficient to meet the wood energy needs of the majority of Ghanaians. In effect living trees are cut to produce wood energy unlike the finding of Bensel (2008). Use of energy inefficient traditional stoves such as the stone fire has contributed to increased exploitation of wood to meet increased wood energy demands in the Ho Municipality a situation similar to the finding of Stosch and Quaye, (2002).

Agricultural land use such as shifting cultivation has contributed significantly to deforestation in Ghana, for example, (Jasen *et al.*, 2007 and previous sections). Reduction of fallow periods contributed to loss of soil fertility which has in-turn compelled farmers to clear more fertile forest lands for agriculture.

3.6 Conclusion

In conclusion, the literature review on proximate and underlying driving forces of deforestation has many dimensions, cutting across global and local scales. Some policy makers and land cover change experts attribute tropical deforestation to high population growth (especially in developing countries) and the use of heavy equipment for commercial logging, while others attribute deforestation to trade policies, agricultural expansion and high wood energy demand in developing countries. The continuous debate and discussions on the different driving forces of land cover change show that, dealing

with multiple driving forces can be complex. The complex nature of the driving forces of deforestation has made it difficult to pinpoint a particular driving force as the cause of deforestation. Understanding the mechanisms for dealing with multiple drivers of deforestation therefore requires in-depth case studies such as that presented here. Areas for further research include the need to investigate the extent to which land title reforms and current environmental policy weaknesses have contributed to forest degradation, and the extent to which culture and local tradition have contributed to deforestation in Ghana.

Chapter Four

Application of Remote Sensing, Surveys and Models to Land Cover Change Assessment

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4.1 Introduction

The literature review in this chapter covers the application of remote sensing in the investigation of global changes in land use and cover change. The use of high or moderate resolution satellite images such as Landsat TM and ETM+ to classify changes in land cover are discussed in detail. The chapter further reviews use of questionnaires in addition to satellite imagery for land cover change analysis. The purpose of reviewing literature on satellite imagery and questionnaires is to understand the nature of land cover changes captured in the images and to explain the socio-economic factors that contribute to land cover changes. The literature review has been divided into four sections; detection of change in land cover (section 4.2); assessment of image accuracy (section 4.3); general applications (section 4.4) and modeling land cover change transition (section 4.5).

4.2 Detection of changes in land cover

Change detection refers to monitoring land surface change over time using repetitive coverage and consistent data generated from satellite images (www.ciesin.org/TG/RS/chngdet.html). Satellite multi-spectral data sets are cost effective and reliable for estimating forest condition and broad scale land cover change (Jones *et al*, 2008). Change detection is useful in identifying changes in land cover over time such as estimation of deforestation using the post-classification change detection statistical method. Detection of change using multi-temporal satellite datasets was, for example, useful in estimating areas of land cover change in south east China and the Amazon Basin using orbital remote sensing (Coppin, *et al*, 2004; Santos *et al*, 2008). Procedures for change detection in remote sensing include multivariate transformations such as the tasseled cap method and principal component analysis (Healey, *et al*, 2005; Muchoney

and Haack, 1994). Other methods for estimating land cover change involve the estimation of biophysical variables using regression analysis (Cohen, 2003). Change detection based on comparison of independently classified remote sensing images can be negatively influenced by classification errors. To minimize such errors, spatio-temporal contextual information is incorporated into the classification of independently classified images and this reduces classification errors and thus improves change detection results (Song *et al*, 2008).

Deforestation estimates in Central Africa using Landsat TM 1990 and ETM+ 2000 images derived from coarse to medium resolution wall to wall images could not, for example, provide much information in the Congo Basin compared to the total area of Central Africa. Furthermore, coarse to medium resolution images that covered wide forest areas could not detect patches of forest change. To solve these problems, unsupervised classification of high spatial resolution images were used for the sampling scheme in the Congo River basin. Five hundred and seventy one sampling sites covering 10 × 10 km were used to estimate the deforestation rates in the Congo river basin (Duveiller *et al*, 2008). Alternatively, in the Budongo forest area of Uganda, images from different sensors were geo-referenced and mosaicked to estimate change in land cover (Mwavu and Witkowski, 2008). High spatial resolution imagery showing the distribution and extent of land covers made up of various ecosystems are considered useful for the spatial assessment and accurate quantification of land cover changes. Hence, Landsat 7 (ETM+) imaging is recommended (Schneider *et al*, 2008). Other satellite data found to be useful for land cover change analysis is the Advanced Very High Resolution Radiometer (AVHRR) imagery (Swinne and Veroustraete, 2008).

Normalized Difference Vegetation Index (NDVI) time series data can serve as base data (under certain assumptions) for deriving vegetation phenology using remote sensing technique**.** The use of NDIV imagery can, however, be hindered by prevalent noise resulting from varying atmospheric conditions and sun-sensor-surface viewing geometries (Hird and Mc Dermid, 2008). NDVI has been used to monitor long term change in vegetation since the early eighties, unlike the short term Land Surface

Temperature (LST) approach which is very sensitive to orbital drift of the National Oceanic and Atmospheric Administration (NOAA) platforms that fly AVHRR sensors (Julien and Sobrino, 2008). A combination of NDVI and LST has helped to determine the annual land cover dynamics of vegetation cycles (Julien and Sobrino, 2008). However, the systematic bias of the visible channels towards slightly smaller values and of the NIR channels toward slightly larger values means that, the overall systematic bias for NDVI range from -0.03 to + 0.06 is generally positive (Trishchenko, 2009).

4.3 Assessment of image classification accuracy

Accuracy assessment is a procedure for correcting conservative and optimistic biases in image classification due to misclassification of land cover classes (Verbyla, 1986). Accuracy assessment involves field visits to randomly selected points which are recorded as reference data to verify actual cover types. Assessment of image classification accuracy entails the production of an error matrix featuring ground truthing against predicted classes for random sample points. The overall accuracy is computed as the total number of correct class predictions (sum of diagonal cells) divided by total number of cells (Verbyla, 1986). For example, accuracy assessment for a classified 500m spatial resolution land cover map for southeast Asia covering the Malaysian peninsular and other major islands in Sumatra, Java and Borneo show the spectral characteristics of the land cover with an accuracy of 82% (Miettinen *et al*, 2008).

Landsat imaging has an advantage over the Advanced Space-borne Thermal Emission and Reflection Radiometer (ASTER) in terms of accuracy. A comparison of Landsat ETM+ 2002 image analysis and ASTER 2001 analyzed image covering the Julin province of northeast China helped researchers to conclude that the 30m resolution ETM+ 2002 image outperforms the 15m resolution ASTER 2001 image. The study determined that the spectral resolution of an image is not as important as the information content of the individual bands that accurately map the land cover. The inferiority of ASTER data has been attributed to the highly repetitive spectral content of its six shortwave bands (Gao and Liu, 2008). On the other hand, the spatial and spectral

resolution of Landsat images make them highly suitable for analyzing both abrupt and gradual changes in vegetation cover. As such, Landsat is useful for monitoring environmental processes of degradation and desertification (Song *et al*, 2007).

Experimentation of change detection in Salt Cedar, Nevada in the USA was carried out using supervised image classification and NDVI. A test of the two methods for accuracy of the classified image shows an overall accuracy of 91.56% and Kappa value of 0.618 for the supervised classified image. As far as the NDVI differencing method is concerned, an overall accuracy of 93.04% and Kappa value of 0.684 indicated that the NDVI differencing method outperformed the supervised classification method. Pu *et al*, (2008) recommend that to gain higher levels of accuracy of change or no-change for most image classifications involving fewer spectral bands, the NDVI differencing method is most appropriate. Land use/cover change from 1990 to 2003 in tropical mountainous watersheds in Brazil has, for example, been been analyzed using Landsat TM/ETM+ images. Large sets of training pixels were used to optimize the representation of environmental heterogeneity in the two image analysis. The overall accuracy for the Landsat TM 1990 classified image was 78.2% and the Landsat ETM+ 2003 image was 79.7%. Thus, both accuracy results were deemed as satisfactory (Muntildoez Villers and Lopez- Blanco, 2008).

4.4 General applications

Analysis of forest structure dynamics and landscape patterns using remote sensing can provide scientific information on deforestation processes (Imbernon and Branthomme, 2004). Although remote sensing is useful for land cover change detection, remote sensing analysis alone is not sufficient to explain all the processes of deforestation (Walsh *et al*, 2005). This is because biophysical factors, national policies and market prices which are important causes of deforestation (see previous chapters) cannot, of course, be determined using remote sensing techniques. In this regard, a combination of socio-economic surveys and satellite data are necessary for land cover change studies (Cudjoe, 2004). For example, analysis of forest cover change using combined methods of

socio-economic data and satellite images have been used successfully to examine land use and cover change in Costa Rica (Calvo-Alvarado *et al*, 2008).

The combination of remote sensing technology and socio-economic surveying using structured questionnaires and focus group discussions were used in Swaziland to examine land cover change transition dynamics (Stringer and Reed, 2007). This combination has also been used in the Manica province of Mozambique Louisa *et al*., (2007) and in Nigeria (Mertens and Lambin, 2000).

Land cover classification using multi-temporal remote sensing imagery has been used to study trajectories of land cover change in the Trim river arid zone of China from 1973 to 2000 (Zhou *et al*, 2008). To determine the driving forces of land cover change in Trim river arid zone, questionnaires were administered to respondents in the study area. Analysis of results concluded that natural environmental forces rather than human driving forces were the key driving forces of land cover change.

Landsat TM/ETM+ satellite images and qualitative interviews were used to evaluate land cover change based on different land use types such as forest, coffee, fallow and agricultural lands using supervised image classification approach and questionnaires in Cote d'Ivoire (Gomez, 1998). Identification of target objects in the image such as differentiating coffee farms from forest lands was difficult initially due to similar signature reflectance. The high spatial resolution of the images made the differentiation possible, however, as it was possible to identify coffee and cocoa farms by feeder roads leading to the coffee farms unlike forest lands that lack road connection (Gomez, 1998). Forest and woody vegetations were clearly distinguished from fallow lands using the spectral signatures of the targets.

The application of remote sensing techniques to acquired data for resource conservation and policy making is important in developing countries where field survey data availability is a problem for research (Buchanna, *et al*, 2008). For example, conversion of the Amazon forest to agricultural land has been monitored using orbital

remote sensing to provide data for policy makers (Santos *et al*, 2008). Apart from providing basic data for analysis, earth observation satellites allow rapid assessment of the land cover across areas that are too extensive to be surveyed or terrains that are difficult to reach when using conventional survey methods (Mayaux *et al*, 2005). Improving human capacity to monitor land cover change and correctly interpret the spatial, temporal and spectral patterns of the changes using multiple remote sensing images are critical for natural resource management (Hayes and Cohen, 2007).

A further example of the application of remote sensing to determine land cover change is a woodfuel assessment carried out in the Sahelian region using multi-temporal Landsat TM images (Millington and Townshend, 1989). Other studies employed Landsat TM 1986 and Landsat ETM+ 2001 imagery to create contemporary land cover maps results from such studies were used to estimate the rates of deforestation in these countries. The spatial resolution of the images is found to be valuable in detecting changes between major land cover classes such as cultivated lands, parklands and savannah woodlands (Bobbe *et al*, 2001).

Though the application of remote sensing technology can enhance research, the high cost of training and equipment in developing countries such as Ghana make it difficult for many researchers to take advantage of this technology. These expenses have compelled the Global Forest Resource Assessment Project initiative to generate accurate statistical data on the world's forests using remote sensing technology over the past 60 years (FAO, 2008).

4.5 Modeling land cover change transition

Land cover modeling involves simulating land use and cover change using sample datasets to define probabilistic transition rules that govern how landscapes change over time (Bone and Dragicevic, 2009). To forecast land cover change transition, contemporary modeling techniques have been developed to simulate stakeholder and

ecosystem dynamics of bio-complexity (Miguel *et al*, 2007). For example, generic models that employ logic based methods for decision making analysis were successfully applied in Venezuela to predict future forest cover changes (Miguel *et al*, 2007). Land cover transition probability matrix analysis for Landsat TM images covering the period between 1986 and 1995 and Landsat TM/ETM + images for the period 1995 – 2000 were analyzed using the Markov model to explain the probability of transition from one land cover category to another (Rovaine, 1996).

Remote sensing image classification is associated with problems of mixed pixels when using coarse to medium spatial resolution images (Le-Hegarat-Mascle and Guerin, 2005). To address this problem, the Markov model is used to perform super resolution mapping at a spatial resolution finer than the size of the pixels of the image. This results in a significant increase in the accuracy of the land cover map (Kasetkasem *et al*, 2005).

Digital analysis of time sequential SPOT-XS image and the Markov chain modelling based on probability matrices has been used to estimate land cover change in the Afram plains in Ghana. Application of remote sensing to analyze the land cover shows that deforested areas are recovering from tree losses due to a decline in cocoa cultivation (Kufogbe, 1999). However, most of the areas that experienced forest re-growth have been simultaneously transformed to farmlands due to the accelerated cultivation of food crops (Kufogbe, 1999).

Modeling remote sensing data using ASTER images is considered viable for determining risk indicators of land degradation as this modeling approach helps to determine land cover change at a regional scale. For example, in south-east Spain the model estimated the extent to which disturbance events have pressed the forest beyond resilience resulting in reduced hydrological and surface energy balance (Garcia *et al*, 2008).

Time series analysis of Landsat TM 1984 and Landsat ETM+ 2000 image data for the purposes of retrospective assessment of the use of rangelands in northern Greece

helped to explain land use transition in the European Mediterranean from forest to a deforested land (Röder *et al*, 2008).

Despite the useful application of modeling and other statistical methods to predict land cover change, such modeling frameworks have their limitations. For example, forest succession accuracy prediction studies undertaken using Landsat Thematic Mapper imagery had some limitations such as pixel sampling errors due to overlap of spectral signatures of forest succession stages (Jansen *et al*, 2008). The overlap of forest spectral signatures in different successions makes it difficult to accurately separate stages of forest succession to more than 3 broad age classes: young, mature and old forest classes with reasonable accuracy (Lui *et al*, 2008). Additionally, the use of different data sources, such as the use of remotely sensed data and statistical inventories on African agricultural fields can contain substantial discrepancies. Such a finding can make analysis difficult as the discrepancies can introduce inconsistencies that have significant implications for assessing land cover changes (Hannerz and Lotsch, 2008).

4.6 Application of Remote Sensing and the Markov model to Ghana

The study in the Ho Municipality used Landsat MSS 1975 and Landsat ETM+ 2001 images to determine land cover changes from 1975 to 2001. A similar study by Kufobge from 1985 to 1990 estimated land cover changes in the Afram plains of Ghana.

This literature review demonstrates the importance of combining different approaches such as the combination of questionnaire surveys, remote sensing techniques and models for scientific studies to achieve accurate and reliable results. A combination of both methods is recommended for attaining comprehensive and credible results. The application of remote sensing to land use and cover change studies is more advanced in developed countries than developing African countries such as Ghana, hence the limted literature on remote sensing applications in Ghana. The limited remote sensing literature may be attributed, as mentioned earlier to the high cost of remote sensing equipment,

software and training. This research aims to overcome some of these challenges and fill gaps in the literature.

Chapter Five

Study Country Ghana and Ho Municipality

5. 1 Location of Ghana

Ghana is a West African country located on latitude 5º 36´ N and 11º 0’0’’ N and longitude 3º 0’0’’W and 1º 0’0´’E extending over an area of 239, 460 km^2. Ghana is bordered to the west by Cote d’ Ivoire, to the south by the Gulf of Guinea, to the north by Burkina Faso and its eastern border is shared with Togo. The map of Africa (Figure 5.1) shows the location of Ghana while the second map (Figure 5.2) is a map of Ghana showing its neighboring countries, the regions of Ghana and location of the study area, Ho Municipality.

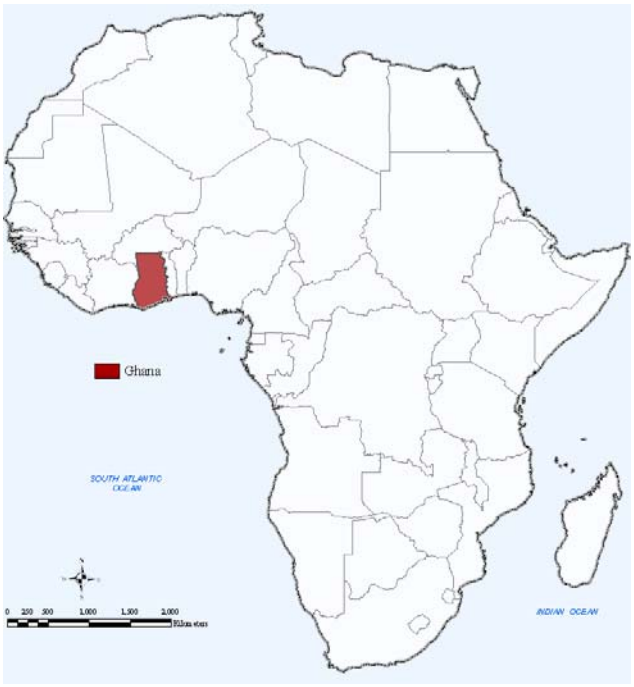


Figure 5.1 Map of Africa showing the location of Ghana

Source: Centre for Remote Sensing and Geographic Information Services, University of Ghana, Legon (2011).

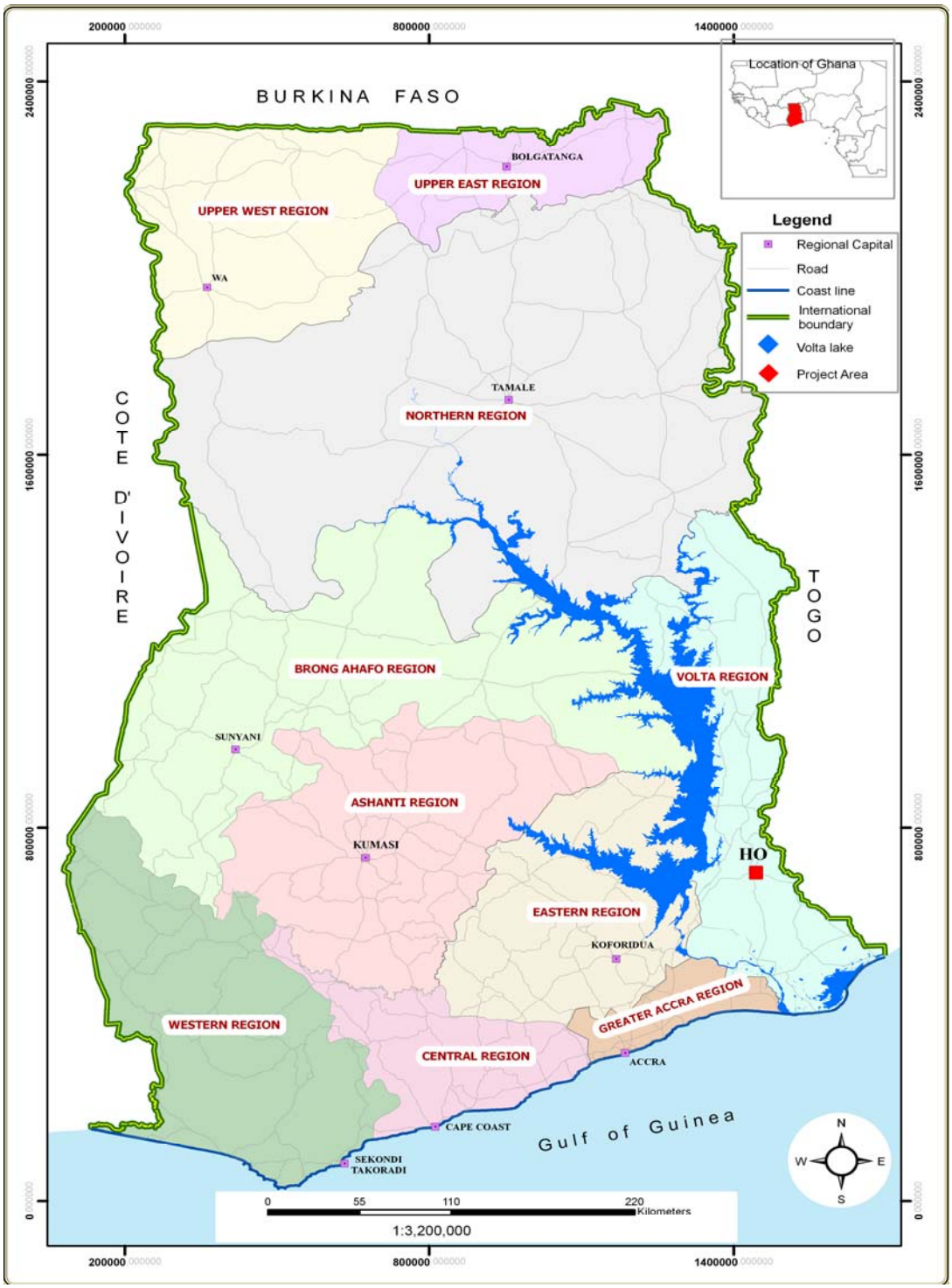


Figure 5.2 Map of Ghana showing the location of the Ho Municipality.
Source: Centre for Remote Sensing and Geographic Information Services, University of Ghana (2011).

5.1. 1 Geographical terrain

The physical environment of Ghana is diverse and contains forests, savannah lands, thickets, built up areas, bare lands and water bodies. Ghana is generally a low lying country with the lowest lands along the coast. A dissected plateau is located at the south-central part of the country with the mountain Afadzato (880m) the highest region. The country is divided into four geographical terrains known as the Low plains, Ashanti uplands, Volta basin and High plains. The low plains comprise the Accra plains, Volta delta and Akan low lands. Ashanti uplands comprise the southern Ashanti uplands and the Kwahu plateau that extends 193 km to the east of Koforidua and northwest of Wenchi. The Volta basin occupies the central part of Ghana which is approximately 45% of the nation's total surface and it is the source of the largest artificial lake in the world created as a result of the construction of the Akosombo dam. The high plain is characterized by a dissected plateau at average heights of between 150m and 300m above sea level (en.wikipedia.org/wiki/Geography_of_Ghana).

5. 1. 2 Demography

The population of Ghana is estimated at 22 931 299 with a population growth rate of approximately 2.7% (Ghana Statistical Service, 2000).

5.1. 3 Land cover and land use

A summary of the land use and cover for Ghana (Table 5.1) shows agricultural land use as the most common land use which constitutes 61.5% of the total land use and the savannah vegetation that extends over 20.1% of the land area while forest and wildlife occupy 3.5% of the land.

Table 5.1 Land use and cover in Ghana

Land use	**Area km^2**	**Percentage total**
Agriculture land	146,810	61.5
Forestry and wildlife	8,400	3.5
Savannah	47,860	20.1
Scrub thicket	73	0.3
Built up area	73	0.3
Bare area	12	0.05
Water body	11,800	5
Wetlands	954	0.4
Unclassified	1,561	0.6
Total	238,539	100

Source: Center for Remote Sensing and Geographic Information Services (CERSGIS), University of Ghana, Legon, 2000.

5.1.4 Climatic conditions

The mean annual temperature of Ghana is 25° C with a diurnal temperature range of 5 – 9°C along the coast and more than 14°C at the northern part of Ghana. High annual rainfall of approximately 2000 mm is recorded in the south and an average of about 1100 mm of rainfall recorded in the north.

5.1.5 Economic activities

The main economic activities in Ghana are exploitation of natural environmental resources such as gold, bauxite and timber for export and agriculture which employs 60% of the labour force and contributes approximately 40% to the Gross Domestic Product of Ghana (Environmental Protection Agency, EPA, 2005). Food processing, mechanical and electrical production plants produce diverse industrial products for domestic use and for export.

5.2 Location, population and climate of study municipality

The Ho Municipality is located approximately between latitude 6° 30' N and 6° 55' N and longitude 0° 30' E and 0° 12' E in the Volta Region (Figures 5.3a and 5.3b). The Ho Municipality covers a total land area of 2,660 sq kms and shares boundaries with North Tongu in the south, Abutia in the west and Ketu district in the east. The population is approximately 235, 331 (Ghana Statistical Service, 2000) which is 28.9% of the population in Volta Region. The population growth rate is 3% per annum (Ho District Assembly Profile). The mean monthly temperature ranges between 32°C and 22°C and the annual maximum and minimum temperatures are between 37.8°C and 16.5°C respectively. There are two periods of rainfall in the district which are from March to July and from mid August to October each year and total annual rainfall ranging between 750 mm and 1020 mm (Ho District Assembly Profile).

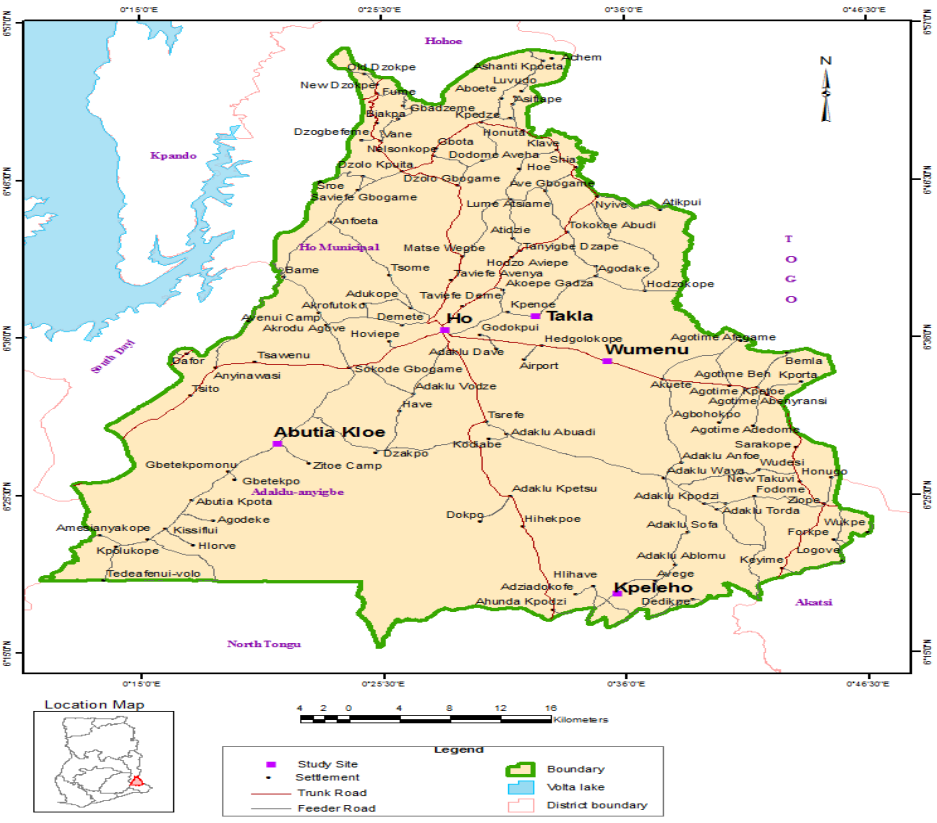


Figure 5.3a Map of study area Ho Municipality.
Source: Centre for Remote Sensing and Geographic In formation Services, University of Ghana, (2011)

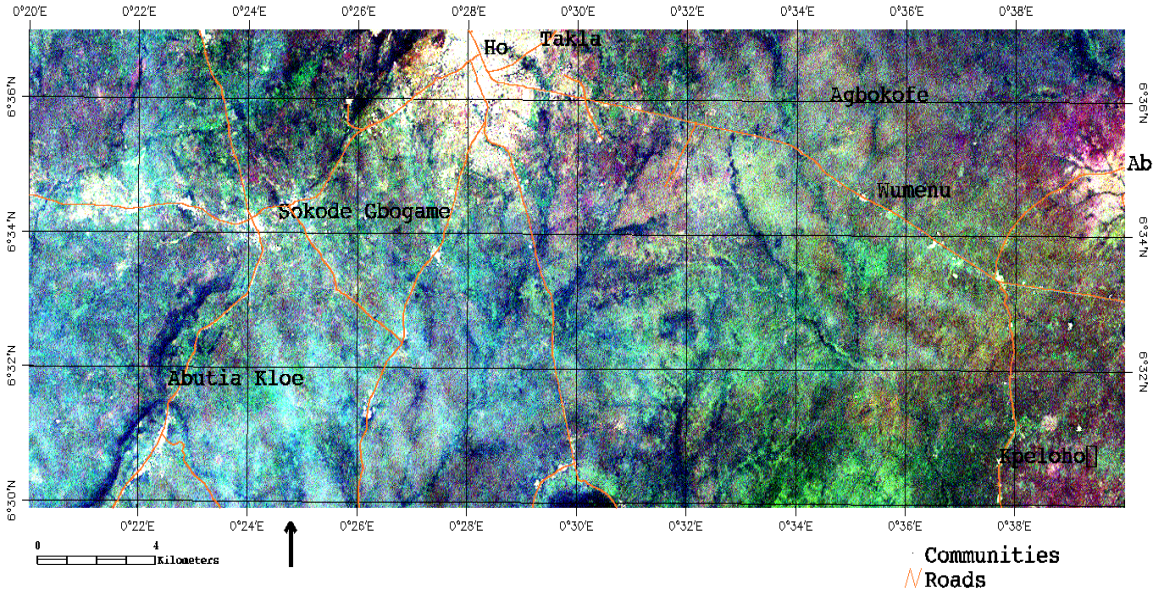


Figure 5.3b Image map of study area Ho Municipality.
Source: Adanu 2008

5.2.1 Vegetation and soil types

The three main vegetation types found in the Ho Municipality are the guinea savannah, the savannah woodland vegetation and the moist semi deciduous forest. The Kalakpa game reserve which is part of the moist semi deciduos forest contains tree species such as *wawa*, "Triplochiton scleroxylon " (K.Schum) *mahogany*, "Khaya ivorensis " (A. Chev) and *odum*, "Milicia excelsa " (C.C. Berg). Nomenclature follows Missouri Botanical Gardens VAST nomenclatural data base (http://mobot.mobot.org/W3T/Search/vast.html)



Figure5.4a Woody vegetation in Takla. Source: Field work, 2008



Figure 5.4b Open grassland in Wumenu Source: Field work, 2008



Figure 5.5 Forest cover in Abutia Kloe. Source: Field work 2008

Different types of soil groups are found in the area such as the moist deciduous forest soil which characterized by forest lithosols, ochrosols and integrates. The savannah woodland soil types are mainly tropical black and grey earths that support annual crops such as maize, cassava, yams, legumes and other vegetables. The forest soil mainly supports root crops and perennial crops such as oil palm, plantain and banana. The soil types determine the agro-economic activities in the area. These soil types are described according to the classification scheme of (Brammer, 1962).

5.2.2 Land use

Agriculture is the major economic activity in the Ho Municipality as 70% of the labour force are self-employed subsistence farmers who are the source of foodstuff supplys in the district, such as maize, cassava and vegetables (FORUM, 2007). The rearing of cattle which involves the immigrant Fulani and the Hausa people of Ghana, is becoming an important economic activity. Other economic activities with regards to land use include charcoal production, carpentry, masonry, and petty trading (Ghana Statistical Service, 2000). In recent times, commercial farming of cassava in Hodzo for the production of industrial starch and alcohol has offered sustained income to some people in the district. The establishment of small scale teak plantations by individuals and families increased over the past 10 years as a result of the Forest Resource Use and Management project (FORUM, 2007).

5.2.3 Social structure

The predominant ethnic group in the Ho Municipality is the Ewe people, who are customarily headed by chiefs based on family succession. Chiefs comprise the traditional authorities of clans and townships that administer stool lands. Families of the same clan trace their genealogy to the same ancestor, clans are thus simply made up of people with common ancestral origin. The native language widely spoken is Ewe, while English is the official language of Ghana. The Ho Municipality which is the regional capital was colonized by the Germans until the First World War when the British took over the territory.

5.2.4 Economic activities

Formal sector workers comprise government employees (public servants) and private sector employees who are employed by road and building construction companies. As mentioned earlier, 70% of the population in the Ho Municipality are employed in the agricultural sector as farmers. Female workers are mostly self employed retailers, traders of agricultural products and industrial commodities while males are mostly self-employed technical workers such as welders, car mechanics, carpenters and tailors (Ghana Statistical Service, 2000). Tourism is an emerging economic activity that has the potential of creating wealth for the people of Abutia Kloe and neighbouring villages given that the Kalakpa game reserve at Abutia Hills, inhabited by birds, waterfowls, monkeys, buffalos, duikers and antelopes receive increasing amount of visitors.

5.3 Summary and conclusion

The annual estimated population growth rate of 3% for the study municipality which is higher than the 2.7% annual population growth rate for the entire country may

be a contributing factor to deforestation especially in the off reserves. Growth in the municipal population may also increase the 70% agricultural labour force that engages in subsistence farming with possible effects of deforestation. The emerging tourism sector has the potential of providing alternative income opportunities to the people of Abutia Kloe who live close to the forest, thereby preventing or minimizing the accelerated pace of deforestation. Transparent management of revenue from the site to ensure equitable distribution of income is necessary for forest protection.

Chapter Six

Study Methodology

6. 1 Introduction

Chapter six explains the methods used in collecting data for the study and how the data collected was analysed. Two major methodological approaches were used to investigate the driving forces of land use and cover change and to determine the nature and extent of land cover change. The framework used to investigate the driving forces of land use and cover change that addressed research question 2 (section 1.4) is Figure 6.1. Research question 1 has been addressed using the framework provided in Figure 6.2 and Figure 6.6 provides the framework used for addressing research question 3 (section 1.4).

Sampling of respondents for data collection in four settlements was carried out using the systematic sampling technique. The Statistical Package for Social Science Research (SPSS) was used to analyze questionnaire data on driving forces of deforestation while ENVI 4.3 software was used for satellite image classification. Prediction of future land cover change involved the Markov model of change prediction. The literature review section in chapter four provides theoretical and practical background explanations to the methods used in this chapter.

6. 2 Methods for investigating the driving forces of deforestation

Methods used for data collection on the driving forces of deforestation were undertaken in two phases. Phase 1 comprised a literature review on underlying and proximate driving forces of deforestation while Phase 2 involved the administering of questionnaires to respondents (Figure 6.1).

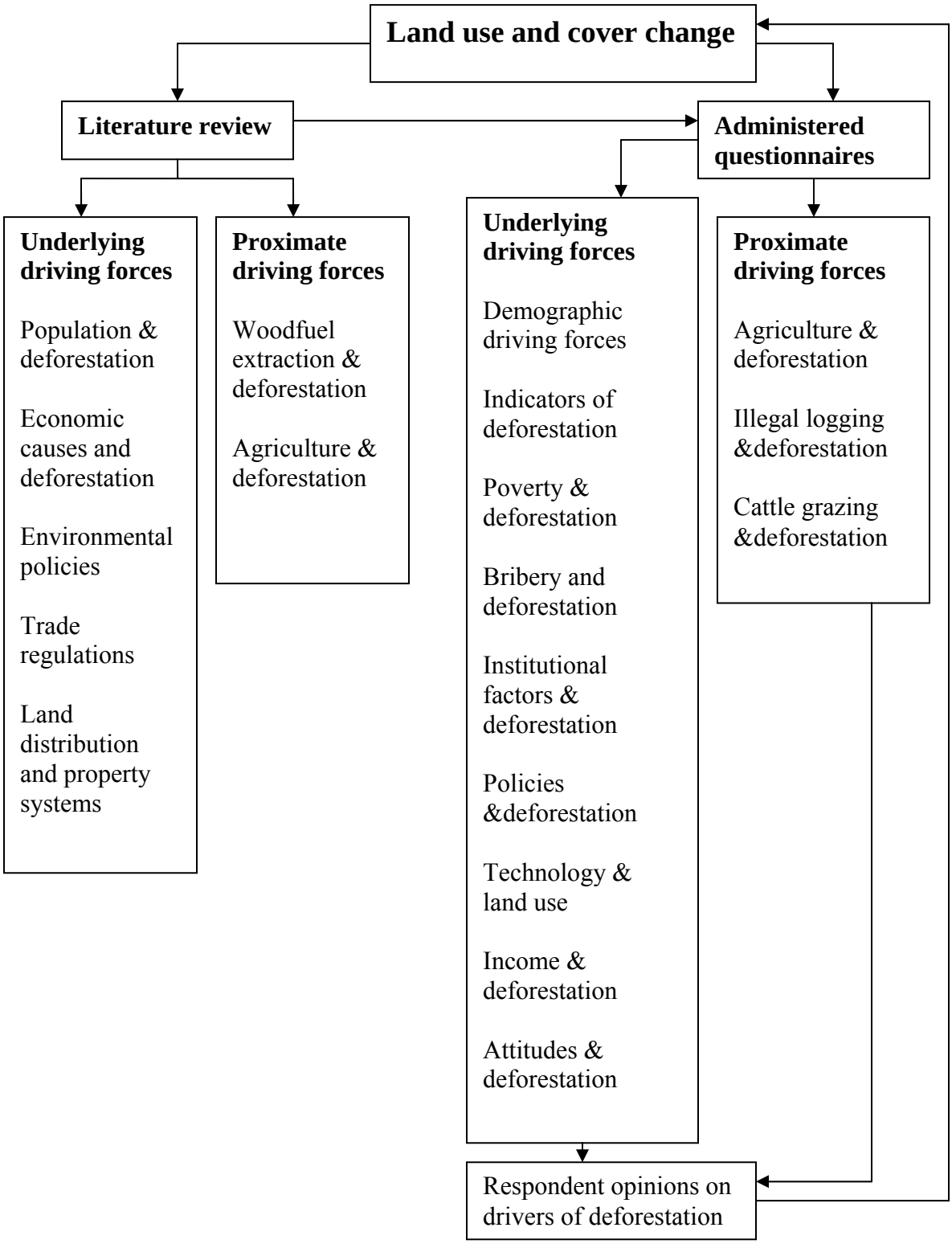


Figure 6.1 Framework for investigating driving forces

Source: Adanu 2008

Thematic areas of the literature review concerning underlying driving forces of deforestation focused on the relationship between population and deforestation, economic causes of deforestation, environmental policies, trade regulations, and land distribution and property systems. The literature review concerning proximate driving forces of deforestation focused on the connection between woodfuel extraction and deforestation on the one hand and agricultural practices and deforestation on the other. At the end of the literature, review sufficient information was gathered to support the design of questionnaires for the study.

Phase 2 of the study methodology involved the administration of questionnaires to respondents on the underlying and proximate driving forces of deforestation. Questions posed on the underlying driving forces of deforestation focused on demographic driving forces; indicators of deforestation; poverty and deforestation; bribery and deforestation; institutional factors; policies; technology; and attitudes contributing to deforestation. Themes for questions on proximate driving forces of deforestation include agriculture and deforestation, illegal logging and deforestation and the effects of cattle grazing on deforestation. Responses to questions posed were analyzed to represent opinions of respondents in Takla, Wumenu, Agbokofe and Abutia Kloe.

6. 3 Image analysis processes

Land use and cover change analysis in the Ho Municipality was carried out using the Environment for Visualizing Images (ENVI) 4.3 software. Selected images for the land cover analysis comprised Landsat Multi-spectral Scanner (MSS) image 1975 (p207r56_2m19751228), Landsat Thematic Mapper (TM) image 1991 (p193r56_4t19911225tif) and Landsat Enhanced Thematic Mapper plus (ETM+) 2001 (p193r56_7t20010204tif) image. These images are free ortho-rectified images downloaded from the Global Land Cover Facility of the University of Maryland http://glcf.uniacs.umd.edu/index.shtmt. Landsat MSS image was downloaded using path

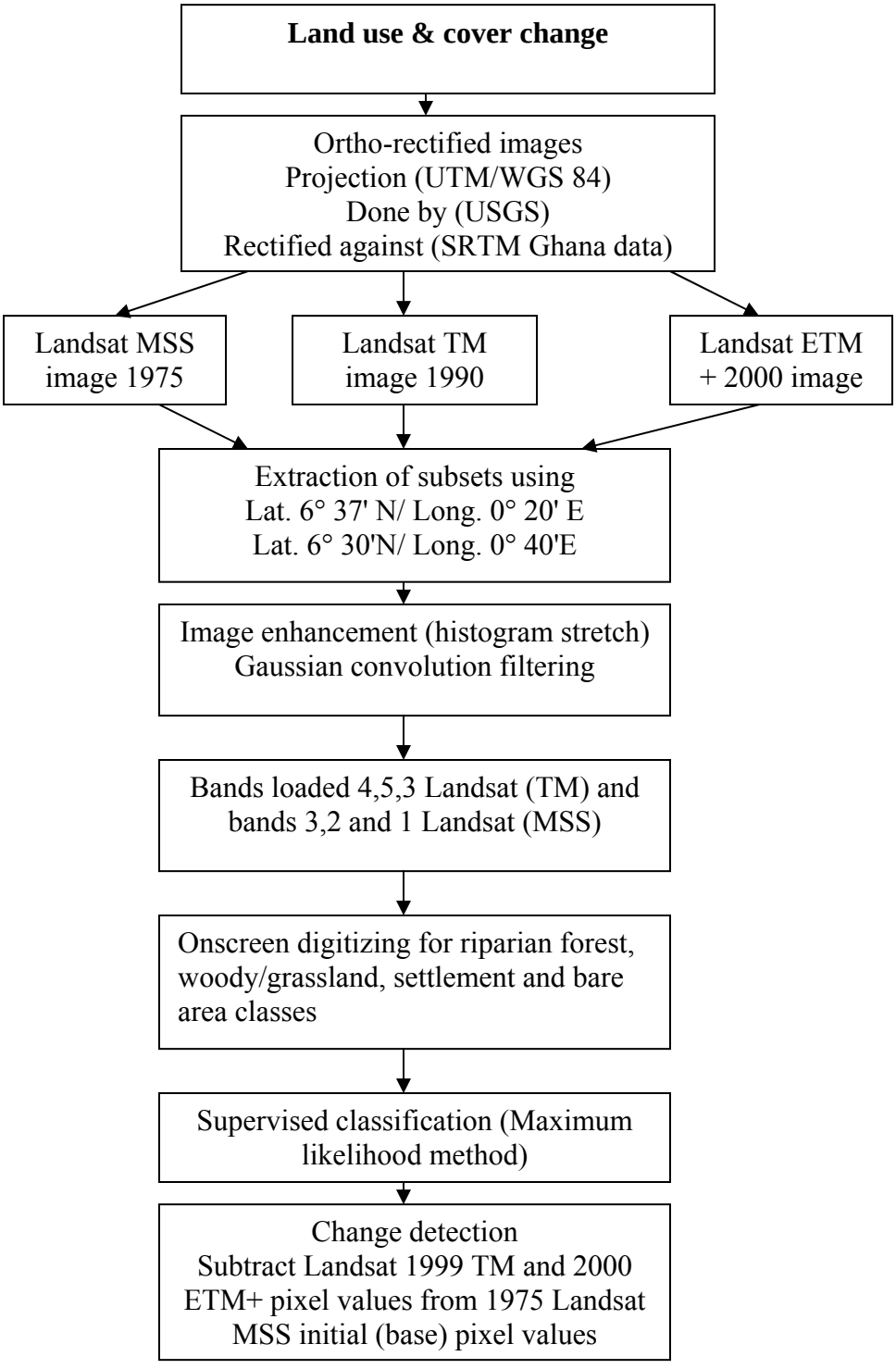


Figure 6.2 Framework for image analysis

Source: Adanu 2008

193 and row 270, while Landsat TM 1991 and ETM+ 2001 images were downloaded using path 193 and row 56 representing the Ho Municipality. The ortho-rectified images covered Takla, Wumenu, Abutia Kloe and Agbokofe namely the study sites in the Ho Municipality. The ortho-rectified images have their terrain and relief distortions corrected using Shuttle Radar Topography Mission Digital Elevation Model of Ghana. Analysis of the satellite data helped to answer research question 1. Figure 6.2 shows the steps followed in classifying the satellite images.

6. 3. 1. Choice of images

The Landsat MSS 1975 image had a resolution of 80 meters, while the Landsat TM 1991 and Landsat ETM+ 2001 images have a resolution of 30 meters. The choice of a lower resolution Landsat MSS 1975 image was based on the fact that medium resolution images such as Landsat TM images did not exist in the 1970s. The choice of the Landsat TM 1991 and Landsat ETM+ 2001 images are appropriate, as these images are medium resolution images that are multi-band (7 bands), hence they provide the required data for the study. It would have been appropriate to use antecedent data for the study but no antecedent satellite imagery and aerial photos exist prior to the 1970,s as such the choice of Landsat MSS 1975, Landsat TM 1991 and Landsat ETM+ 2001 images for the study. The Landsat MSS 1975 image, made up of 4 bands, was loaded into the ENVI 4.3 software using bands 3, 2 and 1. The choice of band combination 3, 2 and 1 for Landsat MSS 1975 image produced distinct spectral signatures for forests, woody lands, settlements and bare areas. Similarly, Landsat TM 1991 and ETM+ 2001 images were loaded for onscreen digitization using the band combination of 3, 4 and 5. The choice of these bands was based on their spectral signature properties. Band 3, for example, which is located in the visible portion of the electromagnetic spectrum, has a high spectral reflectance signature for vegetation due to the fact that it is a chlorophyll absorbing band. Further, band 4 which is located in the near infra-red portion of the electromagnetic spectrum showed contrast between vegetation and soil, hence, was useful for delineating riparian forest areas, woody vegetations and bare soils. Band 5 (mid infra-red) was useful for monitoring vegetation and soil, and hence, provided the basis for

digitizing the land cover class for soil (bare areas) and vegetation (riparian forest and woody vegetations) (Bakker *et al*, 2004).

Before the Landsat MSS 1975 image was used as the base image for the change detection analysis, it was re-sampled using the nearest neighborhood method to ensure that the 80 m pixels of this image matched the 30 m pixels of the Landsat TM 1991 and ETM+ 2001 images. Re-sampling comprises a technique for manipulating digital images and transforming into other forms for purposes of changing the resolution of the images to make their sampling intervals uniform (Gurjar and Padmanabhan, 2005). The re-sampling process ensured that the pixels of the Landsat MSS 1975 image were on par with the Landsat TM/ETM+ images for the change detection results.

It would have been preferred to use images taken in the same month and hour of the day under similar environmental conditions for the 1975, 1991 and 2001 images such that environmental conditions under which the images were taken such as solar illumination may be similar for an efficient analysis. Due to financial constraints, however, the available option was to use free ortho-rectified images for 1975, 1991 (both captured in December) and the 2001 image (captured in February). Though these images are of lower quality considering cloud cover effects on the Landsat MSS 1975 image, for example, and the influence of dust particles on the captured Landsat TM 1991 and Landsat ETM+ 2001 images, the images still provide useful data on land cover change in the study area. In Ghana and other West African countries, the period from November to early March is characterized by dry dusty and hot humid atmospheric conditions during the day and cold nights known as the Harmattan.

6. 3. 2 Extraction of subset images

Subset images were extracted from the three ortho- rectified images using the upper left coordinates (Latitude 6° 37' N/ Longitude 0° 20' E) and lower right coordinates

(Latitude 6° 30' N/ Longitude 0° 40' E) for the Ho Municipality. The subset image files were saved and used for all the digitization and image classifications.

6. 3. 3 *Image enhancement*

The images were enhanced after extracting the subsets to improve the brightness value of pixels using the Gaussian stretch technique. The Gaussian stretch technique operates in the form of a convolution or morphology filter that produces output images where the brightness value of image pixels are functions of a weighted average of the brightness of the surrounding pixels (ENVI, 2006). The high pass convolution filter of the Gaussian stretch technique removed the low frequency component of the images and retained the high component parts. This process enhances the edges between different regions and sharpens the image using a 3 × 3 high pass filter with a value of 8 for the centre pixel. The centre pixel is typically surrounded by a negative weighted value of -1 (Haralick *et al*, 1987). Enhancement of the images sharpened the brightness values of pixels. It was thus possible to identify homogenous areas for digitization by observing the spectral signatures of land cover classes as the brightness value of pixels were concentrated in narrow ranges prior to the image enhancement (Bakker *et al*, 2004).

6. 3. 4 *Onscreen digitization*

Onscreen digitisation was carried out on subset image files referred to in section 6.3.2 after image enhancement. The digitized regions of interest constituted the training sites for all the three supervised classified images (Bakker *et al*, 2004). Onscreen digitization was used instead of visual analysis, as onscreen digitization allows for the interpretation of smaller and complex mapping units and thus offers greater detail (Viovy, 2000). Polygons were drawn around homogenous areas of interest that contained spectral information on riparian forest, woody vegetation, settlements and bare areas. Figures 6.3 and 6.4 show how the onscreen digitized polygons were drawn for the land cover classes. Each digitized land cover class was assigned a specific colour for the

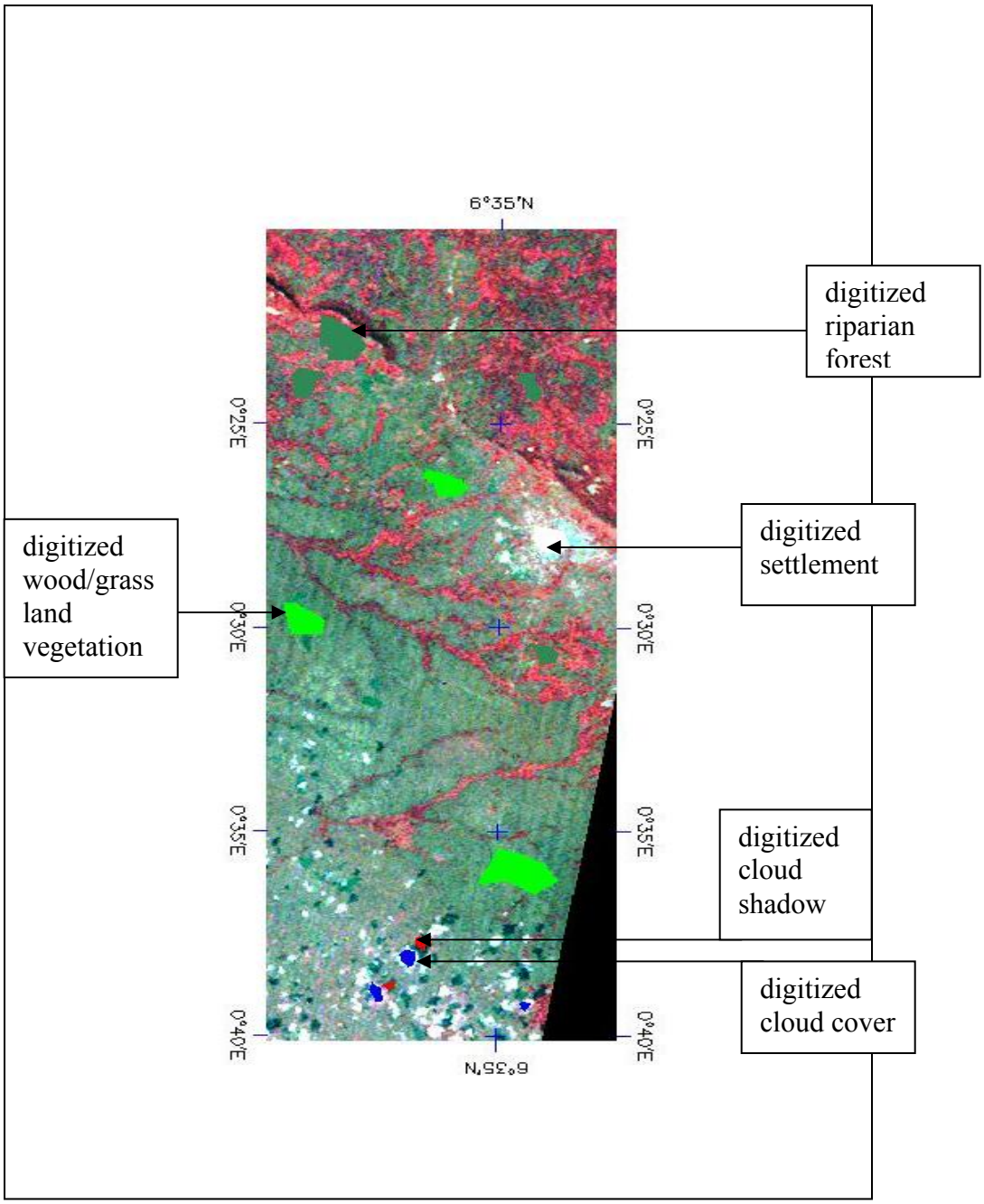


Figure 6.3 Digitized regions of interest for Landsat MSS 1975 image

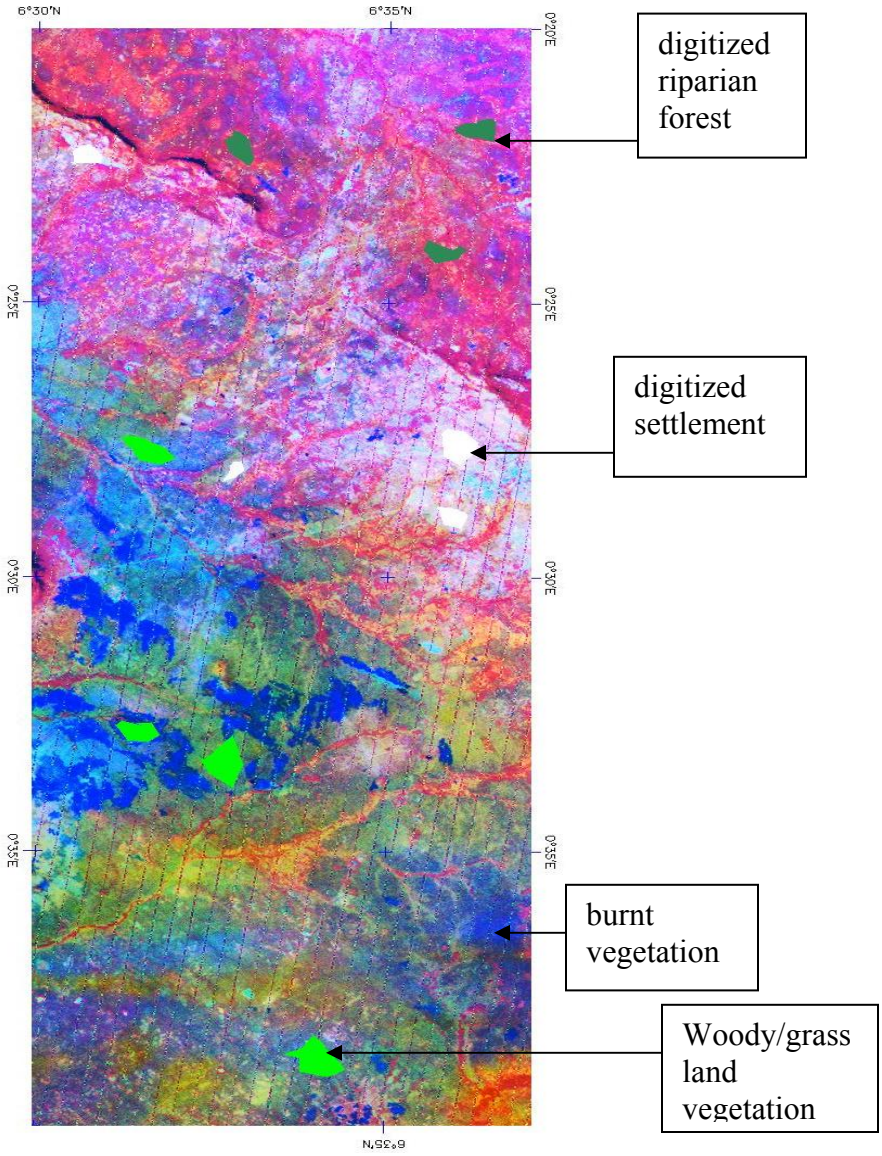


Figure 6.4 Digitized regions of interest for Landsat TM 1991 image

purpose of easy identification of the various land cover classes. The selected regions of interest were exported to n-D Visualizer in order to ensure that the distributions of pixel classes are well separated from one class to the other for purposes of good classification results. The n-D Visualizer is an interactive tool for selecting end members in n-D space to check the distribution of pixels. After the interactive display of pixels, editing was done to eliminate overlaps that existed in some of the image classes (ENVI, 1991).

6. 3. 5 *Supervised image classification*

Supervised classification requires *a priori* knowledge of the test site and as such, ground verification was done to gain first hand information on the land cover types. On the basis of the field observations, maximum likelihood classification was performed to classify the 1975, 1991 and 2001 images. The maximum likelihood method has been based on the assumption that the statistics for each land cover class in each band are normally distributed. With this assumption, the maximum likelihood calculation was based on the probability that each pixel belongs to a specific class as such, every pixel is assigned to a class with the highest probability using a discriminate function for each pixel (Richards, 1999). The probability threshold set for the calculation was 1 pixel values that fell below the threshold remained unclassified. The statistical formula (below) was used for the classification.

$$Gi(X) - \ln p(wi) - \frac{1}{2}\ln\left|\sum i\right| - \frac{1}{2}(X - mi)t\sum i^{-1}(X - mi)$$

Where

$i =$ class

$x = n -$ dimensional data (where n is the number of bands)

$p(wi) =$ probability that class wi occurs in the image

$\left|\sum i\right|$ = determinant of the covariance matrix of the data in class wi

$\left|\sum i^{-1}\right|$ = determinant of the covariance matrix of the data in class w

$Si - 1 =$ the inverse matrix

mi = mean vector

6.3.6 *Ground verification procedure*

The Landsat ETM+ 2001 image has been used for this field work as geographic coordinates of the study sites have been determined on the 2001 image map using the cursor location value of the ENVI 4.3 software. With the help of etrex Global Positioning System, the geographic coordinates of identified land cover classes on the image map were located in the field, though rough terrain introduced error. A minimum of 6 control points were collected for each of the land cover classes. A total of 24 ground control points were determined over 4 days. In similar field work to verify land cover classes in the Mpumalange province of South Africa, the SPOT Multi-spectral 2005 image was used (Mambo *et al*, 2008). A more recent image has not been used in this study, due to unavoidable funding constraints. Available free imagery for the study area captured in 2007 is extensively covered by cloud; hence, it is not appropriate for the study.

The ground verification was completed in December 2007 and February 2008 in Wumenu, Agbokofe, Abutia Kloe and Takla. The months December and February were selected to coincide with the dates the images were captured. It follows that ground verification of the type and nature of vegetation on the ground were matched more accurately. As mentioned earlier, December and February are Harmattan periods in Ghana, characterized by dry, dusty and windy conditions that are conducive for wildfires. The dry conditions during these two months do not encourage the cultivation of crops as a result, most crops were not seen in the field during the ground verification exercise. The remains of harvested crops such as dry corn stocks, yam mounds and wilted vegetables were seen, however. Root crops such as cassava were also seen in the field. The absence of crops in the field around these months of the year coupled with farm sizes smaller than the 30m resolution of the satellite images made it difficult to classify cultivated areas, since woody/grass land vegetation could not be clearly distinguished from cultivated

lands in all the three images. Further, the absence of clearly designated grazing fields placed a limitation on their classification. In reality, cattle and other domestic animals such as goats and sheep graze as free range animals over the grassland and woody vegetation. As a result, no part of the vegetation cover can be classified primarily as pasture or grazing field.

Riparian vegetation is characterized by a dense canopy of tree varieties with average tree heights of between 20 and 40 meters. Due to the dry conditions existing at the time of the field visit, the riparian vegetation cover appeared yellowish green. The woody/grass land vegetation cover observed on the field showed isolated trees and grass land vegetation distributed over the land area. Tall grasses with an average height of between 4 and 3 meters made up of *chromolaena odorata* and spear grass appeared to be the most common grasses in all the four towns. Tree crops found on the woody land include oranges and oil palm.

Crop cultivation, fuelwood and charcoal production were observed as the main land use activities in all four towns.

6.3.7 Accuracy Assessment of classified images

A range of different methods are available for change detection calculation, including tasseled cap, the change detection statistics method, and the principal component analysis methods (Healey *et al*, 2005). In this study, the change detection statistics method was used, as the study is intended to detect pixels that changed from on class to the other, not to detect spectral change of brightness, greenness and yellowness of pixels (channels) which would have required applying coefficients to the input bands (as done in tasseled cap analysis). Neither is the study intended to convert original image datasets into new data channels that are uncorrelated to minimize data redundancy using a mathematical transformation such as a principal component analysis (Seto *et al*., 2000).

Accuracy assessment of how close the classification agreed with the actual land cover on the field was validated by selecting samples of identified locations on the image that were checked directly in the field. The result has been tabulated in the form of a confusion matrix. The confusion matrix has been calculated in ENVI 4.3 using ground truth regions of interest. Values in the cells of the matrix indicate how well the classified data agrees with the reference data. The diagonal elements of the matrix indicate correctly classified values.

The overall accuracy which shows the percentage of correctly classified classes lying along the diagonal was determined as follows:

$$\text{Overall accuracy} = \frac{\sum (\text{correctly classified classes along diagonal})}{\sum (\text{row total or column total})}$$

The producers accuracy (errors of omission) of each class has been computed by dividing the number of samples that were classified correctly by its total number of reference sample as follows:

$$\text{Producers accuracy} = \frac{\text{Number of correctly classified class in a column}}{\text{Total number of items verified in that column}}$$

The users' accuracy (errors of omission) of each class has been computed by dividing the number of correctly classified samples of that class by its total number of samples that were verified as belonging to the class as follow:

$$\text{Users accuracy} = \frac{\text{Number of correctly classified items in a row}}{\text{Total number of items verified in that row}}$$

The Kappa coefficient comprises another measure of accuracy. It is calculated by multiplying the total number of pixels in all the ground truth classes (N) by the sum of the confusion matrix diagonals $\left(X_{kk} \right)$, subtracting the sum of the ground truth pixels in a class times the sum of the classified pixels in that class summed over all

classes$\left({}^{X}K\sum^{X}\sum K \right)$, and dividing by the total number of pixels squared minus the sum of the ground truth pixels in that class multiplied by the sum of the classified pixels in that class summed over all classes as illustrated below:

$$\kappa = \frac{N\sum_{k} x_{kk} - \sum_{k} x_{k\Sigma} x_{\Sigma k}}{N^{2} - \sum_{k} x_{k\Sigma} x_{\Sigma k}}$$

The Kappa coefficient method was used in Salt Cedar Nevada, USA to determine accuracy of Landsat ETM+ 2000 satellite imagery (Pu *et al*, 2008). In Africa, the Kappa coefficient method was used to estimate the error rate of hyperspectral data while discriminating between tropical grasses grown under different nitrogen treatments in the Keiskamma catchment in South Africa (Muntanga, 2004).

6. 3. 8 *Post classification analyses*

Detection of change in the 1975, 1991 and 2001 images was carried out using the Landsat MSS 1975 image as a baseline image for the Landsat TM/ ETM+ images of 1991 and 2001. Pixel values of classified 1991 and 2001 images were subtracted from the classified pixel values of the 1975 baseline image independently. The results of the subtraction indicates changes in the land cover between 1975 -1991 and 1975 – 2001. The first period of change falls from 1975 to 1991, and the second from 1975 to 2001. For each of the two periods, pixels exhibiting significant decreases were represented by negative value pixels while areas with increased cover had positive pixel values (see chapter 7 for details). Post classification accuracy assessment of change detection was similarly done in Uganda to check the accuracy of images taken from different sensors and with different dates (Mwavu and Witkowski, 2008). These processes have been followed to address research question one.

6. 3.9 Normalized Difference Vegetation Index (NDVI) approach

The NDVI method has been used to determine the nature and condition of vegetation cover in the study area. Separation of the vegetation cover from non-vegetated areas has been made possible due to the high quality reflectance from Landsat MSS, TM and ETM+ satellite images. The mathematical operation carried out is defined by the equation:

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

where NIR represents near infra-red. For the Landsat MSS 1975 image, band 4 (NIR) was subtracted from band 2 (red). The result obtained from the subtraction as in the equation is divided by the sum of NIR plus the red band. In the case of Landsat TM and ETM+ images band 4 (NIR) was subtracted from band 3 (red) and the result of the subtraction was divided by the NIR plus the red band. The output of the calculation is explained in detail in section 7.5. By illustration, Song *et al*, (2007) applied NDVI method to a study in China and got a satisfactory result as here.

6. 4 Spectral signature of targets

Classification of the land cover for the study area was based on spectral signature profiles generated by riparian forest, woody/grass vegetation, settlements and bare areas. The signature profiles were based on the remote sensing principle that every natural and synthetic object on or near the earth's surface reflects or emits electromagnetic radiation of a range of wavelengths of the electromagnetic spectrum based on the chemical composition and physical state of the object (Karasek *et al*, 2004). Emitted and reflected energies from targets are represented by unique spectral signature curves, (Figure 6.5) that make it possible to identify and classify objects in satellite images.

Spectral response characteristics of objects are not static but change with the wavelengths or with time. For example, the spectral reflectance curve for water and

vegetation appear similar in the visible portion of the electromagnetic spectrum but reflect differently in the infrared for the wavelengths (Figure 6.5). A combination of wave bands instead of a single band is thus important for the identification of objects for image classification. Changes in the season such as from wet to the dry condition may influence changes in the reflectance properties of objects such as vegetation at different times of the year. Vegetation exhibits low reflectance in the blue and red bands of the electromagnetic spectrum. In the near infra-red bands, however, the internal structure of the plant such as water content, stress and greeness controls the reflectance properties. Generally, half of the incident energy is reflected by the plant and nearly half transmitted, while very little of the energy is absorbed by plants (Sashikiran, 2007). The spectral signature curve for riparian forest reflects higher in the near infrared bands than the visible portion of the electromagnetic spectrum in the Landsat MSS 1975, Landsat TM 1991 and Landsat ETM+ 2001 images. Woody areas show lower reflectance properties in both visible and infrared bands.

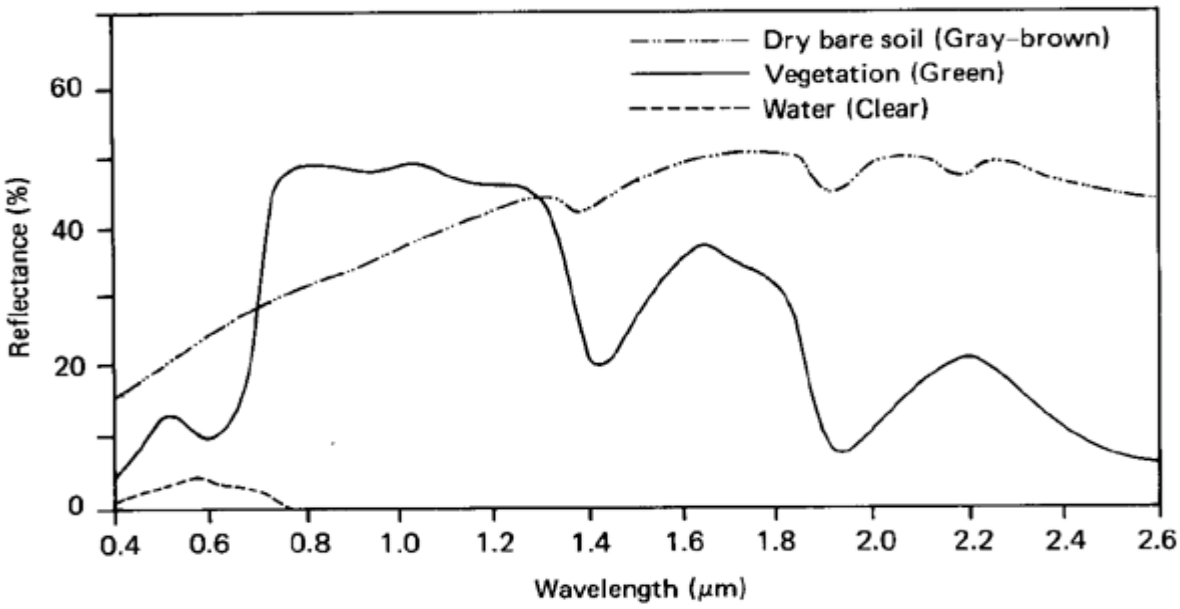


Figure 6.5 Spectral signature curves for vegetation, soil and water
Source: EGI Geomatics Laboratory (http//www5.egi.utah.edu/GIS)

The spectral reflectance curve for soil normally depends on the moisture and mineral content of the soil, as increased moisture in soil decreases the reflectance of the

soil. An increase in the particle size of the soil increases reflectance while an increase in the organic matter content of the soil (dark and brown soils) contributes to a decrease in reflectance (Daniel *et al*, 2004)**.** Soils with high levels of iron oxide experience less reflectance due to the presence of anhydrous iron (Daniel *et al*, 2007).

In this study, the spectral signature curve for bare areas (soil) was high in the near infrared portions of the electromagnetic spectrum, possibly due to the low organic matter content of the soil as a result of over-cultivation of the soil and nutrient depletion. The high spectral signature could also be due to reflectance from bare rock surfaces as the spectral signature for bare areas and settlements are not easily distinguished.

Clouds show strong reflectance in the visible and near infrared bands and are associated with shadows that introduce errors in image classification (Seiz *et al*, 2007). The shadows that accompany clouds help to easily identify them from other land cover classes during image digitization such as the Landsat MSS 1975 image.

Smoke in satellite images appears grey in the visible parts of the waveband and is easily detected when bands 5 and 7 are loaded since the average geometrical radii of smoke particles are smaller than the bands. In this way it is possible to detect the smoke particles in images (Quinto *et al*, 2006).

6. 5 Land cover classification scheme

AFRICOVER defines land cover as the observed physical cover, as seen from the ground or through remote sensing, such as the vegetation (natural or planted) and human constructions (buildings, roads, etc.) that cover the earth's surface. The land cover classes in this study are based on the AFRICOVER land cover classification scheme initiated by the FAO in Addis Ababa in July 1994 (FAO, 1997). A conference was held to develop a digital geo-referenced database system for Africa using geo-referenced land cover maps

derived from the visual interpretation of recent high resolution satellite images. The AFRICOVER project aims to facilitate the establishment of a standardized methodology for the definition and classification of land cover maps in Africa (FAO, 1997).

Water, ice, bare rocks and sand surfaces are considered part of the land cover. Land use is defined by the function and the purpose for which the land is being used for. The AFRICOVER classification scheme recommended an *a-priori* classification system where the land cover classes are defined before data collection takes place. The scheme emphasizes the use of classifiers (criteria used to distinguish the classes) rather than class names. The classifiers are expected to be hierarchically arranged, starting with a broad level class that allows for more detailed sub-classes. The broad level classes identified by the AFRICOVER scheme are vegetated and non-vegetated areas. Definitions of the two broad classes and sub classes are provided below (FAO, 1998).

> A. *Vegetated areas:* "areas that have vegetative cover of at least 4 % of the land and for a period of at least two months in a year. Examples of these vegetation types are: woody lands, herbaceous vegetations, trees, shrubs, forbs, graminoids and mosses/lichens ".
>
> B. *Non-Vegetated areas:* "areas which have a total vegetative cover of less than 4 % during at least 10 months of the year. This class is determined by the time factor of absence of vegetation".

At the second level of land cover classification sub-classes are defined as follows:

> A1. *Vegetated Terrestrial:* "vegetation is influenced by the edaphic sub-stratum which is terrestrial. The vegetation is expected to be found on a soil surface that was formed over time, not over water".
>
> A2. *Aquatic or Regularly Flooded Vegetated Land:* "the environment is significantly influenced by the presence of water over extensive periods of time. That is, water must be present for more than three months in a year and

vegetation becomes present when water is present less than 3 months in a year".

B1. *Terrestrial Non-Vegetated:* "the land cover is influenced by terrestrial edaphic conditions and as such is expected to have no vegetative cover".

B2. *Aquatic or Regularly Flooded Non-Vegetated Land:* "the environment is significantly influenced by the presence of water over an extensive period of time, such that water is present for at least more than three months in a year. This class is mainly determined by the absence of vegetation cover".

At the third level of classification, eight major Land Cover Categories exist:

A11. *Cultivated Terrestrial:* "This refers to areas where the natural vegetation is removed or modified due to anthropogenic activities. Such vegetations are normally artificial for example; wheat fields, orchards, rubber and teak plantations that are created by human beings and maintained over a long period".

A12. *Natural and Semi-Natural Vegetation:* "natural vegetated areas are defined as areas where the vegetative cover is in balance with abiotic and biotic forces. Semi-natural vegetation is defined as vegetation that is not planted by humans but influenced by human actions such as grazing, selective logging and crop cultivation. The human disturbance of such vegetations may be deliberate or inadvertent. The vegetative cover is not artificial as in class A11 and it does not require human management over the long term".

A23. *Cultivated Aquatic:* "water logged areas that are used for the cultivation of aquatic crops such as paddy rice, tidal rice and deep-water rice. Water purification plants are often seen floating on the water surface. This class excludes irrigated cultivated areas".

A24. *Natural and Semi-Natural Aquatic Vegetation:* "areas where the vegetative cover is significantly influenced by water and dependent on flooding (e.g., mangroves, marshes, swamps and aquatic beds). Natural Vegetated Aquatic habitats are defined as biotopes where the vegetative cover is in balance with other biotic forces**."** Semi-Natural Aquatic vegetation is defined as vegetation which is not planted by human beings, but influenced directly by human activities such as urbanization, mining and agriculture that influence biotic factors such as water quality.

B15. *Built-up and Associated Areas:* "areas that have artificial ground cover due to human activities such as construction of cities and towns, the use of extraction sites (open mines and quarries) and waste disposal sites. This class is determined by the absence of vegetation "

B16. *Bare Areas:* "Un-vegetated areas that do not have any artificial cover resulting from human activities. These areas include areas with less than 4 percent vegetative cover such as bare rock and desert".

B27. *Artificial Water Bodies:* "areas that are covered by water due to human construction such as reservoirs, canals and artificial lakes. Without human construction these areas would not be covered by water".

6. 5. 1 Modular-hierarchical phase

Application of the AFRICOVER classification scheme to this study took the form of an *a-priori* classification of the land cover into vegetated and non-vegetated areas. On the basis of these two classifications, further sub-classification using the modular hierarchical approach led to sub-classifications of areas such as riparian forest, woodland/grassland areas, settlements and bare areas.

Under the modular hierarchical phase, land cover classes are created by combining sets of pre-defined pure land cover classifiers that are combined with attributes. Two types of attributes are considered here:

1. Environmental and/or other types of attributes that influence land cover but are not essential for its definition such as soil, altitude and climate.

2. Technical attributes that relate to specific applicators, such as description of crop types in managed terrestrial areas for example the floristic aspect of vegetation such as natural and semi-natural vegetation types. Further definition of such classes can be achieved by adding a combination of other types of attributes.

6. 6 Application of the Markov model to the study.

Markovian modelling techniques have been applied in this study for the purposes of predicting land cover change for the next 25 years. The first order Markov model has been used, as the model is mathematically robust, accurate and realistic since it makes use of field observations. The appropriate nature of the model has made it possible to characterize temporal and spatial changes in land cover to predict future land cover changes. The Markov model has been applied to different studies such as modeling land use and cover change in Senegal (Houet and Hubert-Moy, 2006). A first order Markov process model assumes the probability that a system will be in a given state (land cover class) in a future time (t_2) based on the present knowledge of the state of the system in time (t_1) (Scania, 1994). This means that the transition of land cover from one state to another depends on the given state of the system and the processes of transition to the future state. The Markov conditional probability function is represented by $P(t/x,t_0)$ (Entwisle *et al*, 2006).

Traditionally, global transition probability models are used to assume spatial stationary of transition probabilities across image scenes that may be invalid if the areas

on the scene have varying transition probabilities. To validate the transition probabilities, pixels wise transition models have been developed (Liu *et al*, 2008).

The framework in Figure 6.2 was used to classify Landsat MSS 1975, Landsat TM 1991 and Landsat ETM+ 2001 images. These classified images constituted the source of empirical data for modeling and predicting land cover changes. Figure 6.6 shows the modeling framework followed to predict land cover changes which addressed research question 3. Ortho-rectified images of 1975, 1991 and 2001 were acquired and sub-scenes extracted from the larger images that cover the four study communities. Onscreen digitization and supervised classification of the images followed the extraction of the sub-scene leading to the creation of transition matrices. The matrices provide the required data for computing future predictions. Details of the process are provided in chapter 10.

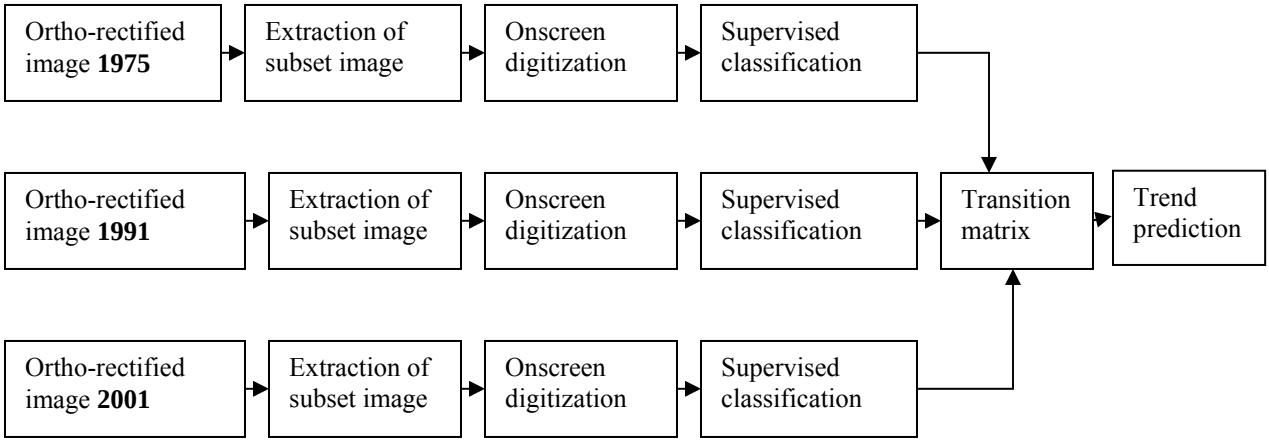


Figure 6.6 Framework for the Markov transition modeling and prediction of land cover.

Confusion matrix accuracy assessment tables generated using the maximum likelihood classification method from 1975 to 2001 provided the data for the Markov modeling process used for the prediction of future land cover changes. The diagonals in the transition matrix tables were pixels that did not change while pixel values on both sides of the diagonal are pixels that changed from one land cover class to another (Wijanarto, 2006). Probability of change between classes was calculated by dividing each cell value

by its row total. Results of the calculation show the probability that a given class in time t_1 will be converted to another class in time t_2 in the future out of all possible changes. The Markov model of change prediction was built using a 4 × 4 matrix of land cover classes comprising riparian forest, woody/grassland vegetation, settlements and bare areas.

6.6.1 Types of Markov Models

There are about 5 major types of the Markov models; namely, the Markov chain model, Hidden Markov model, Markov decision process model, Partially observed Markov decision process model and Markov random models.

The Markov chain model is among the most commonly used stochastic models for interrogating and quantifying land use and cover change for prediction on human landscapes (Muller and Middleton, 1994). It models the state of a system with a random variable that changes through time. An example of this kind of model is the Markov Monte Carlo model. Markov chain models can either be first or second order models, the use of which depends on the choice of the modeler.

The Hidden Markov model deals with observations related to the state of a system. This kind of model is, however, typically insufficient to determine precisely the state of several well known algorithms of hidden Markov models. Examples of such models are the Viterbi algorithms and baum-welch algorithms.

Markov decision process is a kind of Markov chain model where state transition depends on current state and an action vector that is applied to the system. A Markov decision process is used to compute policy actions to maximize some utility with respect to expected rewards.

Partially observed Markov decision process is a decision process in which the state of a system is only partially observed.

Markov Random field model deals with a generalization of Markov chains in multiple dimensions. In a Markov chain, the state of a system depends only on the previous state in time whereas with the Markov random field model, each state depends on its neighbor in any of the multiple directions.

This study used the first order Markov chain model as it uses field observations to predict future changes in land cover based on the present knowledge of the land cover provided by satellite imageries that were used for the study.

6. 7 Data Sources

6. 7. 1 Primary data

Primary data were collected by administering questionnaires to respondents to find out their opinions on the land cover change transitions that took place and the driving forces responsible for the land cover change transitions in 1975, 1991 and 2001. The questionnaires administered contained closed and open ended questions focusing on underlying causes of land cover change such as demographic, economic, socio-cultural and attitudinal causes of land cover change transition (see Appendix A). Close ended questions are considered efficient in collecting data for analysis, as closed ended questions facilitate coding (Smith and Inder, 1993). Further questions in the questionnaire focused on the proximate causes of land cover change such as the size of land cover converted from forest to farm lands. Data on economic driving forces of land cover change included questions about the extent to which an increasing demand for specific crops, animal products and woodfuel influenced land use and subsequent changes in the land cover. Investigations into the socio-cultural driving forces of deforestation included how land ownership, property rights and power structures in the local communities influenced deforestation. Attitudinal questions were asked to find out why, for example,

people burn vegetation even while understanding the consequences for the environment.

6. 7. 2 Secondary data

Secondary data were obtained from journals, dissertations, and unpublished and technical reports which focus on land use and cover change. Information extracted from the materials included land cover change problems and methodologies for land cover change transition investigation techniques. Other sources of literature came from the Ghana Government Departments and Agency publications, University libraries and reports of environmental Non Governmental Organizations (NGOs). A map showing the study sites was composed by the Centre for Remote Sensing and Geographic Information Services of the University of Ghana, Legon. Demographic data was extracted from the Ghana population census reports of 1971, 1984 and 2000.

Table 6.1 Types and sources of information

Type of Information	**Source of information**
Journal	Web based http://www.oaresceicnes.org
Dissertations	• Personal copy • Balm Library, University of Ghana, Legon
Unpublished reports	• Web based • United Nation Environment Programme. • United Nations Development Programme. • Food and Agriculture Organization of the United Nations • NGO offices in Ghana
Technical Reports	• Web based • United Nation Environment Programme. • United Nations Development Programme. • Food and Agriculture Organization of the United Nations
Maps	• Centre for Remote Sensing and Geographic Information Services, University of Ghana, Legon.

6. 8 Sampling procedure

The following procedures were followed to select four towns in the Ho Municipality of the Volta Region for the study. The Volta Region Forestry and Ministry of Food and Agriculture offices were consulted to seek their advice concerning districts in the Volta region that experience high levels of deforestation. Four towns in the Ho Municipality were selected upon the advice of the Forestry Commision and the Ministry of Food and Agriculture offices in the Municipality among other deforested towns. A systematic sampling technique was used to select respondents on a household basis in the selected towns (Shuman and Kalton, 1985). A household here refers to a number of people living in the same house or compound who eat from the same cooking pot. These households are comprised of males and females who engage in land use activities such as farming, cattle raising and woodfuel production.

The decision to use questionnaires for the study was based on the numerous advantages of using questionnaire surveys compared to its disadvantages (Agbesinyale, 2000). Some advantages of using questionnaires include the fact that responses are gathered in a standard manner; hence, questionnaires collect information than interviews; the speed of collecting information using questionnaires; use of questionnaires can ensure quantifiable and reliable sources of information that can be generalized for a larger population. As far as the disadvantages of questionnaires are concerned, open ended questions can generate large amounts of data that can take a long time to process and analyse; and respondents may answer questions superficially if questions take a long time to complete.

A list of households bearing house numbers was used to select every 3rd house after selecting the first house a task that was carried out in each town. As far as gender is concerned, it was planned to have equal representation of males and females. However, during the data collection exercise, it was not possible to obtain the expected equal number of male and female respondents due to the absence of most males from homes during the survey. A total of 376 people participated in the survey: 96 from Abutia Kloe;

90 from Agbokofe; 95 from Takla, and 95 from Wumenu. The total number of respondents stood at 376 larger than the 320 respondents initially proposed for the study. Besides the sample size of 376 respondents, 10 cattle owners were separately interviewed in Kpeleho, as the cattle owners live in distant villages stretching over 4 km from the main settlements. All households engage in farming, hence, the systematic sampling framework was appropriate in selecting respondents who use land for farming. The sampling approach used ensured equal opportunity for all respondents who are of similar social and economic standing. The sampling method was approved by the University of the Witwatersrand ethics committee.

6. 9 Approach to administering questionnaires

Before the interviews were undertaken, respondents were informed that their responses were only for academic purposes, as such their views were anonymous. Respondents were told they were free to abstain from answering the questionnaire or to avoid answering specific questions with which they were not comfortable. The questions were then asked systematically and answers given by respondents were written on the questionnaire. Leading questions such as asking respondents if they agreed that charcoal production was the main cause of deforestation in the study area were avoided. Appendix "A" shows the full list of interview questions.

Interviewing a sample size of 376 people was a substantial task. To maximize time efficiency, a total of 45 research assistants made up of second and final year students from the Statistics Department of Ho Poly-technique were recruited for the data collection. The recruited students were taken through a training programme to enable them to understand the content of the questionnaire to overcome potential field problems such as wrong interpretation of questions from English to the local Ewe language. Mock questionnaire administration was carried out among research assistants after which they paid visits to the field to pre-test the questions. Irrelevant questions were deleted after the

pre-test and questions that were either not clear or were ambiguous were re-worded to make them clearer.

Appointment dates in all four target towns/villages were arranged after first visiting the chiefs of the respective towns to determine convenient dates when communities would be available to answer the questionnaires. Chiefs of the respective towns and villages gave Fridays and Sundays of every week as days in which farmers do not go to their farms, hence, the questionnaires were administered on these days. These days were also convenient for the student research assistants, as Fridays were field trip days for practical training in research methods as a result the data collection fitted into their semester schedule. Sundays were also convenient for the research assistants. The Ho Polytechnic bus was paid for by the researcher to transport students to the study towns; trips generally lasting for a maximum of one and half hours.

A total of seven trips were made by the student research assistants during the data collection period to Abitia Kloe, Agokofe, Wumenu and Takla. Additionally, three trips were made to cattle owners in more distant villages that were outside the study towns. It was possible for the research assistants to reach the targeted number of respondents, as between 30 and 45 research assistants were transported on every trip. Research assistants were given codes attached to their names and these codes were written on the questionnaires given to each of the research assistants. It was thus easy to identify who administered what questionnaire. At the end of each working day, all collected questionnaires were reviewed and responses that were not clearly written on the questionnaires were discussed with the appropriate research assistants for clarification.

6. 10 Method of data analysis

The main analytical software used for the socio-economic data analysis was the Statistical Package for Social Science Research (SPSS). The SPSS software helped to analyse the relationship among the driving forces of deforestation and the kinds of land

cover changes that occurred. Analyses of the driving forces of deforestation were carried out using simple descriptive statistics and factor analysis to assess the inter-correlation of the driving forces. In addition, a Chi-square test was conducted to determine the significance of key driving forces of deforestation such as population pressure and deforestation.

Chapter Seven provides the results for analysis of satellite images used in the study. Sections 7.2, 7.3 and 7.4 describe the accuracy assessment results for Landsat MS 1975, Landsat TM 1991 and Landsat ETM+ 2001 images respectively. Section 7.5 describes the NDVI results. Section 7.6 presents the change detection results from 1975 to 1991 and 1975 to 2001. Limitations of the study are in section 7.7.

Chapter Seven

Results: Classification of Satellite Images to Determine the Nature and Extent of Land cover Transition from 1975 to 2001.

7. 1 Introduction

This chapter discusses the results of classified satellite image analysis to explain the nature and extent of deforestation from 1975 to 2001, addressing research question one. The research question considered how the nature and extent of accelerated land cover transition (deforestation) from 1975 to 2001 is determined by classification of satellite images and variability in underlying and proximate driving forces. The last portion of the research question, seeking to find out the variable underlying and proximate driving forces of deforestation, will be addressed in Chapters 8 and 9.

Results of maximum likelihood classification of Landsat MSS, TM and ETM+ images for periods 1975, 1991 and 2001 are discussed in detail in the subsequent paragraphs. The land cover classes identified in the images comprise riparian forest, woody/grass land vegetation, settlements and bare areas. The accuracy of the classified images has been determined using the overall accuracy, Kappa coefficient and the producer and user accuracy methods. Normalized Difference Vegetation Index (NDVI) calculations for the three images have helped to characterize vegetation cover in the area. Detection of change in land cover has been done using the change detection statistical reports as in Tables 7.7 and 7.8. The Landsat MSS 1975 image covering the Ho Municipality has been classified using the maximum likelihood classification approach. The land cover classes for the image comprise riparian forest (sea green), woody/grass land (green) settlements (white) and bare area (magenta). Cloud cover and shadow have been classified to avoid their misclassification as part of the classified land cover types. Figure 7.1 represents the land cover classes for the 1975 image.

7. 2 Maximum likelihood land cover classification of Landsat MSS 1975 image

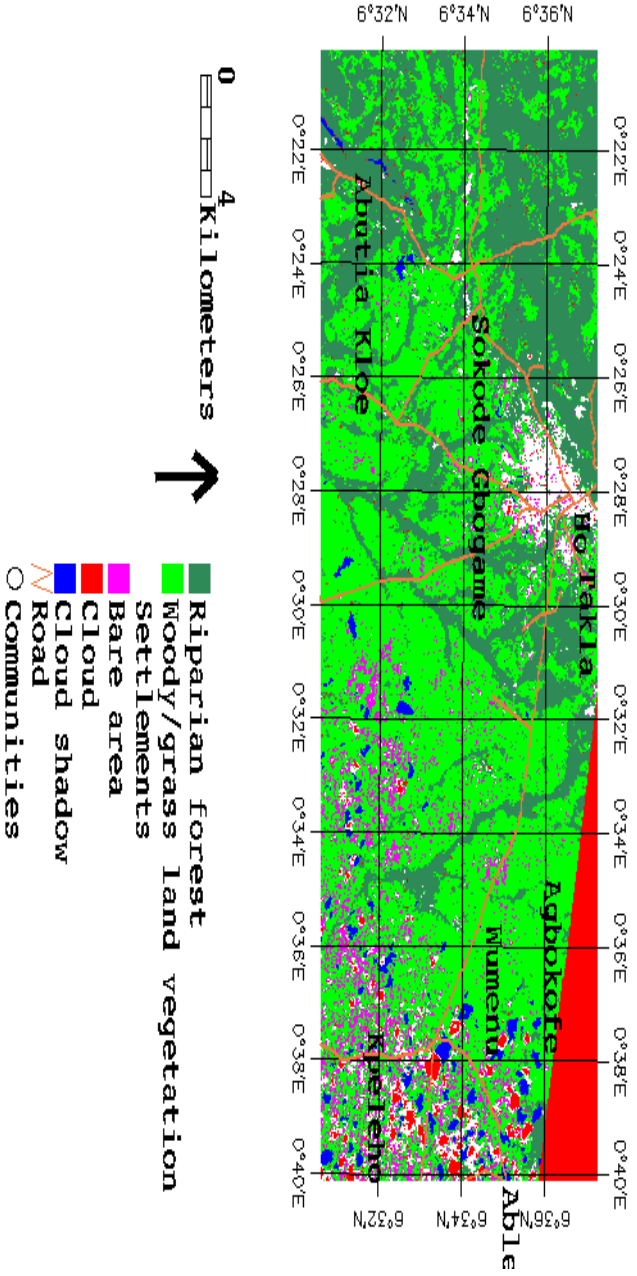


Figure 7.1 Land cover classification for Landsat MSS 1975 image

Source: Adanu 2008

Results of the 1975 classified image show limited forest cover as represented by the sea green color in Figure 7.1. The woody/grass land vegetation cover is the most extensive vegetation. Further, some bare areas can be seen in the classified image map.

7. 2.1 Accuracy assessment for Landsat MSS 1975 classified image.

As mentioned earlier and in the previous chapter remote sensing image classifications are subject to different kinds of errors caused by similarity of spectral responses of certain classes. To reduce these errors, post classification refinements are done using the error matrix to compare two thematic maps such as the ground truth map and the automated image classification (Canadian Centre for Remote Sensing, www.ccrs.nrcan.gc.ca).

Three accuracy assessments have been done to verify the accuracy of the 1975 classified image. As mentioned previously, the importance of accuracy assessment is to ensure accurate and credible results. The first accuracy assessment for the classified image comprised the overall accuracy assessment. An overall accuracy assessment value of 92% has been calculated for the 1975 image by summing up the number of pixels classified correctly divided by the total number of pixels. Pixels classified correctly are found along the diagonal of the confusion matrix (Table 7.1). In Table 7.1, 448, 900, 17 and 20 riparian forest, woody/grass land vegetation, bare area and settlement pixels respectively were correctly classified. Pixel values on either sides of the diagonal in the table represent pixels that were not correctly classified.

The second accuracy assessment comprised a Kappa coefficient assessment, as mentioned previously, calculated by multiplying the total number of pixels in all regions of interest (ROI) classes (N) by the sum of the confusion matrix diagonals (X_{kk}), and subtracting the sum of the ground truth pixel classes (ROI classes), multiplied by the sum of the classified pixels in that class and summed over all classes ($^{\Sigma}{}_{k}{}^{\Sigma}{}_{k}$). This has been divided by the total number of pixels squared minus the sum of the ground truth pixels

(ROI) in that class, multiplied by the sum of the classified pixels in that class summed up over all classes.

Table 7.1 Confusion matrix accuracy assessment report for Landsat MSS 1975 image.

Classes	Riparian forest	Woody/grass vegetation	Bare area	Cloud	Cloud shadow	Total
Riparian forest	**448**	4	0	0	1	453
Woody/grass land vegetation	15	**900**	1	0	1	917
Bare area	0	45	**17**	0	0	62
Cloud	1	1	0	**69**	0	71
Cloud shadow	1	32	0	0	**78**	111
Settlement	0	1	3	16	0	**20**
Total	465	983	21	85	80	1634

Source: Adanu 2008

Kappa coefficient values are categorized into 3 main groupings: a value greater than 0.80 (80%) represents strong agreement, values between 0.80 and 0.40 (80% to 40%) represents moderate agreement, and values below 0.40 (40%) represent poor agreement (Congalton, 1996). Using Congaltons' (1996) criteria, a Kappa coefficient value of 0.8659 has been obtained, which is acceptable as it meets the significant acceptable level.

The third accuracy assessment for Landsat MSS 1975 classified image is the producer and user accuracy assessment (Table 7.2). The confusion matrix contingency

Table 7.2 Confusion matrix contingency producer and user accuracy report for Landsat MSS 1975 image

Classes	Producer accuracy (%)	User accuracy (%)	Producer accuracy (pixels)	User accuracy (pixels)
Riparian forest	96.34	98.46	448/465	448/455
Woody/grass land vegetation	91.56	98.15	900/983	900/917
Bare area	80.95	25.00	17/21	17/68
Cloud	81.18	82.14	69/85	69/84
Cloud shadow	97.50	70.27	78/80	78/111
Settlement	77.17	78.02	71/92	71/91

Source: Adanu 2008

table shows the producer/user accuracy assessment in percentages and the number of pixels classified (Table 7.2). The producer accuracy indicates the probability that the maximum likelihood classifier has categorized such image pixels into given classes. For example, 983 pixels have been labeled as woody/grass land vegetation, however, 900 out of the 983 pixels have been classified correctly (98%). The user accuracy assessment indicates the probability that a pixel belongs to a certain class as the maximum likelihood classifier has labeled such pixels in that class. In Table 7.2, 68 pixels have been labeled as bare area pixels out of which a total of 17 bare area pixels were classified correctly resulting in a low accuracy level of (25%).

7. 3 Maximum likelihood land cover classification for Landsat TM 1991 image

The maximum likelihood classification of Landsat TM 1991 image (Figure 7.2) shows land cover classes for riparian forest (sea green), woody/grass land vegetation (green), settlements (white) and bare areas (magenta). The classified image portrays limited forest cover and extensive bare areas. The bare areas may be attributed to the effects of fire given the evidence of fire scars in the 1991 image (Figure 6.4) which has been determined by observed smoke around the fire scar when bands 5 and 7 of the image was loaded into the ENVI 4.3 software.

7. 3. 1 Accuracy assessment for 1991 image

Accuracy assessment for the 1991 classified image followed the three accuracy assessment approaches used for the 1975 image classification. The first accuracy assessment produced an over all accuracy of 89% which is a high level of accuracy. The confusion matrix assessment report for the 1991 classified image (Table 7.3) shows the number of pixels classified correctly and those that have been misclassified.

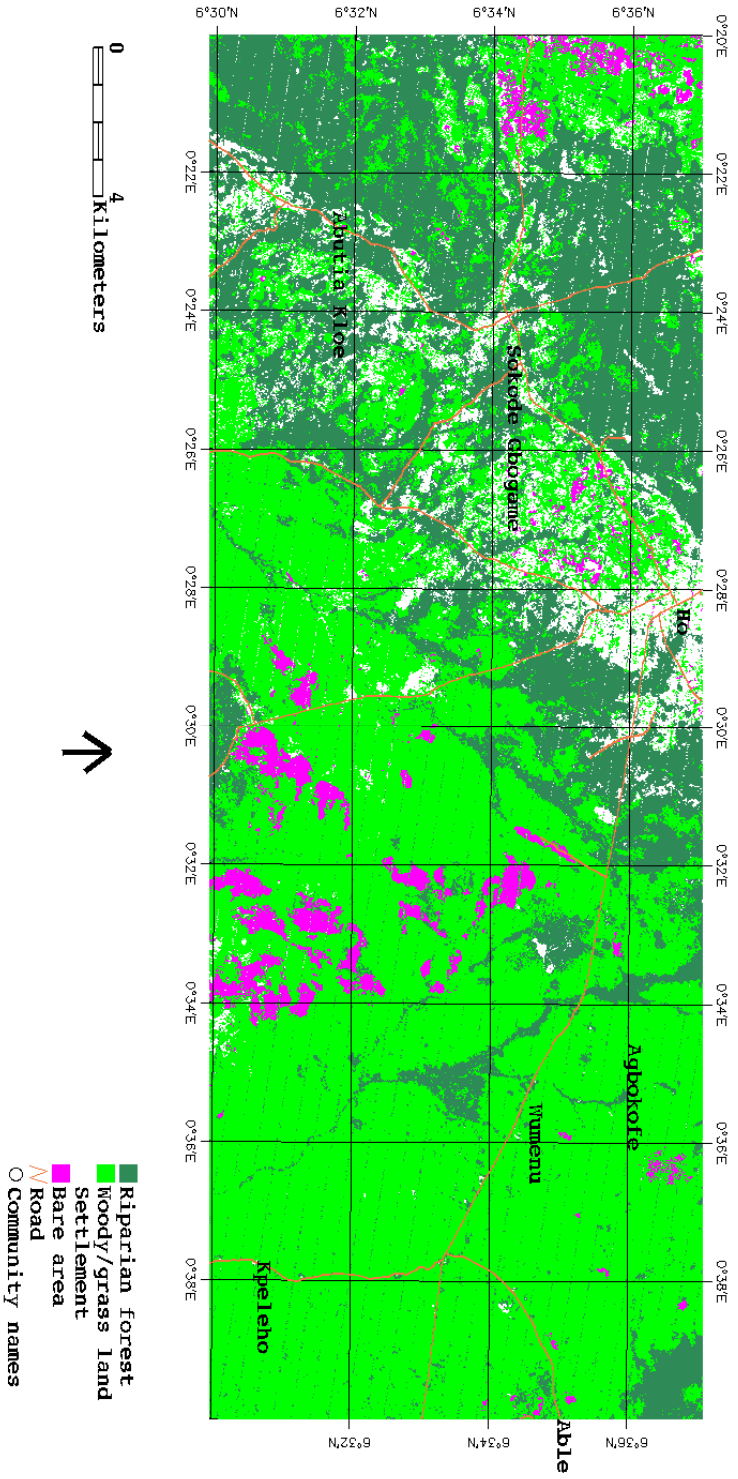


Figure 7.2 Classified land cover map for Ho Municipality (Landsat TM 1991)
Source: Adanu 2008

Table 7.3 Confusion matrix contingency pixel report for Landsat TM 1991 image

Classes	Riparian forest	Woody/grass land veg.	Settlement	Bare area	Total
Riparian forest	**695**	110	0	0	805
Woody/grass land vegetation	87	**797**	9	0	893
Settlement	0	32	**266**	4	302
Bare area	0	3	6	**284**	293
Total	782	942	281	288	2293

Source: Adanu 2008

The column values in Table 7.3 represent ground truth classes for riparian forest, woody /grass vegetation, settlements and bare areas. For example, 695 pixels have been classified as riparian forest out of 782 total pixels. In the riparian forest column, 87 of the pixels changed to woody/grass land and 0 pixels changed to bare area. Such a result implies that digitized regions of interest classified as riparian forest contained other pixel classes such as woodland (87) and bare areas (0). As a result, the classification is not 100% correct but 89% correct as indicated by the overall accuracy. For the woody land cover classes, 797 pixels have been classified correctly out of a total of 942 pixels.

As far as the Kappa Coefficient accuracy assessment is concerned, an overall accuracy of 0.8409 has been obtained, indicating that the result is acceptable (Congalton, 1996). The "producer accuracy" which is the proportion of correctly classified pixels to the total number of pixels in row for the 1991 classified image as in Table 7.3, shows that 805 pixels have been labeled as riparian forest. 695 out of the 805 pixels were, however, correctly classified, giving a producer accuracy percentage value of 89% for the riparian forest class. The "user accuracy" which indicates the probability that pixels in the classified image have been correctly assigned is calculated by comparing the proportion of correctly classified pixels in the diagonal with the total number of pixels in the column. The result indicates that 893 pixels have been labeled as woody/grass land while 797 out of the 893 pixels were correctly classified giving a percentage accuracy value of 89%, an acceptable result.

Table 7.4 Confusion matrix producer and user accuracy report for 1991 image

Classes	Producer accuracy (%)	User accuracy (%)	Producer accuracy (pixel)	User accuracy (Pixel)
Riparian forest	88.87	86.34	695/782	695/805
Woody/grass land vegetation	84.61	89.25	797/942	797/893
Settlement	94.66	88.08	266/281	266/302
Bare area	98.61	96.93	284/288	284/293

Source: Adanu 2008

Concerning bare areas, 288 pixels have been labeled as bare area pixels for the producer accuracy out of which 284 of the bare area pixels have been correctly classified. The classified land cover map in Figure 7.3 shows four land cover classes: riparian forest (sea green) woody/grass land vegetation (green), bare area (magenta) and settlements (white).

7. 4. Accuracy assessment for Landsat ETM+ 2001 image

A confusion matrix calculation for the 2001 classified image produced an overall accuracy figure of 86%. The overall accuracy is the proportion of total number of correctly classified pixels shown diagonally compared to the total number of pixels in the matrix (Table 7.5). Taking the column for riparian forest for example, out of a total of 848 pixels classified as riparian forest 774 of the riparian forest pixels have been correctly classified, while 2 and 67 pixels classified as riparian forest were actually woodland/grass land and bare area pixels respectively. Given that 774 pixels have been correctly classified the classification result is accepted based on the standard error margin. For woody/grass land areas, 516 pixels have been correctly classified out of a total of 683. For bare areas, 44 pixels have been correctly classified out of a total of 66 pixels. In the case of settlements, 276 pixels have been correctly classified out of a total of 283 pixels.

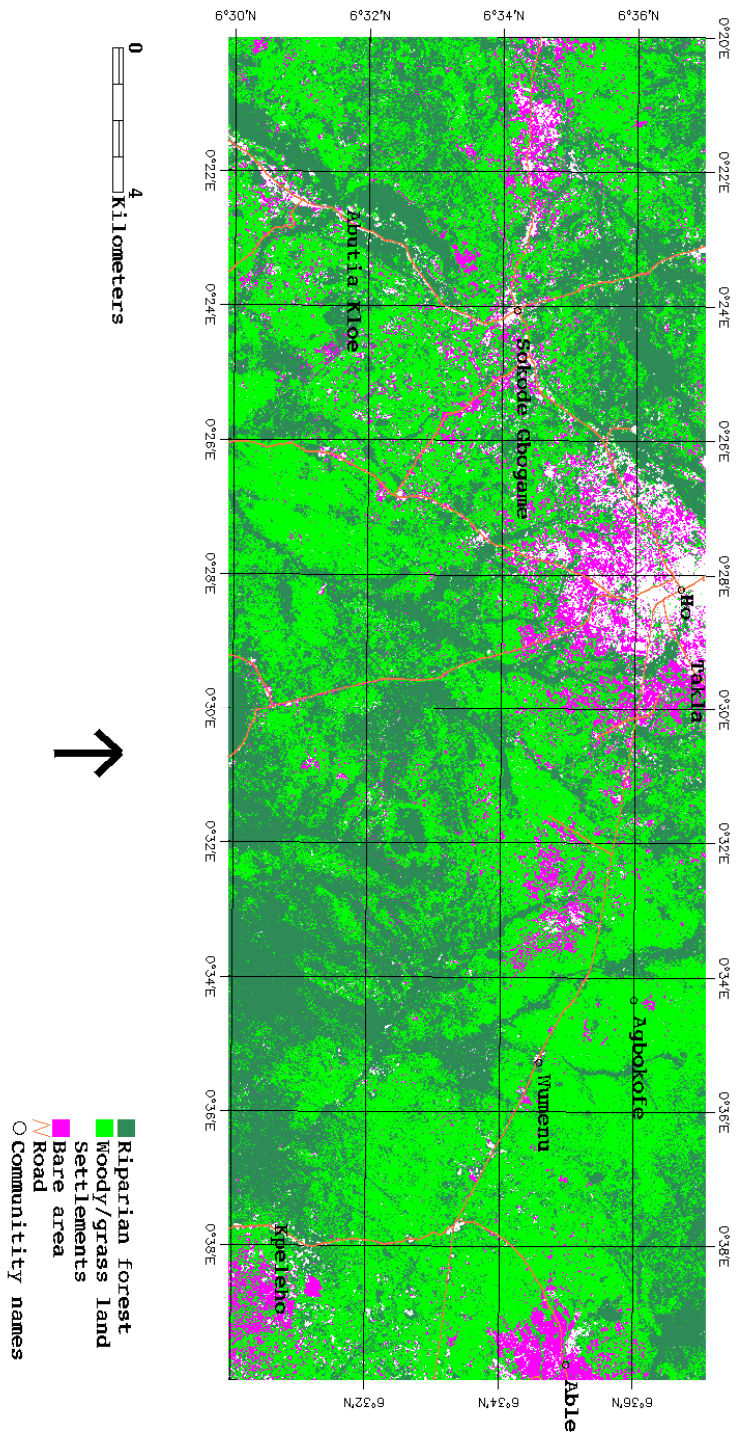


Figure 7.3 Classified land cover map for the study area (Landsat ETM+ 2001). Source: Adanu 2008.

Kappa coefficient calculations for the classified image produced a value of 0.7794 which is within acceptable error margin (Congalton, 1996). The accepted result also shows that the maximum likelihood classification method applied to the study is appropriate. The third assessment of accuracy is the producer and user accuracy measurement shown in Table 7.5

Table 7.5 Confusion matrix contingency pixel report for Landsat ETM+ 2001 Image.

Class	Riparian forest	Settlements	Bare area	Woody vegetation	Total
Riparian forest	**774**	1	0	92	867
Settlement	5	**276**	15	2	298
Bare area	2	2	**44**	73	121
Woody/grass land	67	4	7	**516**	594
Total	848	283	66	683	1880

Source: Adanu 2008

The producer accuracy labeled 848 pixels as riparian forest out of which 774 of the pixels have been classified as riparian forest resulting in a producer accuracy percentage figure of 91%, affirming the accuracy of the result. The user accuracy result shows that 283 pixels have been labeled as settlement pixels out of which 276 of the pixels have been correctly classified as settlements resulting in a 92% accuracy which is within acceptable error margin (Congalto, 1996).

Table 7.6 Confusion matrix producer and user accuracy report for Landsat ETM+ 2001 image.

Class	Producer accuracy (%)	User accuracy (%)	Producer accuracy (pixel)	User accuracy (Pixel)
Riparian forest	91.27	89.27	774/848	774/867
Settlements	97.53	92.62	276/283	276/298
Bare area	66.67	36.36	44/66	44/121
Woody/grass land	75.55	86.87	516/683	516/594

Source: Adanu 2008

7. 5 Normalized difference vegetation index (NDVI) calculation

NDVI calculations have been done for the three satellite images using the procedure explained in section 6.3.8. Normally, healthy green vegetation reflects better in the nearer infrared (NIR) portion of the electromagnetic spectrum and absorbs radiation strongly in the visible red part of the electromagnetic spectrum (Hayes and Sader, 2001). Other surface types such as soil and water bodies show nearly equal reflectance in both the NIR and visible red part of the spectrum. Due to differences in the reflectance properties of vegetation and other objects, NDVI calculations can show large differences between vegetation and other land cover types. Vegetation gives high positive values in NDVI calculations while other objects such as cloud, water and snow give negative values due to high level of green vegetation reflectance in the NIR than the visible red window of the electromagnetic spectrum (Pu *et al*, 2008). For example, NDVI values for soils and rocks are normally near to zero due to their similar reflectance in both NIR and the red bands. Results of any NDVI calculation can be represented numerically such as in an index range of -1 to 1. An index range of 0.2 to 0.8 is common when the vegetation is healthy and green (Mass, 1999)**.** The other alternative is to represent such index values by light and dark tone images. Such an approach was used in this study. Light tone images are associated with the coverage of dense and healthy vegetation, while dark tone images are associated with stressed and unhealthy vegetation (Vicent- Serrano *et al*, 2006). The NDVI result for Landsat MSS 1975 image (Figure 7.4) clearly shows healthy vegetation (riparian forest) with bright grey colour while the woody /grass land vegetation shows a dark colour suggesting unhealthy vegetation. The stressed woody/grass land vegetation is likely to be the result of the dry conditions that exist during December**.**

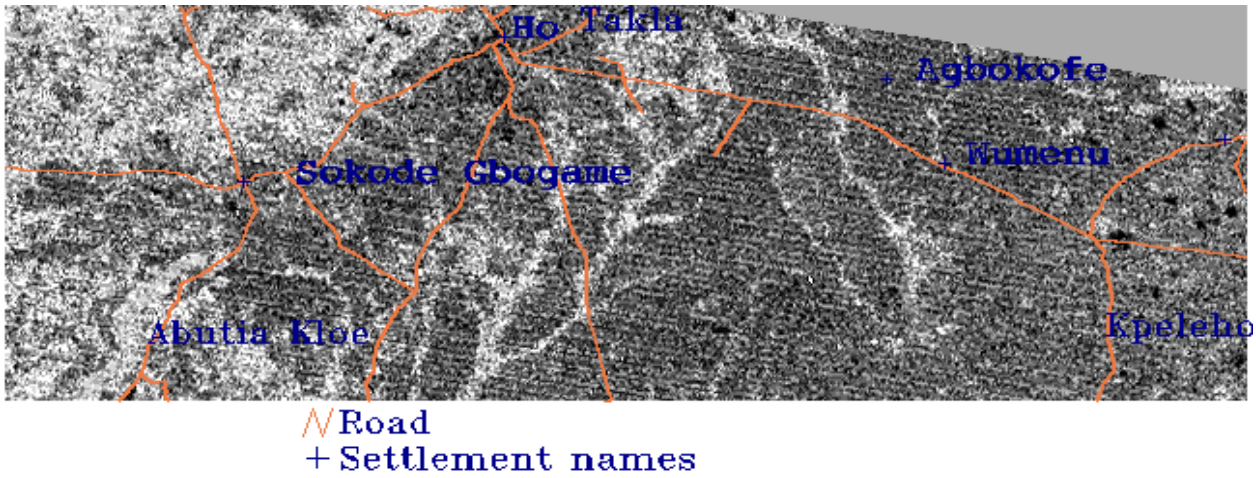


Figure 7.4 NDVI calculation for Landsat MSS 1975 image
Source: Adanu 2008

Figure 7.5 shows bright grey areas with healthy vegetation (riparian forest) and dark areas of unhealthy vegetation (woody/grass land vegetation) while the darker spots represent settlements/bare area.

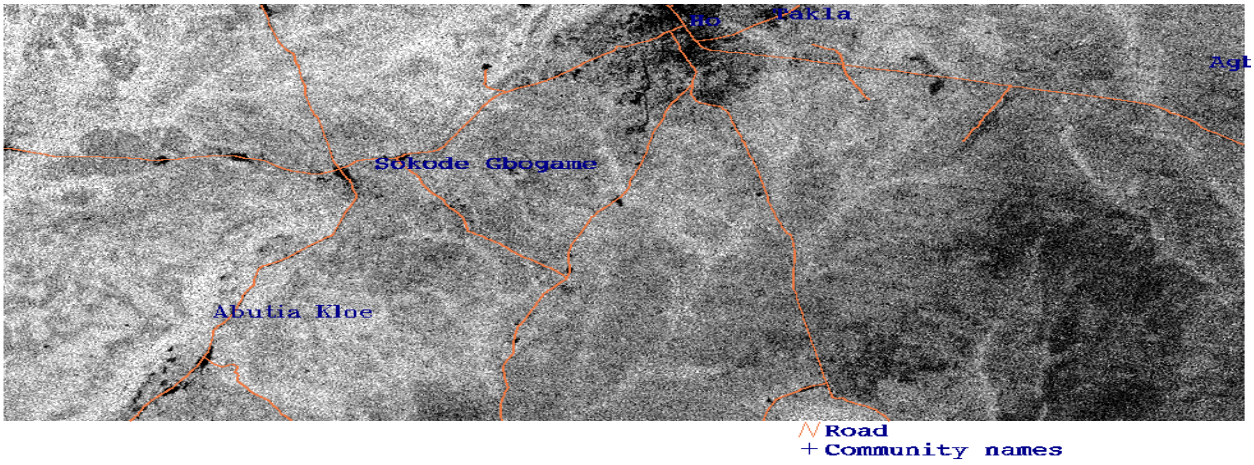


Figure 7.5 NDVI calculation for Landsat TM 1991 image

Source: Adanu 2008

The NDVI calculation for the Landsat ETM+ 2001 image shows healthy green vegetation cover in the municipality. These three NDVI calculations suggest that, the land cover had healthy forest cover.

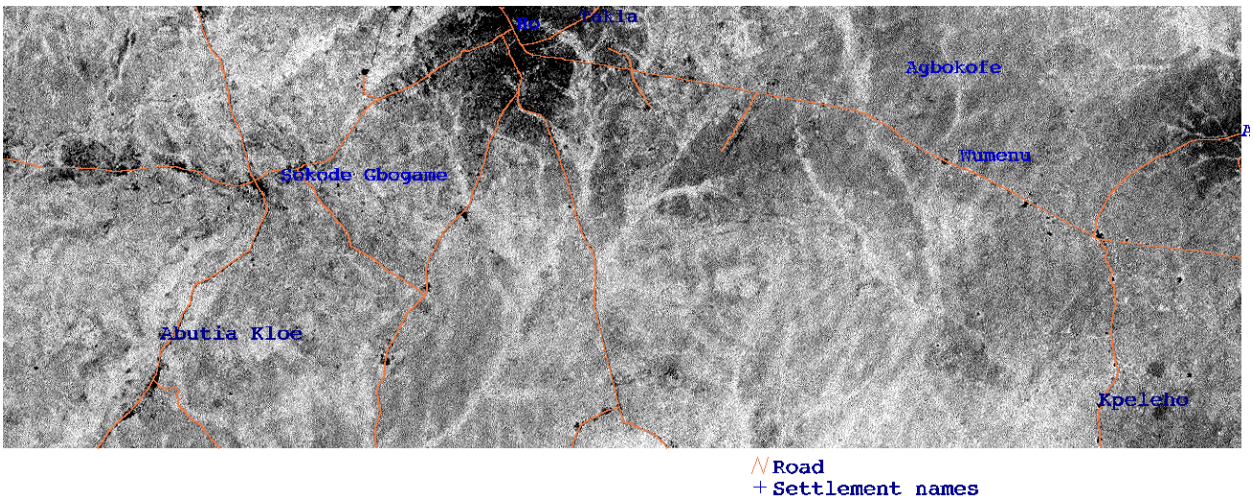


Figure 7.6 NDVI calculation for Landsat ETM+ 2001 image

Source: Adanu 2008.

7. 6 Change detection statistics

As mentioned in section 6.3.7, change detection for this study has been computed by subtracting the classified pixel values of 1991 and 2001 images from the 1975 base image. This process produced a change detection statistics table showing changes between two classified images. The change detection statistical calculation shows the classes into which initial state image pixels have changed to in the final state image. In this study, the initial state pixels refer to the 1975 image pixels, while the final state pixels refer to 1991 and 2001 image pixels. To determine change in vegetation cover, image classes such as riparian forest, woody land with grass, settlements and bare areas have been paired. For example, the riparian forest class for the 1975 classified image has been paired with the riparian forest class for the 1991 classified image. The same process has been followed for the 2001 classified image. After pairing the image classes, pixel values of the 1975 classified Landsat MSS image were subtracted from the pixel values of the 1991 and 2001 classified images respectively, to generate change detection statistics report for the period between 1975 and 1991 (Tables 7.7 and 7. 8). Before the change detection calculation for the 80m resolution 1975 image, the image was re-

sampled (as previously mentioned section 6.3.1) to facilitate comparison to the 30m resolution images.

7. 6 .1 Detection of change from 1975 to 1991

The change detection statistical pixels report for the period 1975 to 1991 is shown in Table 7.7. The initial state classes (1975 classified image pixels) in columns depict only the paired classes and the final state classes (1991 classified image pixels) fall in rows. For example, 8855 pixels classified as riparian forest did not change class. 23294 pixels classified as riparian forest in the initial state changed, however, to woody /grass land vegetation in the final state image. The class total row shows the total number of pixels in each initial state class. For example, 34588 pixels were classified as riparian forest in the initial state image, while 14388 pixels were classified as riparian forest in the final state image. The row total column comprise a class by class summation of all final state pixels that fall into the selected initial state classes. The class change row indicates the total number of initial state pixels that changed class. The class change for riparian forest was for instance, 25733 pixels indicating that 25733 pixels initially classified as riparian forest changed to final classes other than riparian forest.

Table 7.7 Change detection statistics pixel report from 1975 to 1991

Classes	Riparian forest	Woody/grass vegetation	Settlements	Bare area	Row total	Class total
Riparian forest	8855	4623	124	221	13823	14388
Woody/grass land vegetation	23294	34950	1175	3236	62655	65488
Settlement	1371	1995	1058	600	5024	5564
Bare area	1068	9888	350	2877	14183	14730
Class total	34588	51456	2707	6934	0	0
Class change	25733	16506	1649	4057	0	0
Image difference	-20200	14032	2857	7796	0	0

Source: Adanu 2008

It is possible to check and confirm accuracy of classified images by subtracting the column pixel count of land cover classes from the class total the result must be equal to the class change value. For example**,** when the riparian forest column pixel count of 8855 is subtracted from the riparian forest class total of 34588, the result of 25733 confirms the accuracy of the result. The image difference row shows the difference in the total number of equivalent classified pixels in the two images. The image difference is computed by subtracting the initial state class total from the final state class total, and a positive image difference indicates an increase in the class size while a negative image difference indicates a decrease in class size (ENVI, 2006). On the basis of this principle, the image difference for riparian forest pixels was -20200, indicating a decrease in the class size for the forest cover.

Driving forces of deforestation such as population increase, woodfuel production and farming among other driving forces will be explained in Chapter Eight. The image difference for woody/grass land vegetation shows a positive value of 14032 indicating an increase in the class size for woody/grass land vegetation. The increase in class size for woodland/grass was as a result of multiple factors such as agricultural expansion, effect of bush fires, and logging activities which will be explained in detail in Chapters Eight and Nine. Positive image difference figures of 2857 and 7796 show increases in the class size for settlements and bare area pixels respectively. The settlement and bare area pixels have similar reflectance signature patterns, however, the settlements have been differentiated from bare areas based on their shape and location such as along road networks and at village sites that are not linked by major road networks. Knowledge of the area helped in identifying the settlements though there could be some errors in doing so.

Changes that occurred on the land cover from 1975 to 1991 are illustrated in Figure 7.7. The image difference for riparian forest is – 6562 hectares indicating a decrease in the forest cover. A positive image difference of 4558 hectares has been

calculated for woody vegetation with grass while positive image differences of 2532 and 928 hectares recorded for bare areas and settlements respectively.

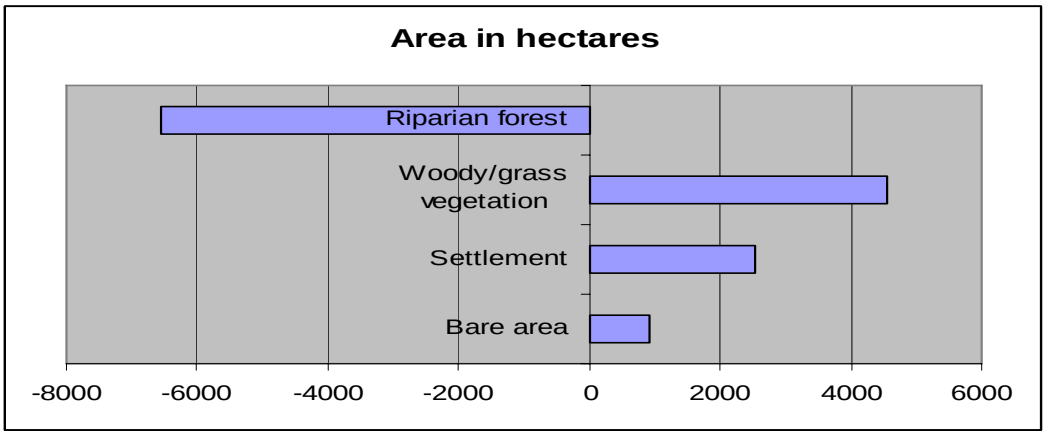


Figure 7.7 Change detection image difference statistics report from 1975 -1991.
Source: Adanu 2008

Further explanations to changes in the land cover are illustrated by percentages of change as shown in Figure 7.8. An overall image difference of – 58%, was recorded for riparian forest. In the case of the woody/grass land vegetation, settlements and bare areas, 27.2%, 105.5% and 112.4% positive changes occurred respectively.

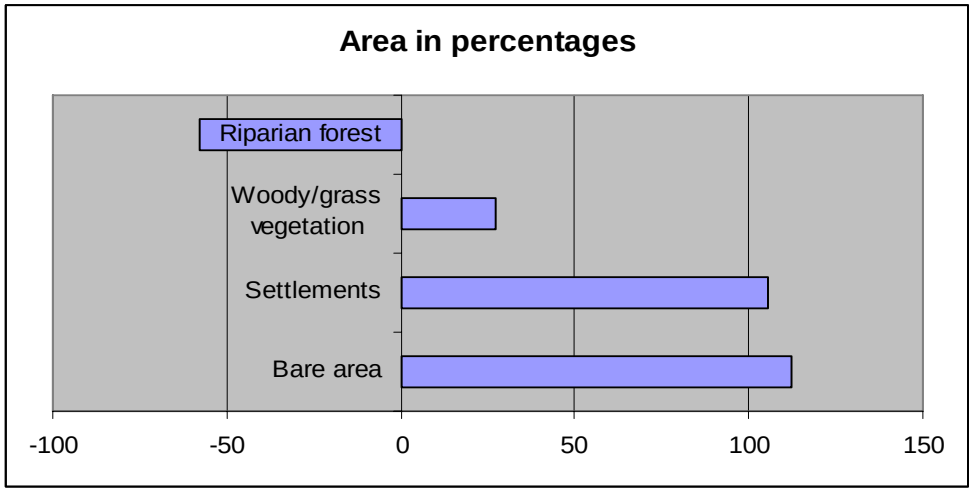


Figure 7.8 Change detection image difference statistics in percentages from 1975 – 1991.

Source: Adanu 2008.

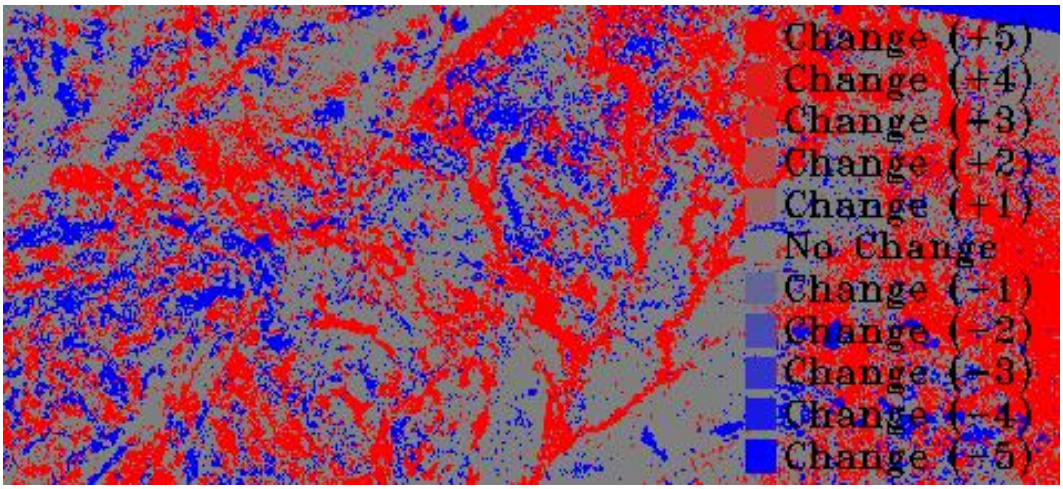


Figure 7.9 Image difference map for 1975 -1991

Source: Adanu 2008.

The image difference classification map (Figure 7.9) shows positive, negative and no changes areas. The positive changes are ranked from +5 to +1, such that higher positive values indicate areas with much more forest cover while lower positive values show positive changes with less vegetation cover. A zero figure shows areas of no change in land cover and the negative values show areas that decreased in vegetation cover; high negative values show areas of high vegetation or forest loss while areas with lower negative values show lesser vegetation cover or bare areas.

7. 6. 2 Change detection statistics report for 1975 – 2001

A change detection statistical report concerning change in land cover for the period 1975 to 2001 is provided in Table 7.8. The initial state classes (1975 image) are shown in columns while the final state classes (2001 image) are shown in rows. In Table 7.8, 18216 pixels classified as riparian forest in the initial state changed to woody/grass land vegetation. The class total row shows the total number of pixels in each initial state class for example, 35690 pixels have been classified as riparian forest in the initial state

image while 26613 pixels have been classified as riparian forest in the final state**.** The row total column is a class by class summation of all final state pixels that fall within selected initial state classes. The row total figures in Table 7.8 show that 23919 riparian forest pixels and 65087 woody/grass land vegetation pixels have been derived from the change detection calculation.

The class change row in Table 7.8 indicates the total number of initial state pixels that changed class. The class change for bare area, for example, is 11010 pixels essentially indicates that 11010 pixels initially classified as bare areas changed to final classes other than bare areas. As explained earlier, confirmation of class change accuracy is computed by subtracting the column pixel count of an image class from the class total to produce a result that must be equal to the class change value in the column. For example, when the bare area column pixel counts of 3036 is subtracted from the bare area total class of 14046, the resultant value of 11010 confirms the result of change in the bare area pixels.

Table 7.8 Pixel count change detection statistics from 1975 – 2001

Classes	Riparian forest	Woody/grass vegetation	Settlements	Bare area	Row total	Class total
Riparian forest	8726	12225	501	2467	23919	26613
Woody vegetation/grass land	18216	37615	1896	7360	65087	71032
Settlement	2452	3039	1487	1183	8161	9277
Bare area	6296	14276	1032	3036	24640	27268
Class total	35690	67155	4916	14046	-	-
Class change	26964	29540	3429	11010	-	-
Image difference	-9077	3877	4361	13222	-	-

Source: Adanu 2008.

The image difference pixel count for riparian forest is -9077, indicating a decrease in the riparian forest cover. The image difference pixel count for woody vegetation is positive (3877); as such, suggesting an increase in the woody savannah vegetation cover. A

decrease in forest cover pixels is due to production pressure, poor land tenure arrangements, agriculture expansion and woodfuel production as will be explained in Chapters Eight and Nine.

The image difference for riparian forest is a negative value of -2949, hectares indicating a decrease in riparian forest cover from 1975 to 2001 (Figure 7.10). Regarding the change in woody/grass vegetation cover, a positive change of 1259 hectares has been gained from 1975 to 2001.

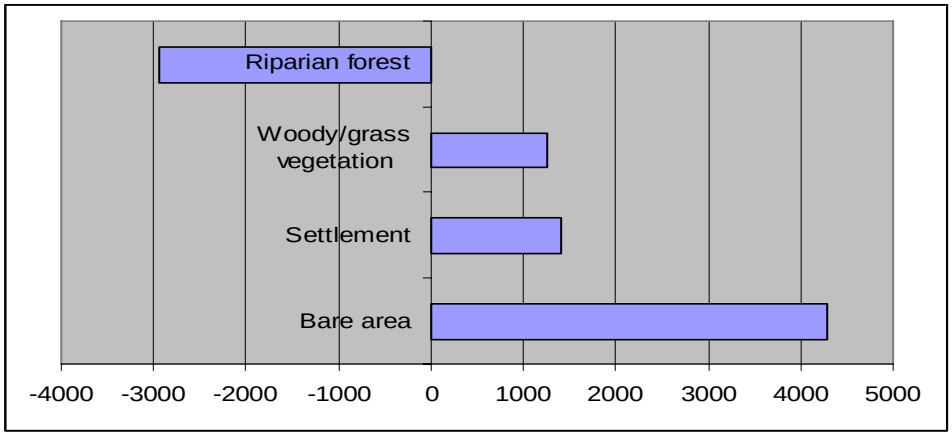


Figure 7.10 Change detection image difference statistics report from 1975 to 2001

Source: Adanu 2008

The settlement sizes in the Ho Municipality changed positively (increased) by 1416 hectares, while bare areas changed positively (increased) by 4295 hectares from 1975 to 2001. Further interpretation of changes in the land cover for the period between 1975 and 2001 are presented in percentages (Figure 7.11)

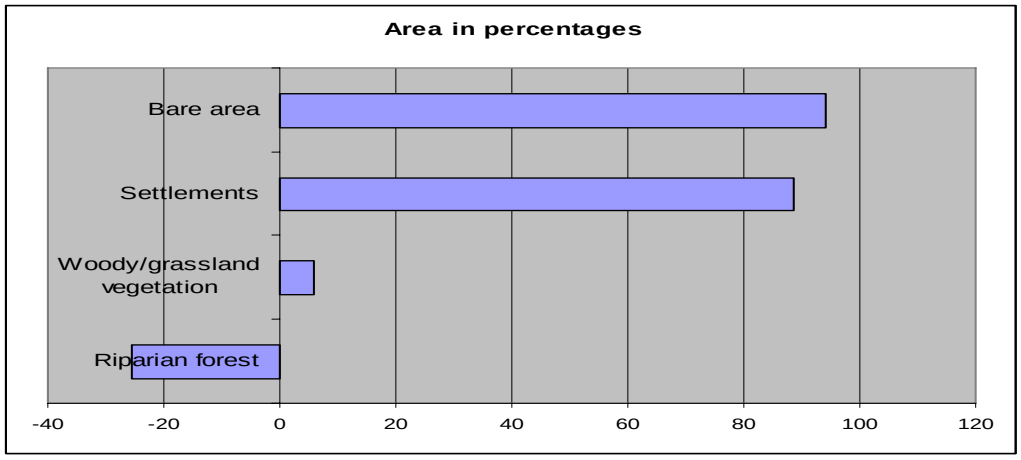


Figure 7.11 Change detection image difference statistics from 1975 to 2001

Source: Adanu 2008.

From 1975 to 2001, a total of 25% riparian forest vegetation cover was lost. Regarding the woody/grass land savannah vegetation cover, a 5.7% increase occurred, while 88.7% and 94.1% increases occurred for settlements and bare areas respectively.

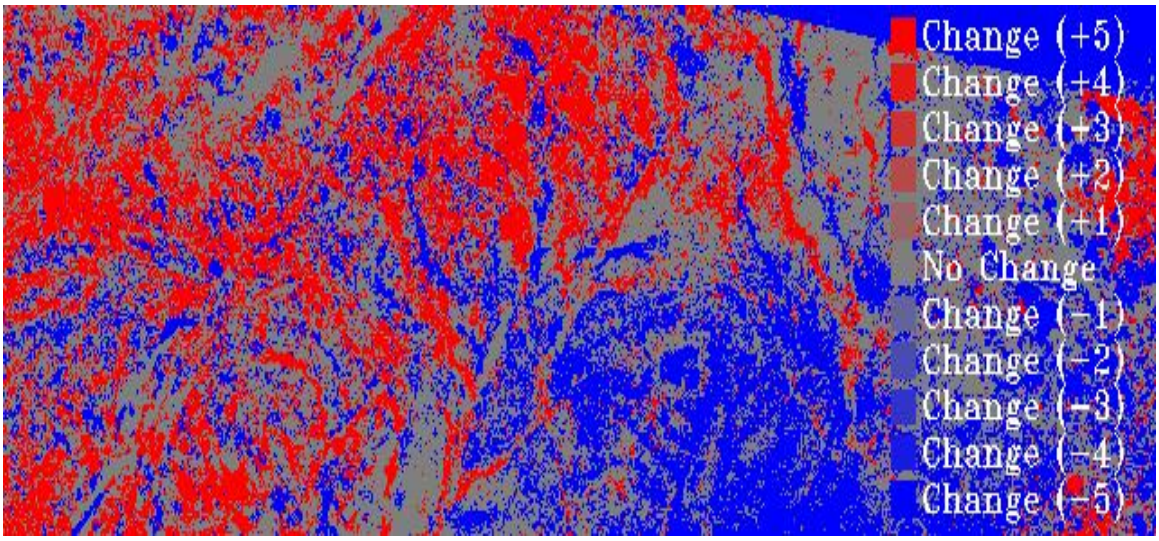


Figure 7.12 Image difference classification map for 1975 – 2001

Source: Adanu 2008.

The image difference map shows a variety of land cover changes thus, positive changes are ranked from +5 to +1 such that higher positive values indicate areas with much more forest cover while lower positive values show smaller increases in forest cover and a zero figure shows areas of no change in cover (Figure 7.12). The negative values show areas that decreased in vegetation cover (-5 to -1). Higher negative values show areas of high vegetation or forest loss, while areas with lower negative values show lesser vegetation cover or bare areas.

7.7 Limitations of image classification

As discussed in the previous chapters, there may be inherent errors associated with image classifications due to factors such as atmospheric effects. As mentioned earlier, the three images used for the image classification were acquired during the Harmattan season specifically December and February (characterized by dry dusty periods with poor and hazy visibility) which accounts for the slightly blurred imagery. The difficulty in identifying targets such as forest, woody vegetation, settlements and bare areas contributed to some overlap of digitized regions of interest. This occurred despite exporting the image to n-D visualizer to separate the land cover classes. The function of n-D visualizer is to separate the purest pixels of a given class into clusters for easy classification. The blurred images, were, however, enhanced using the histogram stretch image enhancement technique. The 1991 image had fire scars that cover part of the image which was excluded from the image classification; hence, the affected land cover was excluded from the image classification to avoid misclassification. Although ground verification of land cover classes has been done, not all the areas were accessible due to thick forest cover and the difficulty of accessibility. Images captured during the rainy season that are devoid of cloud cover may have been better for this image analysis, had funding been available to purchase new imagery.

7.8 Discussion

Application of maximum likelihood classification to the study produced land cover classes for riparian forest, woody/grass vegetation, settlements and bare areas for the periods 1975, 1991 and 2001. Beyond Ghana, maximum likelihood supervised classification has been used by different authors for land cover change detection analysis such as studies in California, United State of America, (Conese and Maselli, 2003; Strahler, 1980). Assessment of image accuracy for the classified images was undertaken using the overall accuracy assessment, Kappa coefficient, and the producer and user accuracy assessment methods. The overall accuracy for the 1975 image was 92%; 89% for the 1991 image and 86% for the 2001 imagery. By comparison, a similar study in the tropical mountain watershed in Ethiopia made use of Landsat TM 1990 and Landsat ETM+ 2003 images for analysis and produced an overall accuracy of 78.2% for Landsat TM 1990 classified image and 79.7% for the Landsat ETM+ 2003 image (Muntildoez and Lopez-Blanco, 2008). Use of confusion matrix to compare accuracy of thematic maps has been useful in refining estimates of image classes thereby determine how reliable the classified imagery is and its relevance for analysis (Foody, 2010). Use of confusion matrix to compare accuracy of thematic maps has been useful in refining estimates of image classes thereby determine how reliable the classified imagery is and its relevance for analysis (Foody, 2010). The Kappa coefficient assessment of accuracy for 1975 image was 0.8659; 0.8409 for 1991 image and 0.7794 for 2001. These results show acceptable error margins. The producer and user accuracy assessment figures as in Table 7.2; 7.4 and 7.6 are further indications that the errors are within acceptable margins.

The NDVI calculation produced results showing healthy vegetation in light tone as shown on the image difference maps, and stressed vegetation in dark tones for the 1975, 1991 and 2001 images. Similar spatio-temporal studies on vegetation health in the Qinghai-Tibetan plateau from 1982 to 2006 revealed poor vegetation health in dark tones for the east of the region and a consistent healthy bright tone vegetation for the southern part of the study site between 2004 and 2005 (Yu *et al*., 2011).

Land cover change detection results from 1975 to 1991 shows negative image difference, indicating a decrease in land cover by -20200 for riparian forest pixels and positive image differences indicating increase in land cover by 14032 for woody/grass vegetation pixels 2857 for settlements pixels and 7796 for bare areas pixels. The image difference map (Figure 7.9) shows areas of positive, negative and no change. Land cover change in hectares is shown in Figure 7.7 and percentage land cover change is shown in Figure 7.8. A study by CERSGIS (2010) using NDVI 2000 and 2008 data covering all the ecological zones of Ghana showed healthy closed canopy forest decreased from 12,607 square kilometers in 2000 to 11, 748 square kilometers in 2008 while unhealthy grass land vegetation increased from 53,718 square kilometers in 2000 to 79,884 square kilometers in 2008 (CERSGIS, 2010).

Change detection computed from 1975 to 2001 reveals a decrease in riparian forest cover pixels by -9077; woody/grass vegetation pixels 3877; settlement pixels 4361 and bare area pixels 13222. The positive image difference values indicate increases in woody/grass vegetation, settlements and bare area covers (Table 7.8). Change in hectares and percentages are shown in Figures 7.10 and 7.11. Figure 7.12 shows the image difference map from 1975 to 2001 indicating areas that changed positively and places of no change. A similar study in the Barekese catchment of Ghana to detect change in land use and cover between 1973 and 2000 show close canopy forest decreased by 43%, open canopy forest decreased by 32% while grassland/open areas increased by 700% (Boakye *et al*., 2008).

Errors associated with the image classifications due to atmospheric effects have contributed to minor errors in the image classes. Notwithstanding this, the results provide useful information on land use/ cover, and changes in riparian forest cover, in particular, in the study municipality

7.9 Conclusions

In conclusion, results of the image analysis addressed research question one, namely the nature and extent of accelerated land cover transition (deforestation) from 1975 to 2001. The nature and extent of deforestation from 1975 to 1991 show a negative change in riparian forest cover, but positive changes or increases in woody/grass vegetation, settlements, and bare areas. In terms of percentages, a decrease of 58% occurred in riparian forest cover. Concurrently, increases occurred by 27.2%, 105.5% and 112.4% in woody/grass vegetation, settlements and bare areas respectively.

From 1975 to 2001 riparian forest cover loss occurred while woody/grass vegetation, settlements and bare areas increased. The percentage decrease in riparian forest was 25% and increase of 5.7%, 88.7% and 94.1% for woody/ grass vegetation, settlements, and bare areas respectively.

Chapter Eight

Results: Population Growth, Density and other Underlying Driving Forces of Deforestation

8.1 Introduction

This chapter addresses research question two, namely 'do population growth and density play any significant role in deforestation compared to the other driving forces of deforestation? ' Population growth and density have been identified as key underlying driving forces of land cover change transition with respect to deforestation problems in the study municipality, as shown by the study results. Other underlying driving forces of deforestation identified in this research comprise technological influence, poverty, income levels and government policies. The results on underlying driving forces of deforestation are based on perception of respondents, which were analysed using simple descriptive statistics and chi-square techniques.

8.2 Demographic driving forces

Between 1970 and 2000, the population of Ho District increased, with an associated increase in the population density per square kilometre for the municipality, according to the population and housing census figures of Ghana (Ghana Statistical Service 1971 and 2000). In 1970, the population of Ho District stood at 37,938 with a population density of 30 persons per square kilometre (Ghana Statistical Service, 1971). In 1984, the population of the district increased to 52,715 people with a population density of 46 people per square kilometre (Ghana Statistical Service, 1984). The 2000 population census figures showed an increase of 235,331 people with a population density of 79.5 people per square kilometre (Ghana Statistical Service, 2000). This chapter discusses whether this increase in the municipal population may have caused significant land cover change in the area. For example, in 1970 the population density of

the district increased from 30 persons per square kilometer to 46 people per square kilometer by 1984. This population increase could be responsible for the decrease in riparian forest cover by 6562 hectares constituting 58% decline from 1975 to 1991. Furthermore, by the year 2000 the population of the municipality increased to 79.5 people per square kilometer with 2949 hectares of forest decline which is 25% of forest loss from 1991 to 2001, suggesting that population increase is a driver of forest decline hence, a key driving force of deforestation. A detailed explanation to the processes of forest cover change is provided next. It is important to mentioning that until 2008 the study area was a district hence the use of district and municipality inter-changeably.

Table 8.1 Population and housing census figures for Ho District from 1970 to 2000.

Years	Population	Density per square km
1970	37,938	30
1984	52,715	46
2000	235, 331	79.5

Source: Adapted from population and housing censuses of Ghana from 1970 to 2000.

To determine the significance of population increase as an underlying driving force of deforestation in the Ho Municipality, a Chi-square test was carried out to test the null hypothesis that:

H_o: Demographic pressure is not a key underlying driving force of land cover change transition.

The decision rule of the test required that the null hypothesis is rejected if the test statistics (calculated value) is greater than the critical value at the 5 percent level of significance.

Results of the Chi-square test that tested the null hypothesis (H_o) that demographic pressure is not a key underlying driving force of "land cover change transition'' is shown in (Table 8.2). The Chi-square test statistics obtained for the test was χ^2 = 364.099 given the critical value of 0.05 (Appendix B) which is equal to a table value of 5.99 less than the test statistics; hence, the null hypothesis is rejected. This

implies that population pressure is a key underlying driving force of deforestation. Figure 8.1 is a graphical plot of the mean of the Chi-square test.

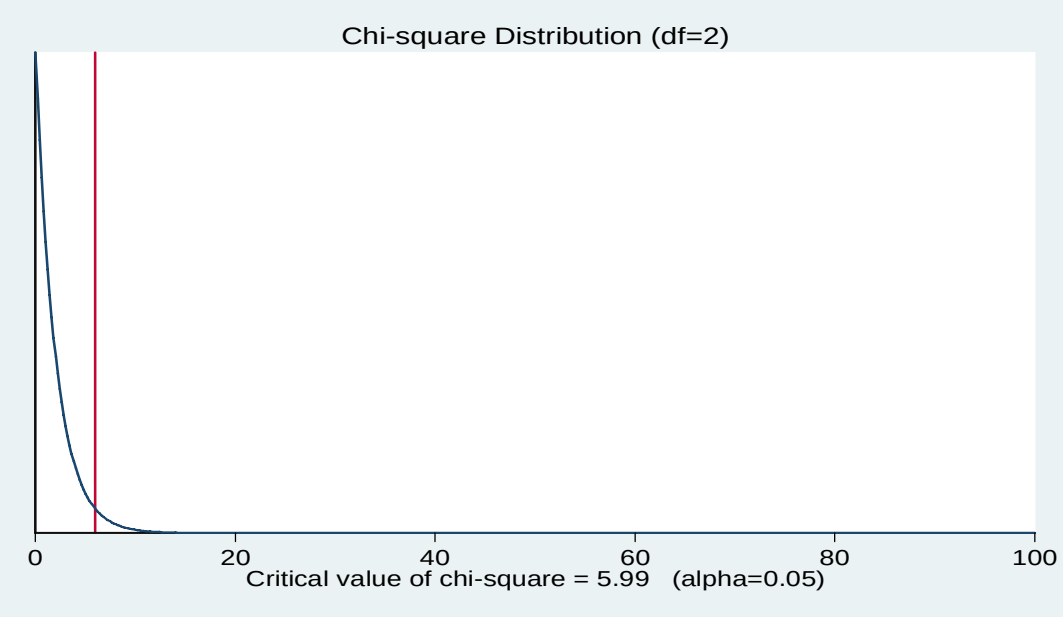


Figure 8.1 Plot of Chi-square test for hypothesis one.

The choice of Chi-square is appropriate for the test of significance as the data variables are parametric, and nominal (categorical data) was obtained from respondents to determine whether population increase causes deforestation or not. The Chi-square test has been used in studies to test the significant effects of socio-economic factors such as household size increase on deforestation (Galiba *et al*, 2001; Mitinje *et al*., 2007).

Table 8.2 Chi-square test result

N= 376	Does population increase play any role in deforestation in your town?	land cover and family size
Chi-Square(a,b)	364.099	290.031
Df	2	3
Asymp. Sig.	.000	.000

Source: Field survey 2008.

A second Chi-square test was done to test the null hypothesis that farmers do not anticipate any increase in their farm size when their family size increases. The test statistic for this test was 290.031 compared to the critical value of 0.05 (table value of 5.99) the null hypothesis is again rejected at the 5 percent level of significance. Results of these two tests indicate that the hypothesis that population growth is a key underlying driving force of deforestation in the Ho Municipality may be supported. This result contributes to explaining the decrease in forest cover by 6562 hectares from 1975 to 1991 and a further decrease of 2949 hectares from 1975 to 2001. Figure 8.2 is a plot of the mean of the test result.

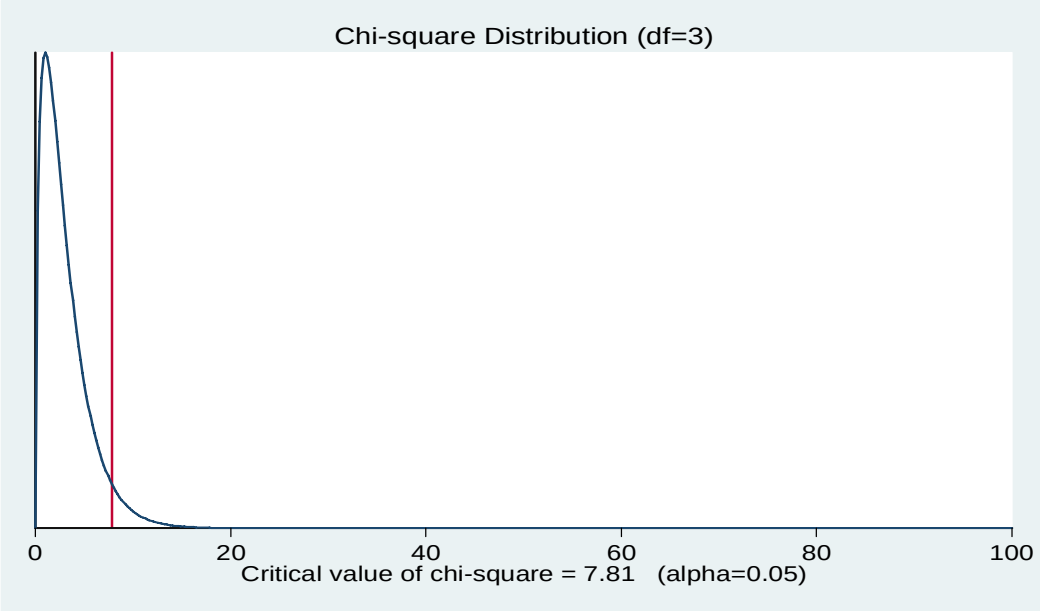
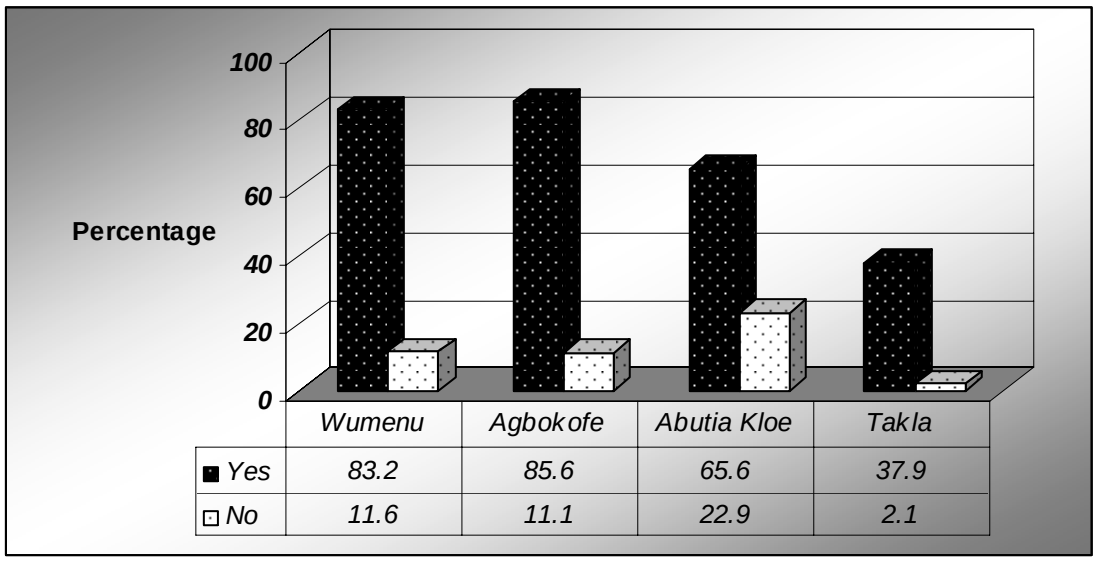


Figure 8.2 Plot of Chi-square test for hypothesis two.

A further explanation to show how population growth contributed to deforestation is illustrated in Figure 8.3, showing the responses to a questionnaire on the perceived role of population in deforestation. The majority of the respondents answered "yes" to the question "is population increase playing a role in deforestation in your town?" The responses were 83.2%, 85.6 %, 65.6% and 37.9%, with the majority obtained in Wumenu, Agbokofe, Abutia Kloe and Takla respectively. Respondents who answered "no" to the question were fewer (11.6%, 11.1%, 22.9% and 2.1% in Wumenu, Agbokofe,

Abutia Kloe and Takla respectively). A total of 95, 90, 96 and 95 respondents in Wumenu, Agbokofe, Abutia Kloe and Takla respectively, responded to the questionnaires administered. The result of this analysis is based on the opinions and views of respondents.



	Wumenu	Agbokofe	Abutia Kloe	Takla
Yes	83.2	85.6	65.6	37.9
No	11.6	11.1	22.9	2.1

Figure 8.3 Perceived role of population increase in local deforestation according to respondents.
Source: Field survey 2008.

Respondents who answered "no" to the question considered other factors besides population such as wildfires and logging to be the causes of deforestation. However, the high percentage of "yes" responses obtained shows that a significant percentage of respondents consider population increase as a major contributing factor to deforestation.

A further question regarding how an increase in family size influences farmers to clear extra land to expand their agricultural production was asked. This shows that 80%, 83%, 71% and 37% of respondents in Wumenu, Agbokofe, Abutia Kloe and Takla need to clear additional land to increase food production as their family sizes increased. Figure 8.4 shows that only 15.8%, 15.6% and 22.9% of respondents in Wumenu, Agbokofe and Abutia Kloe do not consider it necessary to clear extra land for crop cultivation, even in cases where their family sizes increased.

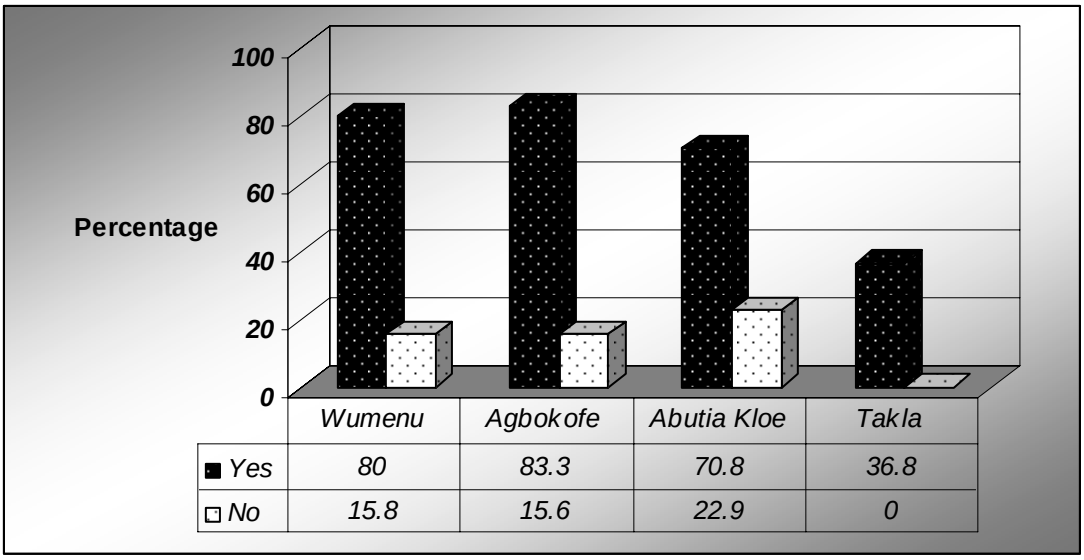


Figure 8.4 Increase in farm size as family size increases according to respondents.
Source: Field survey 2008.

Respondents who indicated that they indeed need to clear extra land as their family size increased noted that the required lands could come from either forest or savannah lands. Approximately 30% of the respondents in Wumenu indicated that they would clear forest areas, while 62% of the respondents said they would clear savannah lands to create additional farm lands when their family sizes increased (Figure 8.5). In fact, Wumenu has almost no forest cover due to farming activities and cutting trees for charcoal and fuelwood production and, as a result only 31% of the respondents indicated that they would clear forest areas when their family sizes increased as compared to 62% of the respondents who said they would have to clear savannah lands. In Agbokofe, 33% of the respondents indicated that they would clear forest lands while 62.1% said they would clear savannah vegetation lands when their family sizes increased. The vegetation cover in Agbokofe is characterized by extensive savannah woodland vegetation; hence, a higher percentage of the respondents claimed they would clear more savannah vegetation than the forest. In Abutia Kloe, the situation was different in the sense that more respondents have the opportunity to clear forest rather than savannah. For example, 59.4% of the respondents indicated they would clear forest areas to create additional farmlands when their family sizes increased. Abutia Kloe is surrounded by mountain forests, part of which belongs to the Kalakpa forest. The extent of the forest surrounding

the town accounts for large amounts of respondents saying that they would clear additional forest areas when their family sizes increased.

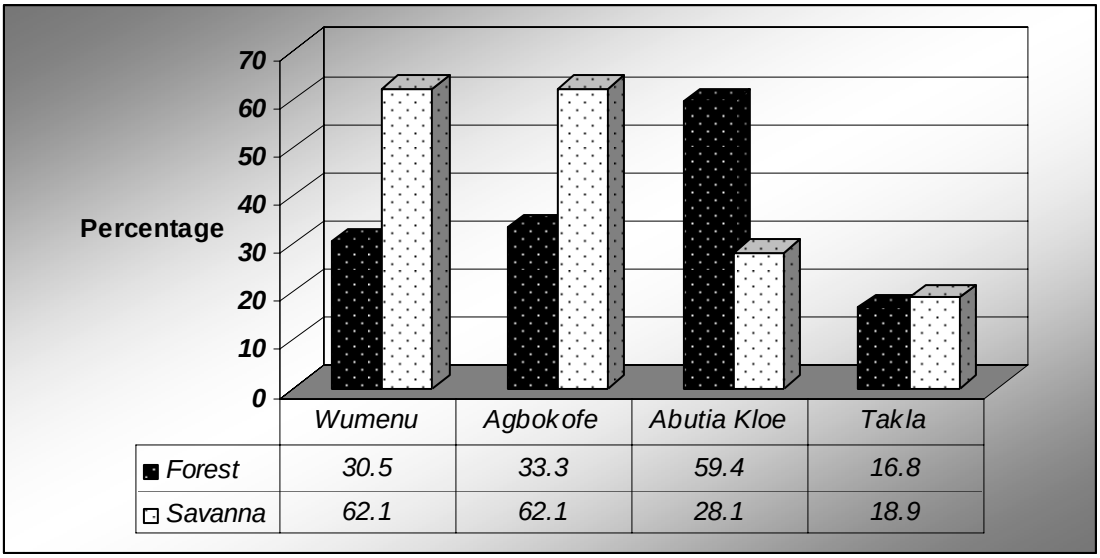


Figure 8.5. Type of land cleared as family size increases according to respondents.
Source: Field survey 2008

Other factors that were shown to contribute to deforestation apart from population pressure and agriculture included wildfire, illegal logging, felling of trees for charcoal and fuelwood production, cattle grazing and poverty, in the view of respondents.

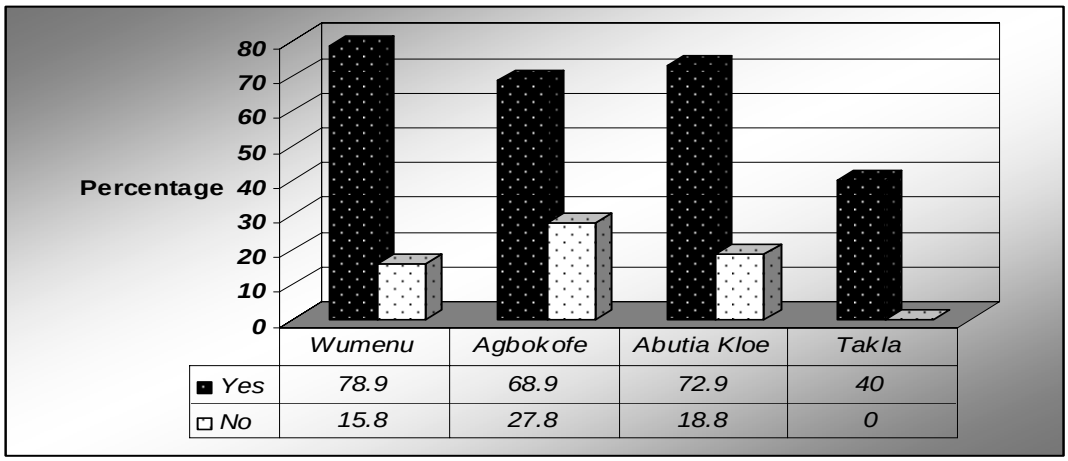
8.3 Indicators of deforestation

A study by Tole (2006) defines indicators of deforestation as widespread decline in forest cover, population growth, growing landlessness, large scale expansion in agriculture, natural resource exploitation and poor agricultural productivity due to decline in soil fertility. The study explored the level of understanding among respondents regarding indicators of deforestation. Respondents were asked to describe what they considered as indicators of deforestation. Answers provided by respondents included the presence of bare lands, absence of forests, loss of hardwood timber species and unreliable rainfall. Such answers portray a clear understanding on the part of respondents regarding

the indicators of deforestation in the municipality. The results also indicate that multiple indicators are responsible for deforestation in the study municipality.

8.4 Poverty and deforestation

Much of the literature on deforestation considers poverty as a major factor of deforestation (Peres and Michalski, 2006), as confirmed in this study. Responses to a question as to whether poverty contributed to deforestation in the study area in 1975 is illustrated in (Figure 8.6). Adults who were over 45 years gave their answers based on personal observations and experiences. Those younger than this age who were not born by 1975 or earlier may have given responses based on 'hearsay'. Hearsay responses have been included in the analysis as they constitute reliable sources of information within the cultural setting in which the study was carried out, as documentation is seldomly done in Ghanaian rural villages. In Wumenu, 78.9% of the respondents consider poverty as the cause of deforestation while 15.8% said that poverty was not the cause of deforestation in 1975. In Agbokofe, 68.9% of the respondents consider poverty as the cause of deforestation and 27.8% did not agree that poverty contributed to deforestation in 1975.



	Wumenu	Agbokofe	Abutia Kloe	Takla
Yes	78.9	68.9	72.9	40
No	15.8	27.8	18.8	0

Figure 8.6 Contribution of poverty to deforestation in 1975 according to respondents.
Source: Field survey 2008

In Abutia Kloe and Takla, 72.9% and 40% of the respective respondents considered poverty as the cause of deforestation, compared to only 18.8% and 0% of respondents who disagreed that poverty played a role in deforestation in 1975.

A question to find out the views of respondents as to whether or not poverty played a role in deforestation in the Ho Municipality from 1991 to 2001 (Table 8.3) produced the following responses. In Wumenu, Agbokofe, Abutia Kloe and Takla, 76.8%, 68.9%, 76% and 40% of the respective towns' sample said that poverty has contributed to deforestation from 1991 to 2000 as against 18.9%, 27.8%, 17.7% and 0% "no" responses obtained. Local respondents are aware that exploitation of the forest cover contributes to deforestation but feel that the consequences of their actions are unavoidable as the people do not have alternative sources of income.

Table 8.3 Poverty as a cause of deforestation from 1991 to 2001

	Wumenu		Agbokofe		Abutia Kloe		Takla	
Responses	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Yes	73	76.8	62	68.9	73	76.0	38	40.0
No	18	18.9	25	27.8	17	17.7	0	0.0
Total	91	95.7	87	96.7	90	93.7	38	40

Source: Field survey 2008

8.5 Bribery and deforestation

Bribery and illegal logging frequently appear as drivers of deforestation in developing countries as agencies and institutions responsible for checking illegal logging implement their mandates imperfectly. Instead, they accept bribes from illegal loggers (Clarkson, 1995). Figure 8.7 presents responses to the question "Do you think corruption such as bribery of forestry officials encouraged illegal logging from 1991 to 2001?'' In Wumenu and Agbokofe, where the forest cover is receding, 54.7% and 33.3% of the people respectively do not believe that bribery influences forestry officials to allow illegal logging. In Abutia Kloe, however, where the forest cover is extensive, the responses are quite different. Here, 50% of the respondents consider bribing forestry

officials as a factor that contributed to deforestation between 1991 and 2001. The study results show that in parts of the municipality where forests abound, bribing forestry officials is a serious issue that has to be addressed when dealing with deforestation problems. The analysis in Figure 8.6 confirms that driving forces such as bribing of forest officials is one of the multiple driving forces of land cover change transition in the Ho Municipality and in the Abutia Kloe area in particular.

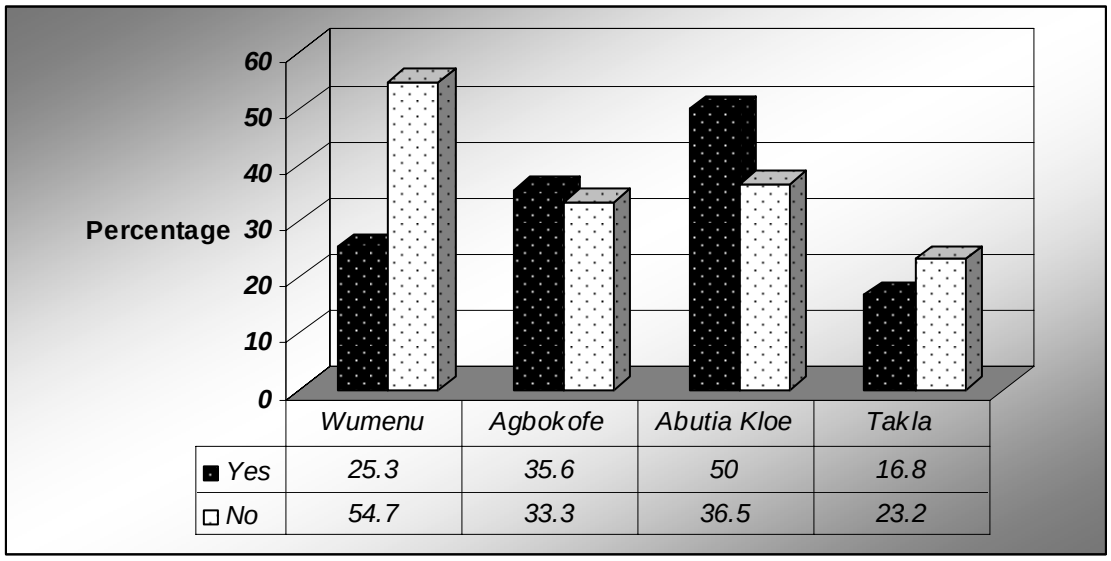


Figure 8.7 Influence of bribery and illegal logging according to respondents.
Source: Field survey 2008.

8.6 Institutional factors (Land tenure)

Gender plays a role in land ownership thus whether an individual is male or female influences the attainment of land tenure title. By tradition, males own land or they are custodians of land hence, and have tenure security during their life time unlike females. People with unsecured land title such as females and settler farmers have, in certain cases been identified as major contributors to reduction of forest cover. Settler farmers are people who move from their district of origin to other districts that have fertile forest lands to engage in farming. In certain cases, such farmers exploit the forest

for immediate financial gains such as cutting trees for wood energy and timber knowing they do not own the land.

Results of responses to categories of people who have land ownership rights show that 60.9% of the respondents indicated that men have the right to own land in their towns while only 1.3% said women have the right to own land (Table 8.4). Approximately 19% of the respondents said that both men and women have the right to own land. Respondents who are of the view that only men have the right to own land indicated that this was the case since inheritance is patrilineal. Besides the issue of patrilineal inheritance, men are the family heads as such they are considered to be in the best position to allocate land. The few women who have land ownership rights buy such land themselves. It is also possible that women who have land ownership rights may have acquired the right from their parents in situations where there are no males in the family, or when women act as family heads while the men are away from home. People who do not have adequate title to land may be interested in immediate gains, and may thus cut trees indiscriminately for woodfuel and agriculture, resulting in deforestation. For example, settler farmers in Abutia Kloe from Ando origin mentioned that 'we have migrated to this place to farm and while here we have agreed with our landlords that every year we will share crop proceeds from our farms. We the farmers take two-thirds while the landlord takes one-third. As the land does not belong to us our ultimate goal is to exploit what we have on the land such as trees to make charcoal in addition to farm products to save money and and return home. We are not interested in nurturing trees on our farmlands as we do not own the trees.'

Table 8.4 Household land ownership rights

Responses	Frequency	Percentage
Men only	229	60.9
Women only	5	1.3
Both	73	19.4
No response	69	18.4
Total	376	100.0

Source: Field survey 2008

The view of respondents to a question regarding whether farmers are free to use their farm lands to grow trees under existing land tenure agreements is shown in Table 8.5. The responses indicate that, 73.7%, 80%, 63.5% and 30.5% of farmers surveyed in Wumenu, Agbokofe, Abutia Kloe and Takla respectively indicated that they are free to use their land for forestry projects. These respondents freely use their farm lands for forestry projects as they own the lands they cultivate. The same situation does not hold for settler farmers, who are normally limited by the titles they hold to their lands that do not allow them to plant trees. When financial and logistical support is provided, as was the case during the Forum project in some towns of the Ho Municipality, gains in forest cover can occur. Respondent opinions on the impact of the Forum project, for example, in the study settlements are represented in Figure 8.8.

Table 8.5 Permission to use available land for forestry projects

	Wumenu		Agbokofe		Abutia Kloe		Takla	
Responses	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Yes	70	73.7	72	80.0	61	63.5	29	30.5
No	22	23.2	15	16.7	25	26	9	9.5
No response	3	3.2	3	3.3	9	9.4	57	60
Total	95	100	90	100	95	100	95	100

Source: Field survey 2008

The views of respondents to a question as to whether they noticed any increase in the forest cover due to the implementation of the Forum project (Figure 8.8) resulted in the following responses. In Wumenu and Takla, respondents were of the opinion that the Forum project did not contribute much to forest increase as reflected in the 44.2% and 27.4% “no” responses. In Agbokofe and Abutia Kloe 28.9% and 68.8% of the respective town respondents interviewed indicated that the Forum project increased their towns’ forest cover. These opinions may be related to the forest reserves in Abutia Kloe other than the off forest reserve areas. The Forum project, which took place in 6 districts of the Volta Region restored a total of 14,212 hectares of degraded forest in 2006 as against 6,400 hectares of forest that existed in 1996 within the forest reserve. There has also been

an increase in woody vegetation cover from 600 hectares in 1993 to 5,817 hectares in 2007 in the six districts (FORUM, 2007).

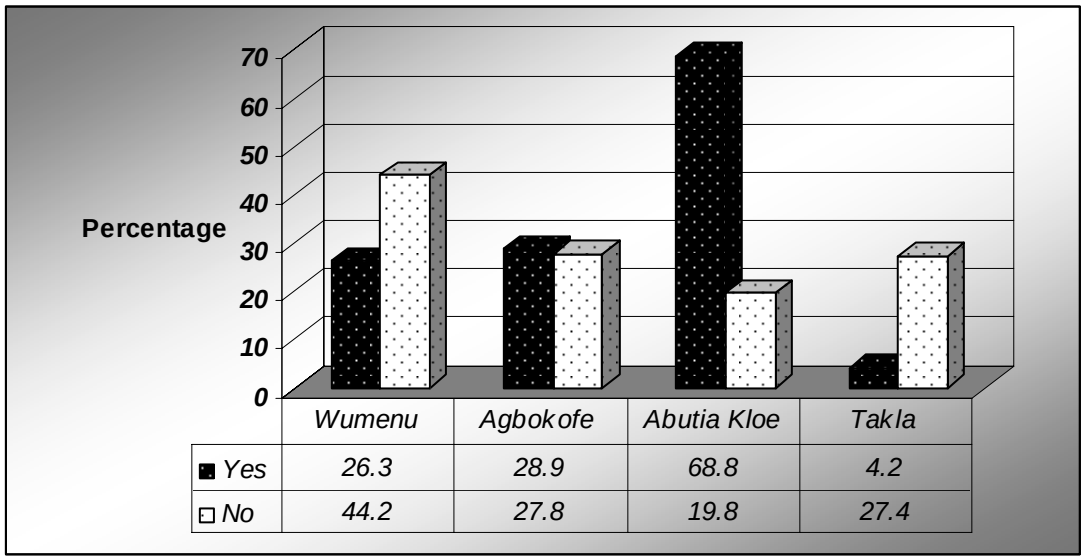


Figure 8.8 Increase in forest cover due to forum project according to respondents.
Source: Field Survey 2008.

In the opinion of the forest guards in Abutia Kloe, the Forum project has contributed greatly to the increase of the forest cover, especially in the forest/wildlife reserve areas. Not only were trees planted; but, further illegal logging has been checked in these areas. The views of the forest guards in Abutia Kloe seem to differ to the opinions of respondents in Abutia Kloe in that illegal logging is a serious issue that needs to be considered when finding solutions to deforestation problems. In Wumenu, Agbokofe and Takla, the vegetation is dominated by woody/savannah vegetation due to emphasis of the Forum project on planting woodlots for fuelwood and charcoal production, and growing teak tree plantations instead of creating forests. Such a difference may contribute to the different responses indicated in Figure 8.8.

8.7 Policies and deforestation

Past national policies such as the structural adjustment policy and economic recovery programme contributed, in part, to deforestation in the study municipality as

noted by respondents. It was also mentioned that economic demand for food crops such as maize, cassava, yam and vegetables contributed to deforestation as forest lands were cleared to grow crops for money (as also discussed previously).

A question posed to respondents to find out whether they attribute deforestation during the 1980s and 1990s to the economic recovery programme and structural adjustment policies has responses as shown in Table 8.6. In response, 62.8% of the 376 total number of respondents are of the opinion that the structural adjustment policies and economic recovery programme of the government during the 1980s contributed significantly to deforestation in the study settlements. The responses show the extent to which government policies contributed to deforestation.

Table 8.6 Effects of economic recovery programme and structural adjustment policies on deforestation

Responses	**Frequency**	**Percentage**
Yes	236	62.8
No	138	36.7
No response	2	0.6
Total	376	100

Source: Field survey 2008

Many of the respondents who were asked whether encroachment on the forest could be attributed to government arbitrary demarcation of forest lands and the forestry commissions' right to trees on individual lands do not agree that these factors were responsible for forest encroachment with the exception of Abutia Kloe, where 50% agreed to the question (Table 8.7). The "no" responses in Wumenu, Agbokofe and Takla are based on the fact that the forest cover had disappeared hence, no forest is available for the government to take over. In Abutia Kloe, the 50% "yes" responses recorded may be directly linked to the manner in which past governments took family lands from the local residents, and declared them as forest reserves without paying compensation to the local people. Discontent among the local people for losing their land may be partly expressed through unlawful entry into the reserves for hunting, as well as setting the forest on fire

during the dry season to hunt animals and to create space for farming, according to some respondents.

Table 8.7 Encroachment on forest reserves due to arbitrary forest demarcations

	Wemenu		Abgokofe		Abutia Kloe		Takla	
Responses	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Yes	16	16.8	15	16.7	48	50	3	3.2
No	48	50.5	39	43.3	32	33.3	26	27.4
No response	31	32.6	36	40	16	16.7	66	69.5
Total	95	100	90	100	96	100	95	100

Source: Field survey 2008

The results in Figure 8.9 represent responses to a question to find out whether crops grown by the people are influenced by government agricultural policy. In the opinion of respondents, the crops they grow are not influenced by central government policy on agriculture. Towns such as Wumenu, Agbokofe, Abutia Kloe and Takla had 82.1%, 92.2%, 79.2% and 36.8% "no" responses in the respective towns to the question posed. The answers given indicate that deforestation in the municipality is driven by factors other than government policy.

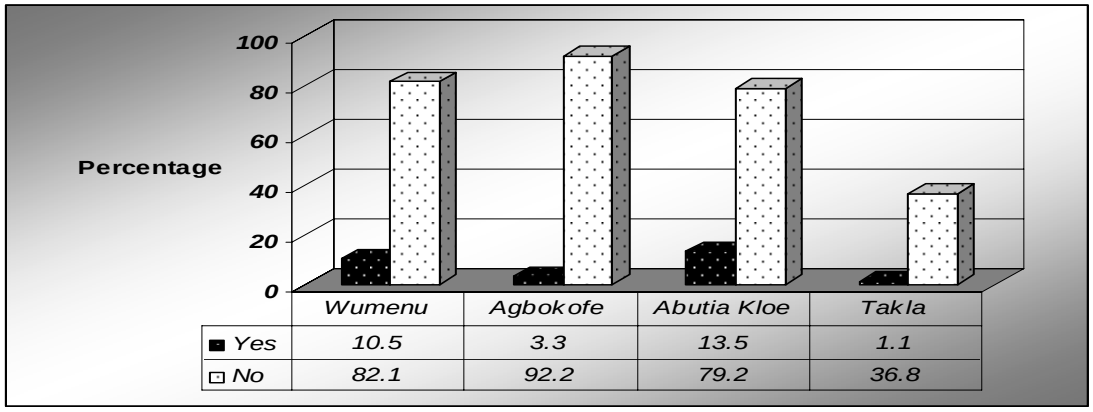


Figure 8.9 Influence of government policy on choice of crops cultivated according to respondents.
Source: Field Survey 2008.

In a related question seeking to find out whether cultivation of crops are based on local economic demands, the responses obtained were predominantly positive. Most of

the respondents share the opinion that the crops they grow are determined by local economic demand thus, buying for domestic consumption and small sacle enterprise uses as reflected in the 67.4%, 70% and 36.8% ‘’yes’’ responses given in Wumenu, Agbokofe, and Takla (Figure 8.10). The implication of the responses are that as economic demand for agriculture crops increases, deforestation accelerates as new fertile farming lands are needed to produce more food. The only exception is Abutia Kloe, where 51% of the respondents do not think local economic demand has any influence on the crops they grow. This indicates that in this area, other factors or reasons are responsible for the type of crops respondents grow such as growing crops for domestic consumption.

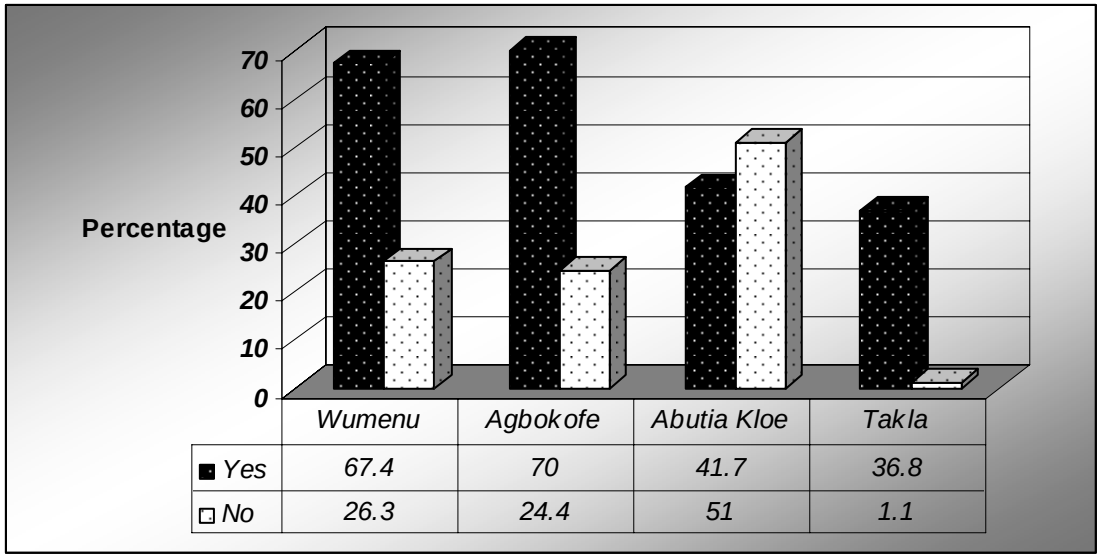


Figure 8.10 Influence of local economic demand on chosen crops according to respondents.
Source: Field survey 2008.

Test of hypothesis three rejected the null hypothesis that land use in the Ho Municipality was not determined by local economic demand instead by central government economic policy (Appendix C). The hypothesis has been rejected based on the test statistics result that χ^2 statistics is 6.204 against the critical value of 0.05 and a table value of 5.99 (Table 8.8). The Chi-square test has been carried out on this question as the question is specific on the needed data to test the hypothesis thus whether municipal economic demand or central government policy drives land use.

Table 8.8 Chi-Square tests for hypothesis 3

	Value	Df	Asymp.sig. (2-sided)
Pearson Chi-square	6.204 (a)	2	0.045
Likelihood Ratio	5.843	2	0.054
Linear-by-Linear Assoc.	3.842	1	0.05
N of valid Cases	296		

Source: Field survey 2008

A plot of the mean of Chi-square test is shown in Figure 8.11

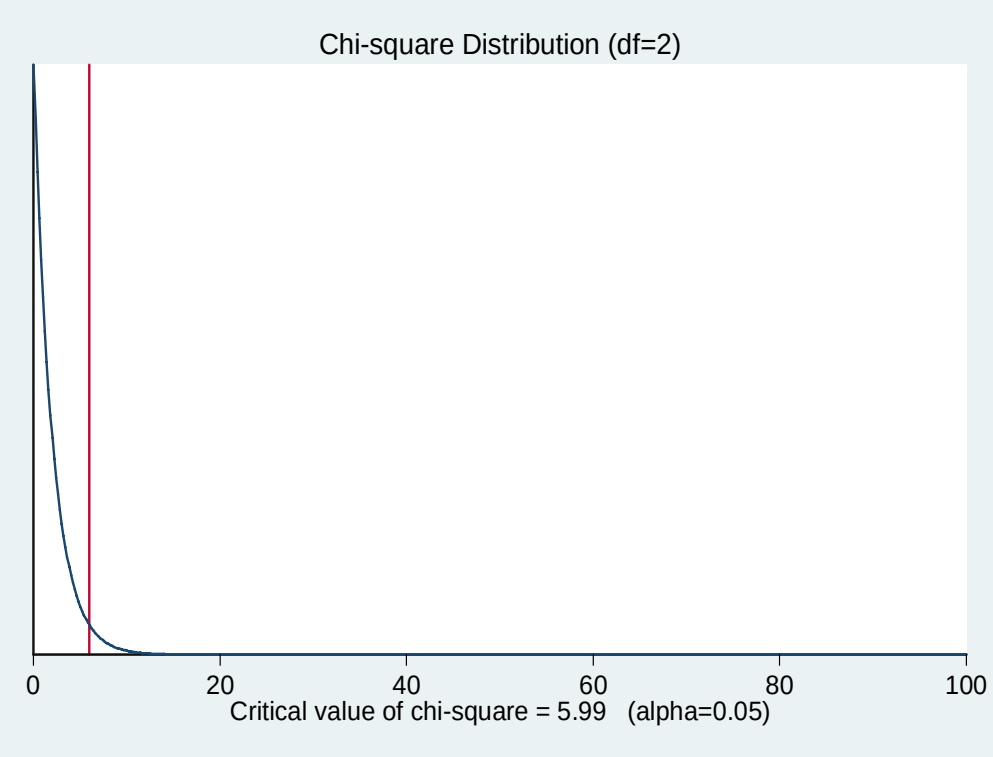


Figure 8.11 Plot of Chi-square test for hypothesis three.

8.8 Technology and land use

The use of technological inputs by farmers are considered as a contributory factor to deforestation, as the weed killers used on farms may destroy plants, thereby preventing the growth of such plants and seedlings from developing into forests. Further, tractor ploughs uproot plants during ploughing, making it difficult for young plants to survive their development into forest. Applications of chemical fertilizers are viewed by respondents as increasing soil acidity; hence, farmers whose farm soils are acidic are compelled to clear forest lands leading to deforestation. Advances in farm technology such as use of high yielding seeds could have helped to reduce the amount of crop land required for farming, yet it has not been seen to help much, as high yielding seeds require the application of fertilizer which subsistence farmers are not able to afford (The Fertilizer Institute, 2007).

The farming technologies used by farmers in all the study towns/villages are displayed in Table 8.9. Farm technologies such as tractors (18.4%) and weed killers (45.7%) are used by farmers and other techniques include the use of high yielding seeds. More farmers prefer weed killers as it is less expensive to apply per acre compared to the amount of money charged per acre for ploughing farmlands. The use of these technologies may prevent the growth of young plants from developing into trees, as mentioned earlier.

Table 8.9 Technology and farming methods

Responses	Frequency	Percentages
Tractor	69	18.4
Weed killers	172	45.7
Other	52	13.8
Total	293	77.9

Source: Field survey 2008

Fertilizer application to crops is a common practice in most of the towns surveyed and details are provided in Table 8.10. The town that applies the most fertilizer is Wumenu, where 50.5% of the respondents said they apply fertilizer to their crops as the soil is poor in plant nutrients. Respondents who could no longer afford the high cost of fertilizers are left with the only option of clearing available fertile forest or woody vegetations, hence, the cycle of deforestation continues. In Agbokofe, Abutia Kloe and Takla, 43.3%, 40.6% and 23.2% of the respondents do not apply chemical fertilizer to their crops.

Table 8.10 Application of chemical fertilizer to crops

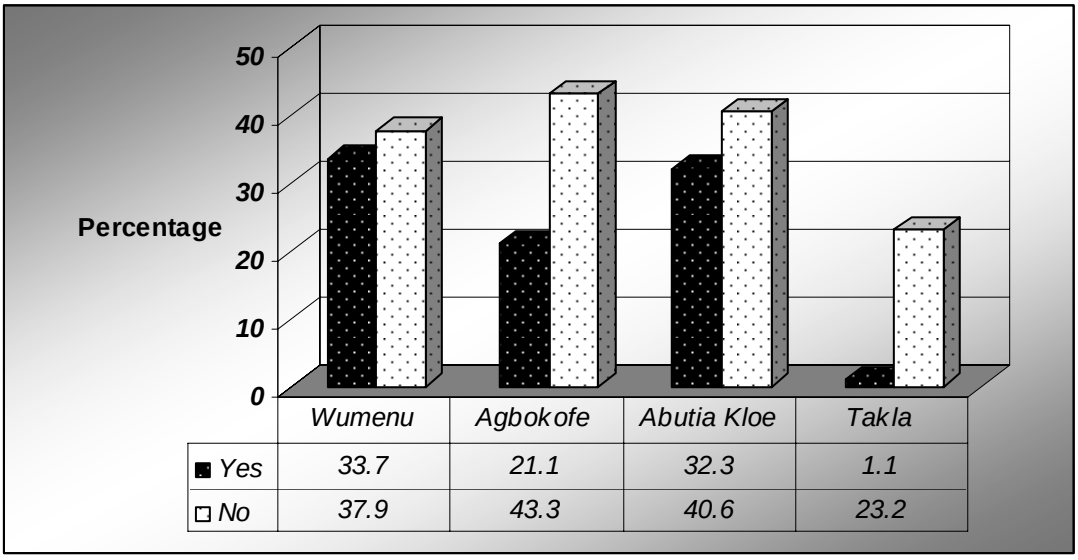
	Wumenu		Agbokofe		Abutia Kloe		Takla	
Responses	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Yes	48	50.5	19	21.1	31	32.2	1	1.1
No	42	44.2	39	43.3	39	40.6	22	23.2
Total	90	94.7	58	64.4	70	72.8	23	24.2

Source: Field survey 2008.

When the respondents were further questioned as to why they do not apply fertilizer, they indicated that they grow mostly cassava (which grows well even in the most infertile soil) hence, they do not need fertilizer.

Mixed responses have been given by respondents regarding the effect of chemical fertilizers on the vegetation and soil (Figure 8.12). Most respondents are of the view that chemical fertilizers do not produce negative effects on the vegetation and soil, given the 37.9%, 43.3%, 40.6% and 23.2% “no” answers given in Wumenu, Agbokofe, Abutia Kloe and Takla, respectively compared to the 33.7%, 21.1%, 32.3% and 1% “yes” responses given by respondents in the respective towns. Those who consider chemical fertilizers to have negative effects on the vegetation and soil mention soil acidity, fast growth of weeds, breeding of pests and diseases as the effects of chemical fertilizer use. Pests, for instance, may attack young tree seedlings and crops and hinder the effective

development of tree seedlings to forests. The acidic nature of the soil may hinder healthy crop growth as farmers working on acidic soils have no option, but to clear fertile forest soils for agriculture leading to deforestation.



	Wumenu	Agbokofe	Abutia Kloe	Takla
Yes	33.7	21.1	32.3	1.1
No	37.9	43.3	40.6	23.2

Figure 8.12 Effects of chemical fertilizer on vegetation and soil according to respondents. Source: Field survey 2008.

8.9 Income and deforestation

Income earned through exploitation of forest lands for agriculture and wood energy may motivate people in the municipality to unwittingly cause deforestation.

Figure 8.13 illustrates how the income farmers earn can serve as motivation for them to clear more forest areas in Wumenu, Agbokofe, Abutia Kloe and Takla. In these towns 56.8%, 36.7%, 50% and 38.9% of the respective town respondents are of the opinion that income earned from forest products and crop cultivation on forest lands encourages deforestation. Those who do not consider income as a motivation for clearing more forest areas are in the minority. Analysis of the results shows that income is a factor that contributes to deforestation. If farmers obtain favorable high market prices for the food crops they produce, they were more likely to clear extra forest areas (Fresco, 2007).

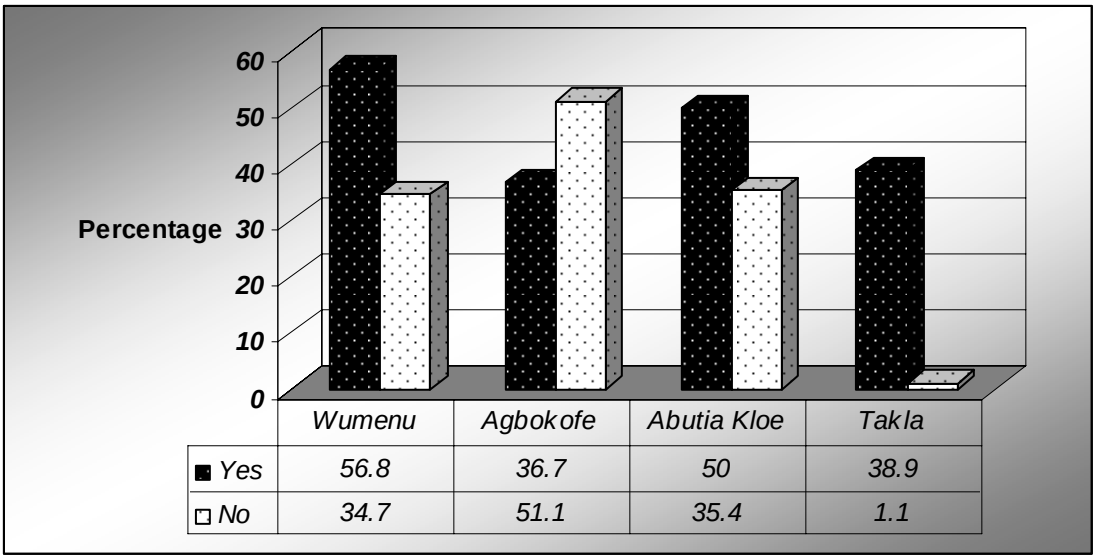


Figure 8.13 Income from farming as motivation for cutting forest trees according to respondents.
Source: Field survey 2008.

The general impression from respondents is that in 1991, the vegetation cover had little forest (Table 8.11). Regarding the appearance of savannah vegetation cover in the study towns, no respondent in Agbokofe, Abutia Kloe and Takla responded to the question, probably because they had no idea regarding the estimation of the savannah vegetation since it is less distinctive next to croplands in 1991.

Table 8.11 Number of people who responded to the question on general appearance of vegetation cover in 1991.

	Wumenu		Abgokofe		Abutiakloe		Takla	
Responses	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Limited forest	53	55.8	52	57.8	79	82.3	34	35.8
Bare area	4	4.2	31	34.4	11	11.5	3	3.2
Savannah	35	36.8	0	0.0	0	0.0	0	0
Total	92	96.8	83	92.2	90	93.8	36	39

Source: Field survey 2008.

8.10 Attitudes

The attitude of setting fire deliberately has contributed to deforestation in the study municipality as discussed in Tables 8.12 and 8.13. Table 8.12 shows that burning of vegetation cover is common in Ho Municipality, as it is in many other parts of Ghana. Fire is one of the multiple factors of deforestation mentioned by respondents in Wumenu (81.1%) and Agbokofe, (82.2%). Other responses include deliberate firesetting in forests to hunt escaping animals for bush meat. There are also instances where palm-wine tappers mistakenly leave fire meant to expel ants from ducts through which palm wine drips unquenched in the bush resulting in accidental fires that may destroy forest.

Table 8.12 Occurrence of annual forest fires

	Wumenu		Abgokofe		Abutia Kloe		Takla	
Responses	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Yes	77	81.1	74	82.2	26	27.1	6	6.3
No	16	16.8	11	12.2	63	65.6	28	29.5
No response	2	2.1	5	5.6	7	7.3	60	63.8
Total	95	100	90	100	96	100	95	100

Source: Field survey 2008.

Further explanations as to the effect of wildfire on the biophysical ecosystem are provided as a cross-tabulation analysis to find out if the vegetation in Wumenu, Agbokofe, Abutia Kloe and Takla gets burnt annually and consequently, to determine the causes of fire (Table 8.13). The responses show that the vegetation is burnt every year as a result of humans setting fire to the bush. Only six respondents said the vegetation does not get burnt annually. In the opinion of these few respondents, fire burns the forest but not necessarily on an annual basis. A cross tabulation to find out the impact of fire on forest and woody vegetation covers is based on a strong view held by the local people that that human induced forest fire is a major cause of forest degradation in the Municipality. The opinion of respondents is supported by the FORUM, (2007) project

report which indicated that from 1994 to 2007, annual bush fires comprise a major challenge to the forest resource implementation project.

Table 8.13 Cross tabulation on annual bush fires and their causes

N = 376		Causes of fire		Total
		Human	Natural	
Burn vegetation every year	Yes	258	5	263
	No	6	0	6
Total		264	5	269

Source: Field survey 2008

8.11 Discussion

Demographic driving forces: The population of the study municipality increased from 1970 to 2000, with associated high densities per square kilometer that could have resulted in loss of forest cover by 6562 hectares from 1970 to 1991 and a loss of 2949 hectares in 2001. Test of the null hypothesis H_o that demographic pressure is not a key underlying driving force of land cover change transition was rejected, allowing for the acceptance of the alternate hypothesis indicating that demographic pressure is a key underlying driving force of deforestation. The Chi-square test result suggests a positive relationship between population pressure and deforestation from 1970 to 2000. Population pressure can result in over utilization of agricultural lands, leading to deforestation and other forms of land degradation (Stringer, 2008). For example, devastating land use activities such as clearing of forest lands for agriculture in the Kenyan highlands due to population pressure caused extensive deforestation in that country (Olsen *et al*, 2008).

Indicators of deforestation: Given that deforestation has been an issue of concern in the municipality, an attempt was made to find out the level of understanding of respondents concerning indicators of deforestation. Answers given include: existence

of bare lands, absence of forest and loss of timber species. These responses show that respondents are knowledgeable of indicators of deforestation, and as such, they are aware of actions that could result in deforestation. Related studies in Jamaica's Cokpit County showed that indicators of deforestation include widespread decline in forest cover, population growth, growing landlessness, large scale expansion in agriculture, natural resource exploitation and poor agricultural productivity due to decline in soil fertility (Tole, 2006). Further, lack of green forest vegetation and clearing of large tracts of forest which creates bare lands are indicators of deforestation (Garica, 2008 and Brazil, 2005).

Poverty and deforestation: Study results show that poverty is a factor of deforestation given the majority of affirmative responses against the "no" responses when respondents were asked to give their opinion on whether poverty was the cause of deforestation from 1975 to 2001. Growing poverty around protected forest areas has made it difficult to prevent encroachment on tropical forests (Adams *et al*, 2004). As a further example, poverty in Rosario la Limeira in Brazil had similarly contributed to deforestation in that country (Achinelli, 2004). Lack of assets and access to capital drives poor people to clear forest lands for income and as the soil losses its nutrients the poor are compelled to move to new forest lands to create farms resulting in deforestation (Pfaff *et a*l., 2008; Zwane, 2002).

Bribery, deforestation and illegal logging: Enforcement of forest laws to check deforestation has been compromised by designated institutions responsible for monitoring the forest. Such was the case in Abutia Kloe, for example, where half of the sampled respondents say bribing of forestry officials in the study community encourages deforestation through illegal logging. Illegal logging was responsible for tropical deforestation with environmental consequences such as biodiversity loss (European Commission, 2008).

Institutional factors: Deforestation may, in certain cases, be associated with people who do not have secured title to land (such as settler farmers and women). Land managers/farmers without secure title may not have any interest in keeping trees on the

land they are given to cultivate once they know they are not beneficiaries of the trees. Respondents with insecure land title are also not allowed to plant trees on the land they use for farming after clearing the initial forest for farming, resulting in deforestation. Though a majority of the respondents said they are free to plant trees, they are not actively involved in tree planting except in Abutia Kloe where the FORUM project was implemented. Inequitable land distribution and colonial land tenure legacies were found to be the root causes of excessive exploitation of the forest with associated environmental problems such as deforestation (Clover and Eriksen, 2009)

Policies and deforestation: Past government policies relating to structural economic reforms and arbitrary demarcation of family lands without any consultation with land owners and non-payment of compensation contributed to deforestation in the municipality, especially in Abutia Kloe, where there is forest. Further, forest lands cleared for agriculture were due to local economic demand for food crops. The Chi-square test of the null hypothesis 3 'that land use in the Ho municipality is not determined by local economic demand was rejected. Acceptance of the alternate hypothesis means that economic demand for local foodstuffs was a driving force of deforestation. Previous studies indicate that land use and cover change that resulted in deforestation in Ghana were national policies, market related variables, structural adjustment policies and macroeconomic changes (Braimoh, 2009). In Nicaragua, as a further example, structural adjustment policies implemented in that country negatively contributed to loss of the country's forest cover, as agricultural frontiers advanced into forest reserves (Glomsrod *et al,* 1999).

Technology and land use: Application of fertilizers over long periods of time has been associated with poor soil fertility by a section of respondents. Due to the poor soil conditions for farming, farmers are compelled to clear fertile forest lands for farming, with consequences for deforestation. Further, the use of various technologies for farming such as weed killers and tractors do not directly cause deforestation, but may prevent and retard the growth of young plants that can develop into forests. Forest lands have come under pressure due to scarcity of fertile agricultural lands. For example, the demand for

fertile agricultural lands resulted in deforestation in South America (Boyd *et al*, 2007). Technological inputs in the form of capital goods such as fertilizer, pesticides and herbicides have contributed to intensive and extensive cultivation, as a result, hectares of tropical forests get lost as in Costa Rica (Angelsen *et al*., 2001)

Income and deforestation: Exploitation of forest lands to earn income due to an expanded market for agricultural products comprises another factor of deforestation, as mentioned by respondents. In India, for example, an increase in the demand for timber coupled with high income earned from timber sales accelerated pressure on the natural forest leading to deforestation (Anonymous, 2007). Economically fragile communities in the Kalimantan Malaysia have deforested 2 million hectares of forest through timber smuggling to earn income given economic hardships faced by people in the area (International Development Assistance, 2011).

Attitudes: Attitudes of respondents such as lighting fires in the forest has seems to have resulted in burning of the forest cover, causing forest degradation and deforestation. In the process of setting fire to clear farmlands for planting, the fire sometimes escapes farm boundaries, resulting in the burning of property, crops and fire sensitive ecosystems, for example (Francis, 2006).

8.12 Conclusion

The statistical analysis of the study has addressed research question two which states: “do population growth and density play any significant role in deforestation’’?. Comparison of population figures from 1970 to 2000 shows that as the population density per square km increased, the forest vegetation cover also decreased by 58.4% from 1975 to 1991. A further decrease of 25.4% forest cover occurred from 1991 – 2001 when the population increased, suggesting that population growth and density contributed to deforestation. Statistical analysis such as the Chi-square test of significance based on the

opinions of respondents produces a significant value of 6.204 which suggests that population growth contributed to deforestation from 1975 to 2001. Other statistical analyses show that as population size increases families clear additional lands and as such deforestation could continue. Direct quote of a respondent in Takla is provided here to support population increase as a driver of deforestation, "Our population has increased and we need extra land to farm as our present land parcels are now too small to contain us. It is for this reason that we clear part of the forest to meet our farming needs" Another quote from a respondent in Abutia Kloe indicates that "Our household size has increased and we need to increase our output, but our farmlands (soil) are impoverished so what do we do? Sould we go hungry when there is fertile forest land available? We have to clear part of it to survive as it is God that has given the forest land to our ancestors and we have now inherited it so we have to use it". This statement again shows that respondents are of the opinion that population increase contributes to deforestation. Other underlying driving forces of deforestation, as discussed in this chapter, include policies, technology, attitudes and income as contributory factors to deforestation.

Chapter Nine

Results: Proximate Driving Forces and Inter-relationships among Driving Forces of Deforestation

9.1 Introduction

This chapter addresses research question two which seeks to determine how other proximate driving forces contribute to deforestation besides population growth and density. The driving forces of deforestation discussed in this chapter are mainly proximate driving forces such as agricultural land use, effects of wood energy production, illegal logging and cattle rearing in the Ho Municipality. Analysis of the proximate driving forces are based on opinions of respondents to a questionnaire.

9.2 Preparation of agricultural lands and deforestation

Clearing of forests for farming contributes to deforestation given the methods used. For example, slash and burn method of clearing farm lands involve clear cutting of forest and woody vegetations which are burnt before cultivating crops (Figure 9.1)

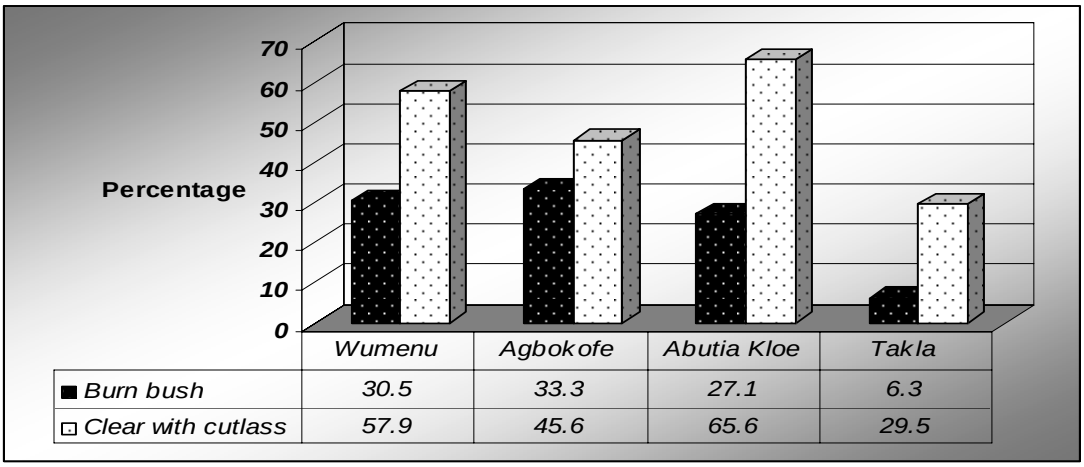


Figure 9.1 Methods for preparing farm lands according to respondents.

Source: Field survey 2008.

Most respondents clear their land with cutlasses. Burning the bush as a means of preparing farm lands appears not to be a popular method given the 30.5%, 33.3%, 27.1% and 6.3% responses obtained in Wumenu, Agbokofe, Abutia Kloe and Takla respectively. Even though most of the respondents said they clear their land with cutlasses, they mostly burn the slashed vegetation before planting their crops (Table 9.1). The use of fire to burn the vegetation in preparing farmlands and the slashing of the vegetation negatively affects forest regeneration as the fire is often left uncontrolled as such the fire spreads beyond farm lands to destroy forest and woodland vegetations close to farms. When respondents were further asked the first time they ever cleared a forest in their life time, they indicated periods between 1948 and 2008 showing that forest clearing had occurred for years.

Respondents were asked whether they practice slash and burn farming or not and it became obvious that slash and burn farming is common among all the towns (Table 9.1). Only 13.7%, 16.7%, 9.4% and 3.2% of the respondents do not practice slash and burn agriculture in Wumenu, Agbokofe, Abutia Kloe and Takla respectively. Slash and burn agriculture is responsible for deforestation as large tracts of forest lands are cleared to grow crops. Burning of the slashed vegetation destroys tree stems that have the potential to coppice.

Table 9.1 Slash and burn farming

	Wumen		Agbokofe		Abutia kloe		Takla	
Responses	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Yes	78	82.1	67	74.4	81	84.4	31	32.6
No	13	13.7	15	16.7	9	9.4	3	3.2
Total	91	95.8	82	91.1	90	93.8	34	35.8

Source: Field survey 2008.



Figure 9.2 An example of slash and burn farming practice in Abutia Kloe.

Source: Adanu 2008

9.3 Illegal logging and deforestation

Illegal logging is defined as the harvest, transportation, sale or purchase of timber in violation of applicable national laws (European Commission, 2008). Illegal logging is a driving force of deforestation in the Ho Municipality as study results reveal. People who engage in illegal logging fail to obtain permits as they want to avoid paying permit

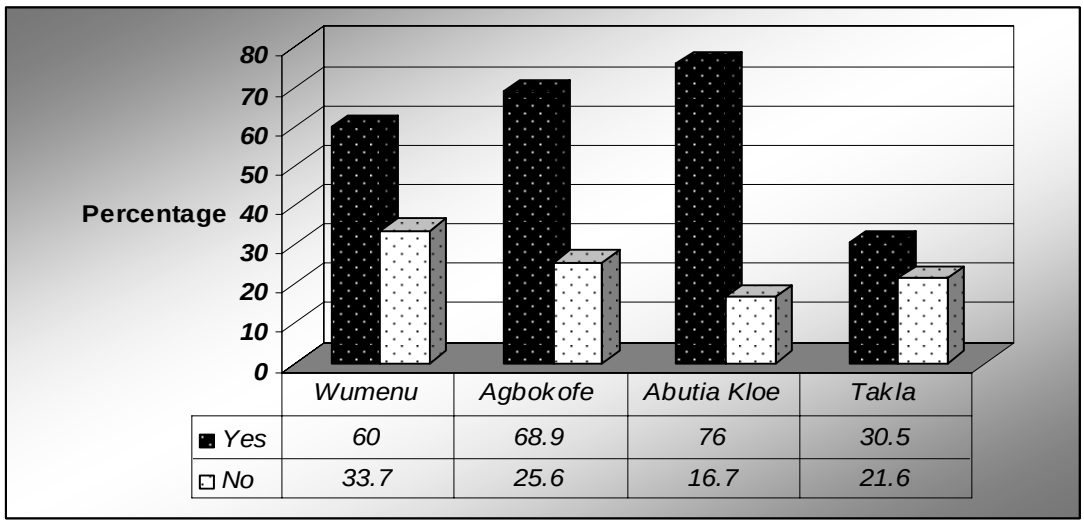


Figure 9.3 Illegal logging and deforestation

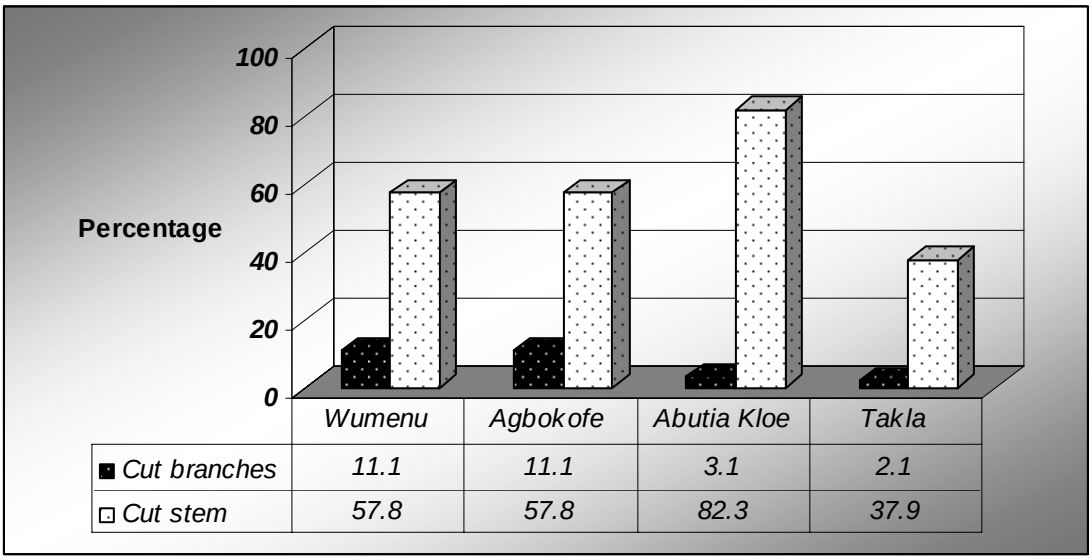
Source: Field survey 2008.

fees as they feel they own the trees; hence, do not need any institutional permit. The views of respondents on how illegal logging has contributed to deforestation from 1975 – 2001 show that indeed, illegal logging is a cause of land cover change transition in the study municipality (Figure 9.3).

9.4 Wood energy production and deforestation

Extraction of wood from forests and woodlands in the municipality contributes to deforestation since wood based energy, such as charcoal and firewood, are basic energy sources for the majority of households.

A wood harvesting method for charcoal and firewood production by respondents is to cut the stem of trees in Wumenu, Agbokofe, Abutia Kloe and Takla (Figure 9.4). Preferred tree species for charcoal production in the settlements include Hehe (*Anogeissus leiocarpus*), Eyorkuti (*Vitellaria paradixa*) and Etoti (*Afzelia africana*). These tree species produce quality charcoal for sale.



	Wumenu	Agbokofe	Abutia Kloe	Takla
Cut branches	11.1	11.1	3.1	2.1
Cut stem	57.8	57.8	82.3	37.9

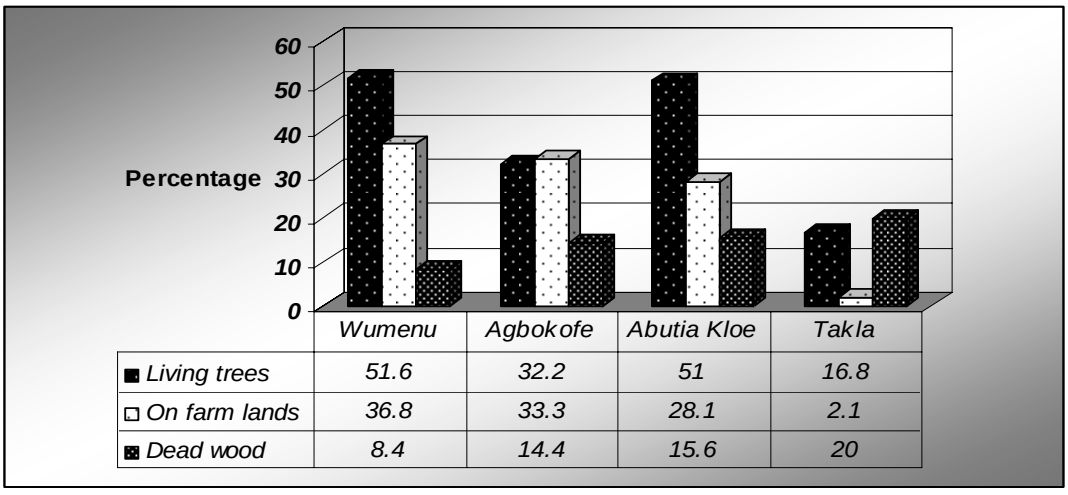
Figure 9.4 Method for cutting trees.
Source: Field survey 2008.

Cutting the stems of trees causes deforestation, and secondly, prevents trees from coppicing especially when the stem is cut very low. If the majority of the respondents had cut branches of trees instead of the stems, the trees could have coppiced to produce wood for sustainable charcoal production in the study Municipality.



Figure 9.5 Bundles of firewood in Agbokofe
Source: Adanu 2008.

Bundles of fuelwood extracted from the natural forest and woodland areas are not dead trees, but trees that are cut green and allowed to dry before offered for sale.



	Wumenu	Agbokofe	Abutia Kloe	Takla
Living trees	51.6	32.2	51	16.8
On farm lands	36.8	33.3	28.1	2.1
Dead wood	8.4	14.4	15.6	20

Figure 9.6 Sources of fuelwood.

Source: Adanu 2008.

The majority of the respondents cut living trees which they dried and used in homes or sold. The act of cutting living trees for energy results in deforestation (Figure 9.6). Those who obtain their energy from farm lands equally contribute to deforestation as trees on farmlands were felled while clearing the land for farming. Most people in the study communities depend on wood energy as there are no cheaper alternative energy sources to turn to and this suggests that wood energy is a key driver of deforestation.

The average number of trees cut by respondents in a month to produce charcoal show that 64.2%, 38.9%, 49% and 15.8% of the respondents in Wumenu, Agbokofe, Abutia Kloe and Takla cut over 10 trees in a month (Table 9.2), (with diameters ranging from 5m to 30m).

Table 9.2 Average number of trees cut per month for charcoal and firewood

	Wumenu		Agbokofe		Abutia Kloe		Takla	
Number of trees cut	Frequency	%	Frequency	%	Frequency	%	Frequency	%
1 - 5	6	6.3	15	16.7	19	19.8	12	12.6
6 – 10	18	18.9	16	17.8	9	9.4	5	5.3
Over 10	61	64.2	35	38.9	47	49	15	15.8
Total	85	89.4	66	73.4	75	78.2	32	33.7

Source: Field survey 2008.

Cutting over 10 trees in a month means a heavy toll on the environment in terms of deforestation as noted in the satellite image analysis results. Not only are trees lost but also the soil fertility decreases when the fertile top soil is used to cover piles of wood that are burnt to charcoal (Figure 9.7).



Figure 9.7 Charcoal mound in Abutia Kloe

Source: Adanu 2008



Figure 9.8 Bags of charcoal in Agbokofe

Source: Adanu 2008.

Figure 9.9 confirms the importance of wood energy as a basic energy source for the people given that 64.2%, 77.8%, 75% and 33.7% of respondents in Wumenu, Agbokofe, Abutia Kloe, and Takla respectively depend on firewood as their main source of domestic energy. Charcoal is the second most used energy source after firewood, while

Agbokofe, Abutia Kloe, and Takla respectively depend on firewood as their main source of domestic energy. Charcoal is the next most used energy source after firewood, while

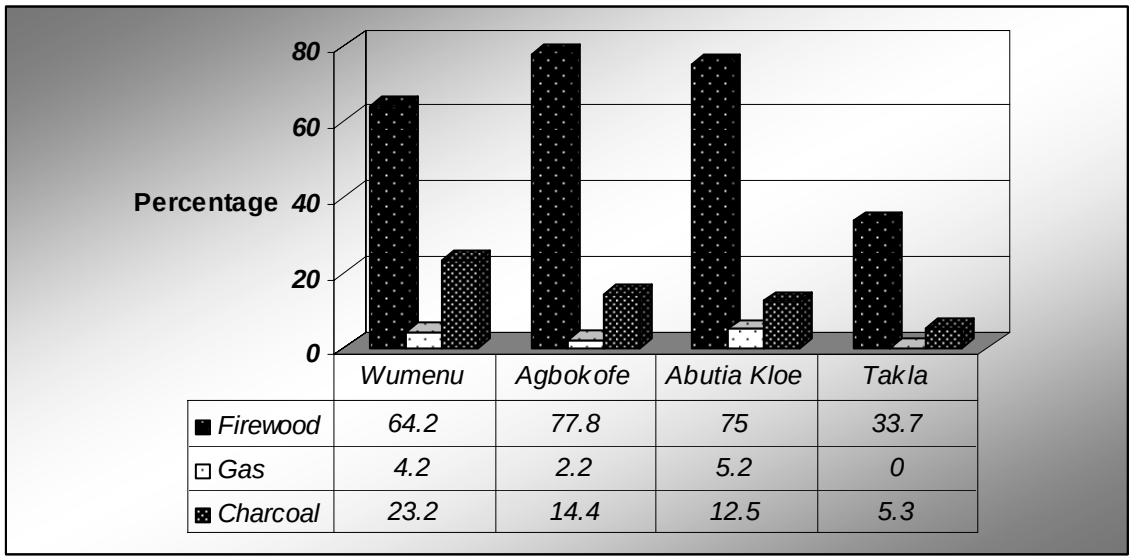


Figure 9.9 Main sources of domestic energy.
Source: Field survey 2008.

gas is the least used as gas is paid for while firewood and charcoal are obtained for free in most cases. As wood is the primary energy source for the people of this municipality and no alternatives are available deforestation will continue.

Table 9.3 Types of stoves used in study settlements.

	Wumenu		Agbokofe		Abutia Kloe		Takla	
Type of stove	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Clay fan	50	52.6	69	76.7	76	97.2	34	35.8
Stone	20	21.1	6	6.7	0	0	2	2.1
Coal port	22	23.2	10	11.1	13	13.5	2	2.1
No response	3	3.2	5	5.6	7	7.3	57	60
Total	95	100	90	100	96	100	95	100

Source: Field survey 2008.

The type of stoves used in cooking determines the thermodynamic efficiency factor of heat transfer from the stove to the cooking pot hence an influence on how

frequent trees are cut for wood energy when the energy gets wasted. The use of clay stoves by most respondents accounts for the large number of trees used for energy as clay stoves are inefficient; much heat is lost through the open design. The loss of energy is even greater from a stone fire since the cooking pot hangs above the fire with no direct contact with the heat source.

9.5 Cattle grazing and deforestation

The survey carried out on cattle grazing and deforestation shows that cattle grazing is not a major driver of deforestation in the study municipality. A total of 10 cattle owners were interviewed in Kpeleho and 8 of those cattle owners fed their cattle on a free range basis while 2 claim they fed their cattle in ranches. The size of free range grazing fields utilized by the cattle is between 2 hectares and 12 hectares. The total number of cattle owned per respondent was between 30 and 200 cattle but few people in the study area reared cattle, as such cattle grazing was not found to be a key driving force of deforestation in this study. However, challenges posed by cattle rearing on the vegetation include extensive fire damage to the forest when cattle owners light fires to enhance the growth of fresh grass for their cattle. Grassland fires often spread to woody and forest vegetations leading to forest cover loss.

9.6 Contributions of multiple driving forces to deforestation

Analysis of the driving forces of deforestation involves simple descriptive statistics and more advanced statistical analysis such as factor analysis to determine the key factors among the multiple factors of deforestation in the Ho Municipality. The factor analysis in part provide data to explain hypothesis two which states: the existing forest cover will decrease by half of its existing size in the next 25 years due to underlying and proximate driving forces of deforestation.

Factor analysis is a procedure used for data reduction whereby a large number of variables (many of which are correlated) can be reduced to manageable levels for further analysis (Joseph and Robert, 2003; Joseph, 2008). The algebraic expression for the factor analysis model is as follows: The variables for the analysis p are represented by $X_1, X_2, \cdots X_p$ measured on a sample of n subjects. Variable i is written as a linear combination of m factors stated as $F_1, F_2 \cdots F_m$ where $m < p$. Thus,

$$Xi = aiF_1 + ai_2F_2 + \cdots + ai_mF_m + e_i$$

Where the a_is are the factor loadings or scores for variable i and e_i that are part of variable X_i that cannot be explained by the factors. With this equation, the initial factors were loaded using the principal component method followed by Varimax factor rotation in SPSS 12.0. Eigenvalues were chosen after which the factor scores were calculated using a regression method leading to the display of final factor scores (Manly, 2005). To examine whether factor analysis is appropriate for the study, the Kaiser- Mayer Olkin (KMO) method has been applied to establish thresholds of between 0.5 and 1 as the significant values for the factor analysis (Alistair *et al*, 2003). Values less than the threshold are not considered as significant for the analysis.

For this study, seven variables have been considered as the key underlying factors for the analysis (F1 to F7). These seven factors were questions posed to the respondents in the field and the responses they gave provide basis for the analysis. The question numbers are represented by Q3, Q34, Q71, Q51, Q35, Q43 and Q54 (Appendix C). Most of the factors chosen for this analysis are linked to agriculture, a major land use activity in the Municipality as 67 % of the people are employed in farming activities (Ghana Statistical Service, 2000).

1. F1 = Q3. Is population increase playing a role in deforestation in your town?
2. F2 = Q34. Do chemical fertilizers have any negative effect on the vegetation and soil?
3. F3 = Q 71. How do you obtain firewood?

4. F4 = Q51 Is income from farming a motivation for cutting more forest trees for crop cultivation?
5. F5 = Q 35 Is the vegetation in your town burnt every year?
6. F6 = Q 43 Do you practice slash and burn farming?
7. F7 = Q 54 Are agricultural products being produced because government policy favors their production?

In Table 9.4 the initial values are constant at 1.000 and the extraction column values show the association that exists among the various factors. The decision rule is that when the extracted values are less than 0.5 then there is no communality among the variables being considered. Communalities show the level of variance a variable has in relation to all other variables that are being considered and determine intercorrelations or which variables share common relationships. The higher the communality value the better the association with other variables. Based on the cut-off point (established at 0.5) it can be observed that there is a strong communality among four out of the seven variables examined: how firewood is obtained, use of chemical fertilizers, slash and burn

Table 9.4 Factor analysis showing communalities

	Initial	Extraction
Population increase and deforestation.	1.000	.551
Chemical fertilizer use on crops.	1.000	.725
How firewood is obtained	1.000	.879
Income as motivation for cutting trees for crop cultivation.	1.000	.574
Burn vegetation every year	1.000	.541
Practice slash and burn farming	1.000	.704
Government policy and high demand for agric products.	1.000	.694

Source: Field survey 2008.

agriculture, and agriculture products in high demand due to favorable government policy. The communality values are explained more clearly using the Eigenvalues. Eigenvalues

help to determine factors to extract to explain the total variance of each of the factors. The decision rule is that Eigenvalues must be greater than 1 to qualify for extraction. Those that fall below 1 do not qualify to be extracted for the analysis. Table 9.5 shows the eigenvalues for this analysis. The eigenvalues represent variance in the data that is accounted for by each factor. Since all variables are standardized in the factor analysis, each variable contribute a variance of 1 to the factor extraction and the sum of eigenvalues equals the number of variables in the analysis.

Table 9.5 Overall Eigenvalues

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	1.278	18.264	18.264
2	1.207	17.241	35.505
3	1.152	16.458	51.962
4	1.031	14.722	66.685
5	.877	12.526	79.210
6	.783	11.189	90.399
7	.672	9.601	100.000

Source: Field survey 2008.

Eigenvalues that are more than 1 (Table 9.5) are factors F1 (1.278), F2 (1.207), F3 (1.152) and F4 (1.031). Thus, population increase, use of chemical fertilizers, exploitation of fuelwood and income from farming are key factors that contribute to deforestation in the Ho Municipality. These factors are important in this analysis as they constitute the key driving forces of deforestation in the Municipality. These factors should be considered top priority should any effort be made to deal with deforestation problems in the area. These four factors explain the total of 67% of the variance in the data and this is adequate for obtaining reliable results. With this factor analysis result, it can be explained that though there are multiple drivers of deforestation, four of these driving forces could be responsible for the decrease of the forest cover by half in the next 25 years. Further explanations to hypothesis two is provided in chapter 10.

Four out of seven driving forces are the most salient drivers of deforestation in the municipality notably population increase, use of chemical fertilizers, exploitation of fuelwood and income from farming (Figure 9.10). The scree plot has its high values

between 1 and 4 and begins to slope downwards from 5 indicating the importance of the four factors mentioned earlier as key drivers of deforestation and the lesser drivers falling from point 5.

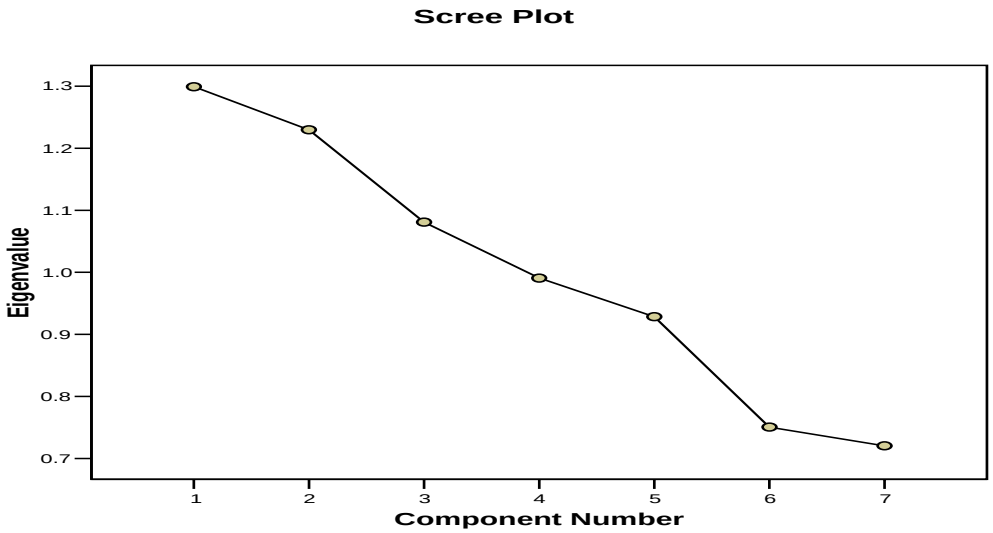


Figure 9.10 Scree plot for factor analysis test.

Source: Field survey 2008.

9.7 Discussion

Agriculture and Deforestation: Deforestation takes place when forest lands are slashed and burnt for crop cultivation. The burning of vegetation often results in destroying plants thereby making it difficult for any future regeneration. Intensive cultivation of crops accounts for deforestation and loss of ecosystem resources (Grau *et al*, 2008). Clearing of forest for agriculture is not only a developing country problem, but also a developed country problem. For example, in Queensland, Australia, approximately 40% of the natural forest and 50% of the woody vegetation was converted to agriculture (QDMRW, 2007). It is globally estimated that 735 million people clear forests to grow crops as agricultural lands are becoming scarce (Chomitz and Buys, 2007). Nicaragua in Central America has been losing its forest cover since 1950 due to agricultural expansion

as shown by analysis of Landsat imagery for the period 1978, 1987 and 1999 (Zeledon and Kelly, 2008).

Illegal logging: Illegal cutting of trees in the forest for timber and other commercial purposes has contributed to deforestation given responses obtained in Wumenu, Agbokofe, Abutia Kloe and Takla where 60%, 68.9%, 76% and 30.5% "yes" responses were obtained to confirm that illegal logging contributes to deforestation. Earlier responses in this chapter indicates an interplay of various factors of deforestation of which illegal logging is just one of the contributing factors to deforestation as such there is no single important cause of land cover transition in the municipality. In Indonesia illegal logging has resulted in vast deforestation at a rate that is comparable to two football fields of forest lost in a minute (Schmidt, 2010).

Wood energy extraction: extraction of wood energy for domestic use and for commercial purposes drives deforestation in the study municipality. Apart from causing deforestation through cutting tree stems, which does not enhance coppicing for forest recovery, average trees cut in a month are high due to high dependency on wood energy making deforestation an issue of concern. Cutting of young trees for purposes of fuelwood to cure tobacco and tea in Malawi constitute 21% of national fuelwood consumption (Moyo *et al*., 1993). The use of fuelwood to process raw materials has increased demand for fuelwood as the local industrial capacity has increased in the study Municipality. The use of inefficient stoves also contributes to wastage of firewood; hence, more trees were cut to meet increasing wood energy demands. Cutting trees for charcoal and firewood increased dramatically in Tanzania with consequences of deforestation in the Katavi National Park (Schffner, 2010).

Cattle grazing: Study results show that cattle grazing activities are not the major causes of deforestation in view of the fact that cattle population is low. However, the act of burning grass by cattle owners to provide fresh grass for cattle contributes to fire straying to burn forest lands. Browsing of the Aspen vegetation by cattle and use of fire to enhance growth of fresh vegetation for cattle has suppressed tree growth, tree density

and regeneration as cattle browse the trees and fire destroys plants on the field (Durhan and Marlow, 2010)

.

Contribution of multiple driving forces: Factor analysis results provide some information to explain the hypothesis that the existing forest cover may decrease by half of its existing size in 25 years due to underlying and proximate driving forces of deforestation. Determination of four key driving forces of deforestation such as firewood collection, chemical fertilizer use, slash and burn agriculture, and clearing of forests to grow crops due to high demand for the crops may continue to drive deforestation in the future. The factor analysis result supports evidence of deforestation as suggested by results of satellite data analysis in the Ho Municipality as reflected in 65629 hectares of negative change in the forest cover from 1975 to 1991 and 29491 hectares negative change from 1975 – 2001. Economic, political and social driving forces of deforestation contribute to deforestation and habitat alterations. (Wood *et al*, 2000). The European Commission has categorized multiple drivers of deforestation in Sub-Saharan Africa into direct and indirect causes. Direct causes noted are infrastructure development, woodfuel extraction and agriculture expansion. Indirect causes include population growth, governance and policy issues and economic factors (European Commission, 2010).

9.8 Conclusion

The analysis in this chapter addressed the proximate driving forces of deforestation aside from population growth and density (addressed in chapter 8). Analysis of the proximate driving forces of deforestation addresses the second part of research question two; thus, the other driving forces of deforestation. Results of the analyses show that four driving forces are the key causes of deforestation. Cattle grazing is not a key driving force of deforestation considering the fact that not many cattle exist in the study area.

Chapter Ten

Results: Assessing the Potential Utility of the Markov Model to predict Land Cover Change and the Implication for Future Forest Areas

10.1 Introduction.

This chapter addresses research question three which seeks to determine the potential utility of "land cover change transition" modeling for predicting the future state of forests in the Ho Municipality. Transition probabilities are used extensively for modeling and analysis of land use and cover change (Muller and Middleton, 1994).

"Land cover change transition" in the study Municipality involves a transition from forest to woodland vegetation /grassland vegetation characterized by isolated trees and in some instances bare areas in the off reserve areas. This kind of transition depicts a negative change in the sense that losses rather than gains in the forest vegetation cover has occurred (as shown by satellite image analysis in chapter seven).

Models of land use and cover change are powerful tools that have been used to understand and analyze the linkages between socio-economic processes, agricultural activities and natural resource management (Turner and Meyer, 1991). Modeling of land cover change using satellite image data forms part of the statistical process of predicting change given the present state of the forest. These modeling capabilities would therefore require the use of appropriate models such as Markov models. The Markov transition probability model has been previously used for simulating land cover change from observed variables such as those derived from remote sensing image analysis (Hobbs, 1998). Other applications of the Markov model include studies such as land use and cover modeling (Houet and Hubert- Moy, 2006). Application of the Markov chain model to predict land cover change in this study is appropriate for consideration, as the Markov

model of change prediction is mathematically compact and developed from observed data that is capable of making predictive simulations.

A first order Markov model makes the assumption that a system would be in a given state (land cover class) in a future time (t_2) based upon knowledge of the state of the system at the present time (t_1) (Scania, 1994; Biondini and Kandus, 2006). In effect, transition of a system or land cover from one state to the next depends on the present state of the system and the processes involved in the transition to the next state. The Markov conditional probability function is represented by $P(tx, t_0)$ (Entwisle *et al*, 2006). Land cover change prediction is calculated using matrices of transition probabilities (transition matrix, P), with elements, p_{ij}, that summarize the proportion of cells of land cover types that change to other land cover types over given time intervals. The diagonal of the matrix, p_{ij}, are the proportion of cells that do not change. Results of the modeling can help in selecting measures that need to be put in place to contain the predicted changes.

10.2 Application of the Markov Model to predict future forest changes

To project change in the land cover from time t to t_{+1}, the equation $x(t_{+1})= Px(t)$ was used. When the state of a system (land cover class) denoted by the vector x is known, the future state of the system (land cover change) can be projected as: $x_{t+1} = x_{tP}$ that is, the state vector x multiplied by the transition matrix. The projection for time t_{+2} can be stated as $x_{t+2} = x_{t+1}P = x_{tP,}$ $P = x_{tP2}$. Details of the Markov transition matrix model projection are as follows:

$$P = \begin{array}{c} \\ \text{From } S_1 \\ S_2 \\ S_3 \end{array} \begin{array}{c} \begin{array}{ccc} \text{To} & & \\ S_1 & S_2 & S_3 \end{array} \\ \begin{bmatrix} p_{11} & p_{12} & p_{13} \\ p_{21} & p_{22} & p_{23} \\ p_{31} & p_{32} & p_{33} \end{bmatrix} \end{array}$$

subject to:

$$\sum_{j=1}^{n} p_{ij} = 1 \qquad i = 1, 2, \ldots m$$

Transition probability (p_{ij}) shows the probability that class *x* would be in state *j* at time *t+1* given that class *x* was in state *i* at time *t*.

$P_{ij}^{t+1} = \Pr [x_{t+1} = j \mid x_t = i]$

In this study, four discrete states of land cover class transitions have been used i.e. riparian forest, woody land/grassland vegetation, settlements and bare areas. The transition period considered for the study is from 1975 to 1991 and 1975 to 2001.

10. 2.1 Assumptions and limitations of the Markov model

A number of assumptions are associated with the application of the Markov model. For this study the following assumptions have been made:

1. Spatial independence: Transition probabilities are assumed to be the same at all locations, but this assumption may be violated due to spatial covariates and neighborhood effects. This assumption is still useful despite the possibility of it being violated as it helps specify and prioritize data needed to implement and parameterize the model (Usher, 1992).

2. Temporal independence: Inherent in the Markov model is the assumption that to predict the future state of a system there is the need to know the current state of the system that is, the state of the system at time *t* is contingent upon the state at time t-1 and not on any previous state. This short-term, linear "memory" explains why Markov

models are sometimes called first order Markov chains. In reality, there are situations whereby information about prior states is needed such as the historical information on land use. For example, if the previous land use has had residual effects on future succession dynamics, then the system retains a "memory" of antecedent conditions. Hence, the dynamics are not first-order models, as such higher-order Markov models are needed to solve the problem. This means that, it would be necessary to know the state of the system at time t-1 and t-2 to predict the systems future state.

3. Stationarity: The stationarity assumption states that transition probabilities are assumed to be constant as such to predict the state of a system at time t+1, information on the state of the system at time t is required. This assumption is, however, rearly valid for real landscapes as land values or land use activities fluctuate. For landscapes that have maintained relative uniform use for long periods of time, such as subsistence agriculture and wood energy exploitation, fair predictions can be made.

10.2.2 Weakness of the Markov model and other models

The Markov model is capable of making transition probability predictions in diverse disciplines such as Physics, Chemistry and Economics and applicable to land cover change prediction with accuracy (Howard, 1971). Also, there are different types of statistical models that are used to make predictions such as the multiple regression model and neural networks (Guisan and Zimmernann, 2000). These models are not perfect in their predictions due to the central mechanism of the models being based on probability which results in uncertainties of simulating land cover change in complex human environment systems (Lambin, 2010). Uncertainties occur as it is not easy to control the driving forces of land use and cover change assumed as basis for the predictions as the behavior of individuals and society cannot be predicted.

However, weaknesses of such models can be based on the indices of performance of the models as the indices address the level of confidence one can have in the prediction. Despite the usefulness of indices they may fail to reveal some forms of

systematic deviations between observed and predicted behavior. These limitations not-withstanding, model indices provide objective and readily interpreted summary of the performance of models hence the usefulness of predictive models as guides to determine trends of events if not accurate results (Ross, 1996).

10. 2. 3 Calculation of transition probability matrices

The transition probability matrix calculation in this section addresses research question three. Calculation of the transition probability matrix in Table 10.2 has been computed using values in Table 10.1 which has been generated through change detection statistical calculation as in (section 7.6). Table 10.1 shows the change detection statistical report for the 1991 – 2001 data. The procedure involved dividing the row class values of each land cover class by the row totals in each of the rows in Table 10.1 to arrive at the Kappa index transition probability for the period 1991 to 2001 as in Table 10.2. For example, riparian forest row class value of (2779ha) was divided by riparian row total value of 14267 to arrive at a Kappa transition index of 0.19 in Table 10.2. Calculation of probability of change in hectares has been computed by multiplying the row class values of each land cover class by the row total and then divided the results of the multiplication

Table 10.1 Change detection statistics report in hectares 1991 – 2001

Classes	Riparian forest	Woody/grass vegetation	Settlement	Bare area	Row Total
Riparian forest	**2779**	8109	329	3050	14267
Woody/ grass vegetation	2073	**12068**	420	2207	16768
Settlements	115	1109	**735**	56	2015
Bare area	258	2369	427	**169**	3223
Grand Total					**36273**

Source: Adanu 2008

by the grand total of the row total values (36273). For example, in Table 10.1, (row class value) 8109 × (row total) 14267 = 115691103 ÷ (total) 36273 = 3189ha in Table 10.2 under woody/grass vegetation).

As a basic rule for the calculation of the Kappa index, each of the values in the row of the probability matrix has to be ≤ 1.0 (Landis and Koch, 1997). The diagonals of the probability matrix table show pixels or areas that have not changed while the off diagonal figures indicate the probability of change from one class to the other.

The transitional probability values in Table 10.2 show conditional Kappa index values that indicate the degree to which a particular land cover class at present will change at a later date (Fung and Le Derew, 1988; Lopez *et al.*, 2001). For a better understanding of the results in Tables 10.2, and 10.4 the results have been classified into ranges of Kappa index groups of reliability of predictions. Values between 0.81 – 1 represent almost perfect reliability and 0.61 – 0.80 represent substantial reliability and 0.41 – 0.60 show moderate reliability, 0.21 – 0.40 is a fair prediction, 0.00 – 0.20 is slightly reliable and values <0.00 are poorly reliable predictions (Cohen, 1960).

Table 10.2 Kappa index conditional transition probability matrices for Landsat TM 1991 and Landsat ETM+ 2001 images

Classes	Riparian forest		Wood/ grass vegetation		Settlement		Bare area	
	Kappa index	Hectares	Kappa index	Hectares	Kappa index	Hectares	Kappa index	Hectares
Riparian forest	**0.19**	1093	0.56	3189	0.02	129	0.21	1199
Woody/grass vegetation	0.12	958	**0.71**	5578	0.02	194	0.13	1020
Settlements	0.05	6.38	0.54	61.60	**0.36**	40.82	0.02	3.11
Bare area	0.08	22.92	0.73	210	0.13	37.94	**0.05**	15.01

Source: Adanu 2008

From the above table, riparian forest has 0.12 (958ha) Kappa transition probability of change to woody/grass vegetation which is a slightly reliable prediction of

forest cover loss by 958 ha. There is also 0.05 (6.38ha) Kappa transition probability of change from forest to settlement and 0.08 (22.92ha) probability of change from riparian forest to bare area. These slightly reliable Kappa transition predictions show minimal loss of forest cover. The prediction of forest loss to woody/grass vegetation by 958ha appears un-exaggerated for the forest reserves, but could be more in the off reserves. The loss of forest to settlement and bare area by 6.38ha and 22.92ha respectively show the forest is not likely to be converted to these land cover types by large margins given existing settlement and bare area expansion dimensions over the past 30 years when observing the satellite imageries classified. Seasonal effects of bush fire may convert forest lands to bare areas during the dry season of harmattan**,** but the forest will appear green when the rainy season begins.

Woody/grass vegetation has 0.56 (3189ha) Kappa transition probability of change to forest which will be a moderate increase in forest cover should this occur. There is 0.54 (61.60ha) probability of woody/grass vegetation being converted to settlements and 0.73 (210ha) probability of change from woody/grass vegetation to bare area, an indication of future loss of woody/grass vegetation to settlement and bare areas respectively. Conversion of woody/grass vegetation to settlement and bare areas are more likely when population expansion takes place resulting in quarrying of the land to obtain stones for building houses and also extraction of sand for making concrete structures.

There are 0.02 (1295ha), 0.02 (194ha) and 0.13 (37.94ha) Kappa transition probabilities of change from settlement to riparian forest, woody/grass vegetation and bare area respectively. These slightly and fairly reliable probabilities of change according to Cohen (1960) represent enormous change in settlement sizes. Any change from settlement to forest and woody/grass vegetation will increase the forest and woody/grass vegetation covers in a positive manner, but such changes are unlikely to occur unless under conflict situations when settlements are abandoned such as was the case in Kporvi (Kpetornu) town in the Volta Region in the early 1980s when the Tsito and Peki war took place. Government intervened by taking control of the land and prohibited both warring factions from entering the land leading to the gradual development of forest over the past

settlement and nearby farm lands. Intra-ethnic conflicts between the people of Peki and Tsito in Ghana occurred as a result of a land dispute, as land is a prized possession for both parties (Human Development Report, 2007).

Finally, bare area has 0.21 (1199ha) Kappa transition probability of being converted to forest and 0.13 (1020ha) Kappa transition probability of being converted to woody/grass vegetation. These fairly reliable predictions could occur depending on the driving forces of land use in the future. The 0.21 probability of bare area changing to forest could help increase the forest cover if such a change should occur. Given the existing driving forces of deforestation, the probability of bare area changing to forest is unlikely to occur.

10.2.4 Comparison of 1991 - 2001 and 1975 – 2001 Kappa Index/hectares transition probability results.

The change detection statistical report for 1975 – 2001 data which was used to produced the Kappa index transition probability figures in Table 10.4 is shown in Table 10.3.

Table 10.3 Change detection statistical report in hectares for 1975 - 2001

Classes	Riparian forest	Woody/grass vegetation	Settlements	Bare area	Row Total
Riparian forest	**2835**	3971	162	801	7769
Woody/grass vegetation	5918	**12221**	616	2391	21146
Settlements	796	987	**483**	384	2650
Bare area	2045	4638	335	**986**	**8004**
Grand Total					**39569**

Source Adanu 2008

The Kappa index conditional and hectares calculation based on data in Table 10.3 show predicted land cover change that will be compared to the Kappa index transition values in Table 10.2. Table 10.4 predicts that riparian forest has 0.27 (3162ha) Kappa index transition probability of changing from riparian forest to woody/grass vegetation

as compared to a predicted probability change of 0.12 (958ha) for the 1991 - 2001 data in Table10.2 indicating the probability of enormous loss of forest when underlying and proximate driving forces intensify in the future. There is a Kappa index transition probability of riparian forest changing to settlement by 0.30 (53.30ha) and to bare area by 0.25 (413ha) as in Table 10.4 which are fairly reliable predictions compared to a

Table 10.4. Kappa index conditional transition probability matrix for Landsat MSS 1975 and Landsat TM 2001 images.

Classes	Riparian forest		Wood/ grass vegetation		Settlement		Bare area	
	Kappa index	hectares	Kappa index	hectares	Kappa index	Hectares	Kappa index	Hectares
Riparian forest	**0.36**	556	0.51	779	0.02	31.80	0.10	157
Woody/grass vegetation	0.27	3162	**0.57**	6531	0.02	329	0.11	1277
Settlements	0.30	53.30	0.37	66.10	**0.18**	32.34	0.14	25.71
Bare area	0.25	413	0.57	938	0.04	67.76	**0.12**	199

Source: Adanu 2008

predicted probability of change of 0.05 (6.38ha) and 0.08 (22.92ha) respectively in Table 10.2. Both scenarios show change in forest cover that is not positive for forest cover increase. Though both scenarios show negative changes the predictions made on 1991 – 2001 data are not positive. These predictions may occur when driving forces of deforestation, such as revealed by questionnaire analysis in chapter eight (Figure 8.4) regarding rise in poverty, agriculture expansion (Figure 8.2) and population increase result in pressure on the forest (Figure 8.1).

Woody/grass vegetation has 0.51 (779ha) Kappa index transition probability of change to forest which portrays a moderate reliable prediction of increase of forest cover in the next 25 years as compared to the predicted Kappa transition probability change of 0.56 (3189ha) as in Table 10.2 which will add substantial forest cover. Woody/grass vegetation has 0.37 (66.11ha) fair reliability prediction and 0.57 (938ha) moderate reliable probabilities of change to settlement and bare area respectively based on the 1975

– 2001 data in Table 10.4 compared to 0.54 (61.60ha) and 0.73 (210ha) probabilities of woody/grass vegetation changing to settlement and bare areas respectively which are indications of woody/grass vegetation loss using 1991 – 2001 data in Table 10.2. The scenario prediction for 1975 - 2001 data show a moderate reliable probability of woody/grass vegetation changing to settlement while the prediction for 1991 - 2001 data indicate enormous woody/grass cover loss in 25 years which are detrimental to the physical environment. Woody/grass vegetation cover loss may occur when driving forces such as slash and burn agriculture intensifies as observed while analyzing questionnaire data (Figure 9.2).

Predictions are settlements have 0.02 (31.80ha) probability of change to riparian forest and 0.02 (329ha) slightly reliable Kappa transition probability of changing to woody/grass vegetation (Table 10.4). There is 0.04 (67.76ha) probability of change to bare area and these probabilities of change show minimal changes that could occur in settlements when driving forces of change such as war occur. War situations may result in settlements being converted to forest and woody/grass vegetation when such settlements are abandoned. Comparing data in Table 10.4 (1975 - 2001) to Table 10.2 (1991 – 2001), there is 0.02 (129ha) Kappa probability of settlement changing to riparian forest and 0.02 (194ha) Kappa probability of settlement changing to woody/grass vegetation. Conversion of settlements to forest or woody vegetation may occur when settlements are abandoned during conflicts (Human Development Report, 2007). Both scenarios do not indicate much increase of forest and woody/grass vegetation should this occur. The column for settlement shows a 0.13 (37.94ha) probability of settlement changing to bare area in 25 years when using the 1991 – 2001 data.

The column for bare area shows 0.10 (157ha) probability of change to forest and 0.11 (1277ha) probability of change to woody/grass vegetation which are fair reliable Kappa probabilities of change that could contribute to improvement in forest cover and woody vegetation cover (Table 10.4). A 0.14 (25.75ha) probability of bare area changing to settlement would have no negative effect on vegetation cover as bare areas and settlements have no vegetation. Comparing Table 10.4 to Table 10.2, it can be observed

that Kappa index transition probability of 0.10 and 0.11 of bare area changing to forest and woody/grass vegetation respectively show minimal changes compared to the fair reliable expected change of 0.21 (1199ha) and 0.13 (1020ha) slightly reliable Kappa index transition changes using the 1991 – 2001 data. The scenario showing increases in forest and woody/grass vegetation could occur should forest management such as planting of trees increase in the next 25 years as was done during the Forum project in the Volta region.

On the basis of all the comparisons, it can be concluded that different kinds of changes are possible in 25 years such as the probability of forest cover decrease as multiple driving forces of deforestation such as population increase, application of chemeical fertilizers, farmland expansion using slash and burn method and influence of government policies which are the key driving forces of deforestation may persist. The hypothesis that the forest cover will decrease by half in the next 25 years due to underlying and proximate driving forces of deforestation as mentioned could occur given the evidence of forest cover decrease established through satellite image analysis even though trees were planted during the Forum project in the municipality to increase the forest size.

10.3 Implication of land cover change transition modeling for the future state of forests.

The results of the Markov model of land cover transition show different probabilities of forest cover change including a high probability of forest cover decrease in the future. The probability of forest decrease in the next 25 years will negatively affect forest size as driving forces such as extraction of wood energy to meet domestic and commercial needs may not stop. When the forest is cleared due to the driving forces discussed in chapters eight and nine woody/grass vegetation will increase in size as replacement to the forest. On the whole there is the probability that forest lands will

decrease by 3162ha to woody/grass vegetation based on 1975 – 2001 data and a decrease of 958ha using 1991 – 2001 data which are scenarios showing forest cover loss.

The diagonal figures in bold (Table 10.2) are expected to be stable all things being equal, hence there would not be any incidence of deforestation or change in the existing land cover. The occurrence of no change is only possible in a situation where the forest/game reserves are kept intact such that no deforestation occurs even in areas that are located outside the forest reserve. The driving forces of land cover change are difficult to control, as such the probability of no change in the forest cover may be difficult to achieve except in the forest reserves. It is more likely that, negative changes will occur especially in the off forest reserve areas.

Lack of alternative job opportunities, coupled with poverty, have left the respondents with no option but to continue to depend on the natural environment for farming, logging of wood and exploitation of wood energy. The unavoidable exploitation of the natural environment, given the harsh economic realities that confront the people may compel them to exploit the forest regardless of the consequences of deforestation. The forest ecosystem will be negatively affected such as loss of plant and animal species and habitat in the event of any extensive disturbance of the forest ecosystem. In the long term, the number of poor people will increase and the consequences may include; further losses in soil fertility with its resulting poorer crop yields that will lead to hunger and malnutrition as direct consequences of the poor crop yields. Coupled with the poor yield is the issue of climate variability such as prolonged droughts that may worsen the plight of farmers.

In addition to the analysis of the Markov modeling result, the questionnaire analysis has implications for future forest areas as the Chi-square test results confirmed the hypothesis that demographic pressure is a key underlying driving force of deforestation. These results project future losses in the forest cover if the population continues to increase over the next 25 years. In the event of any population increase, the

probability of losing 67% and 51% of the forest cover may increase further due to increased exploitation of wood energy for firewood and charcoal.

The factor analysis results further show that the exploitation of wood energy, slash and burn agriculture, and the use of chemical fertilizers were the key factors that led to deforestation in the study Municipality. Use of chemical fertilizers for instance has contributed to increased deforestation as application of fertilizer is perceived to be a contributory factor to soil acidity, as explained earlier hence, farmers move from acid soil to clear fertile forest lands leading to deforestation. This means that if such driving forces intensify in the next 25 years loss of the forest cover will occur. Any loss of forest cover may be associated with the loss of medicinal plants, genetic resources and the loss of water resources that are currently being protected by the forest. Other ecosystem services such as fresh air, storage of carbon dioxide in trees to prevent climate change may decrease, resulting in possible environmental and health effects such as global warming and eye cataract cases in the West African sub-region (Chika, and Ozor, 2010). The population statistics for the study area from 1970 to 2000 indicate sustained increase in the population (Table 8.1) as such it is possible that the population will increase in the next 25 years. Any future increase in the population of the study area may contribute to deforestation.

10.4 Discussion

The concept of transition has been applied in land use/cover change studies at different spatial and temporal scales such as at county, district, regional and national scale where different scenarios of forest cover change such as transition from forest to woody vegetation are predicted (Mather and Needle, 1998). In this study different scenarios of change have been predicted such as forest remaining forest, forest changing to woody/grass vegetation and bare areas. The driving forces of land cover chage such as socio-economic and technological factors are examples of variables that may result in any future changes should there be changes in these driving forces. A stochastic simulation of land cover change in Traverse City, Michigan made it possible to generate future land

cover scenarios based on socio-economic information using Landsat MSS 1973, Landsat TM 1985 and Landsat 1991 images. Transition probabilities analyzed in Michigan were transitions from non forest to forest and from forest to non forest (Brown *et al*., 2002). Maeda *et al*., 2010 applied a simulation model to predict expansion of agricultural and cattle raising activities in the fringes of the Xingu National Park using cellular automata transition algorithms and scenario analysis for 2015 show pasture lands will remain pasture lands while expansion in crop land is expected to replace 50% forests by 2015.

10.5 Conclusion

Analysis in this chapter addressed research question three which sought to examine the implication of land cover change transition modeling for the future state of forest areas. Results of the study predicted various possibilities of change in land cover depending on the driving forces of deforestation. For example, the possibility exists for forest areas to remain stable when the driving forces of deforestation such as population increase and excessive exploitation of wood energy do not increase in the next 25 years. However, in event of any increase in these driving forces the prediction is that current forest lands may be converted to woodland and grassland areas. As such, the undesirable loss of forest lands may have serious consequences for the environment, agriculture and human health by 2026. The diverse findings illustrate some of the challenges in using a range of methods to answer research questions in human-environment work.

Loss of the forest cover could contribute to the release of greenhouse gases into the atmosphere with consequences for climate change. Extensive cultivation of the same agricultural lands may contribute to further decline is soil fertility with the consequent effect of poor crop yields. Climate variability resulting from global warming may also contribute to water stress on agricultural lands which could have negative consequences for food security. Human health in the study area may deteriorate due to hunger and malnutrition when the agricultural production declines due to loss of soil fertility and climate variability as rainfall becomes unpredictable and severe droughts occur. Finally,

application of the Markov Model to predict land cover/use change is shown, with limitations, to have some utility despite the land use/cover changes.

Chapter Eleven

Summary, Recommendations and Conclusion

11.1 Summary of key findings

11.1.1 General background

This study focused on land use and cover change transition in the Ho Municipality in response to the global environmental change issues. Land cover change transition in this study refers to change of the forest vegetation cover to woody savannah vegetation, grassland and bare areas due to crop cultivation, wood energy exploitation and cattle grazing (known as the proximate driving forces of land cover change). Population increase, use of technology for agriculture, economic, political and trade regulations and property systems were the key underlying driving forces of deforestation in this study. Based on the study focus, three research questions were posed for investigation:

1. How is the nature and extent of accelerated land cover transition (deforestation) from 1975 to 2001 determined by classification of satellite images and variability in underlying and proximate driving forces?,
2. Do population growth and density play any significant role in deforestation compared to the other driving forces of deforestation?
3. What are the implications for future forest areas by assessing the potential utility of Markov model in land cover transition modeling?

11.1.2 Study Methodology

The methods used to investigate the above research questions involved the administering of questionnaires and an analysis of satellite images. Questionnaires were

administered to obtain the opinion of respondents regarding the causes and effects of deforestation in the Ho Municipality. A total of 376 respondents and 10 cattle owners responded to the questionnaires. Themes for the questionnaires administered were population dynamics, land tenure issues, policies, technology and land use intensity, agricultural land use, income levels, market opportunities and woodfuel exploitation. The analytical softwares used for the statistical analysis were SPSS and Excel. The second method involved analysis of satellite images using ENVI 4.3 software. Although the image classifications have produced useful results there were some limitations to the classification process.

11.1.3 Image analysis results

Results of the classified Landsat MSS 1975 image produced an overall accuracy of 92% and Kappa coefficient of 0.8659 indicating an acceptable result. The classified Landsat TM 1991 image produced an overall accuracy of 89% and Kappa coefficient value of 0.8409. The Landsat ETM+ 2001 image produced an overall accuracy of 86% and Kappa coefficient value of 0.7794 which are also acceptable results.

Normalized difference vegetation index calculations for the study show that the forest vegetation looked healthier than the woody vegetation (given the bright colour tone for riparian forest vegetation and the dark colour tone for the woody vegetation). Determination of change in vegetation cover from 1975 – 1991 and from 1975 – 2001 were calculated using the change detection statistics method. From 1975 to 1991, an image difference of -6562 hectares of forest loss representing 58.27% has been computed. For the period 1975 to 2001, a negative change of 2949 hectares occurred representing 25.4% of forests cover loss. In assessing the potential utility of the Markov model to predict future land cover change for the next 25 years, there is a probability that riparian forest would change to woody/grass vegetation by a Kappa index of 0.12 representing 958 hectares of forest cover loss and a change of riparian forest to bare area by Kappa index of 0.08 representing 22.92 hectares of forest loss based on 1991 – 2001

data. Predictions based on 1975 - 2001 data, using the Markov model, predicts change from riparian forest to woody vegetation by Kappa index value of 0.27 representing 3162 hectares of forest loss. A predicted loss of 413 hectares of forest to bare area has been made based on the 1975 – 2001 data. The results from the prediction indicate that the Markov model has utility potential but must be considered alongside information regarding the prevailing key drivers of deforestation.

Results of the image analysis addressed research question one. Results for the three classified images show that in 1975, 1991 and 2001, the nature of the vegetation covers showed evidence of forest cover loss. As far as the nature and extent of deforestation from 1975 to 1991 is concerned, results of the change detection statistics calculation showed a negative image difference of 6562 hectares which indicates that the nature and extent of deforestation had increased. From 1975 to 2001, the nature and extent of deforestation indicates a further decrease in the forest cover by 2949 hectares. However, there were some limitations to this study. The acquisition date of the images were December and February which in Ghana are harmattan seasons characterized by dry and dusty atmospheric conditions that would have made the images unclear. The 1991 image showed scenes of burnt areas that affected the quality of the classified satellite image. Notwithstanding these limitations, the image classification results have addressed research question one.

11.1.4 Underlying driving forces

Analysis of the underlying driving forces of deforestation, notably population growth and density, from 1975 to 2001 showed evidence that these factors have contributed to deforestation. The results address research question two which seeks to reveal whether population growth and density play any significant role in deforestations. The answers provided for research question two are based on the opinions of the respondents. For example, results of Chi-square test of significance rejectes the null hypothesis that demographic pressure is not the key underlying driving force of land

cover change transition given a test result of 364.099 (Table value 5.99) against the critical value of 0.05. The result confirms the opinion that population pressure has contributed significantly to deforestation from 1975 to 2001. Furthermore, the analysis of the opinion of the respondents regarding whether population increase contributes to deforestation gives 83.2% "yes" responses indicating that population increase contributes to deforestation.

Respondents noted that poverty has contributed to deforestation given the 78.9%, 68.9%, 72.9% and 40% affirmative responses obtained in Wumenu, Agbokofe, Abutia Kloe and Takla, respectively. It is the opinion of respondents that illegal logging which led to deforestation was one of the multiple driving forces of deforestation in the study area from 1975 to 2001. This opinion is reflected in the 60%, 68.9%, 79% and 30.5% affirmative responses obtained in Wumenu, Agbokofe, Abutia Kloe and Takla townships.

Results of the study also show that local economic demand is a further underlying driving force of deforestation that determines the types of crops that are grown and the size of forest or woody vegetation lands that are cleared by farmers. A Chi-square statistical test on this opinion produced a value of 6.204 (Table value of 5.99) against the significant value of 0.05 and this result has rejected the null hypothesis that government policy determines the type of crops farmers grow. However, previous colonial land demarcations contributed to deforestation as such land demarcation was arbitrarily done without consulting land owners as such people disregarded the demarcations and encroached on the forest leading to deforestation.

11.1.5 Proximate driving forces

Analysis of the proximate driving forces of deforestation shows that exploitation of wood energy and farming activities are key proximate driving forces of deforestation. Cutting of tree stems for charcoal and fuelwood does not allow trees to coppice and regenerate. The majority of respondents in Wumenu, Agbokofe, Abutia Kloe and Takla

cut trees at the stem level instead of tree branches for wood energy production. Some respondents cut living trees for wood energy production compared to 36.8% and 28.1% of the respondents in Wumenu, and Abutia Kloe respectively who obtained wood energy from their farmlands when they clear the land to grow crops. Exploitation of wood energy as a basic source of domestic and micro-industrial energy drives deforestation. Scooping the earth to cover piles of wood that are burnt to charcoal also contributes to the loss of top soil nutrients that could facilitate the fast growth of woodlands to forest.

Existing technology for farming such as ploughing farmlands and the use of chemical fertilizers partly contributed to deforestation in the study settlements. Income earned from farming has motivated farmers to clear more fertile lands (mostly forest lands) to increase their profit levels.

Cattle grazing is not considered as key driving force of deforestation in this area this is because very few people own cattle. Cattle grazing may become an issue of concern as far as deforestation is concerned if the cattle population increases.

Results of the factor analysis show four drivers of deforestation which are use of chemical fertilizers, extraction of wood energy, income from farming and slash and burn farming as the main contributing factors to deforestation. Future changes in forest cover will occur as a result of these driving forces.

Attitude towards burning forest and woodland areas during the dry season to hunt animals has contributed to the loss of forest lands. In some cases, cattle owners burn the vegetation to ensure growth of fresh grass for cattle to graze and fires accidentally spread to forest areas. Slash and burn farming is a common farming method used in all the towns as reflected in the 82.1%, 74.4%, 84.4% and 32.6% “yes” responses in Wumenu, Agbokofe, Abutia Kloe and Takla respectively. Burning of the slashed vegetation sometimes burns beyond farm boundaries resulting in the destruction of forest lands.

In summary, analysis of the proximate driving forces of deforestation has addressed the other driving forces of deforestation besides population factors and four key driving forces have been identified as the dominant driving forces of deforestation which are: population growth and density, chemical fertilizer use, wood energy exploitation and slash and burn agriculture. Other driving forces of deforestation include illegal logging.

11.1.6 Implications of transition probability matrix

The transition probability matrix calculation addressed research question three which sought to assess the potential utility of Markov model to predict changes that may occur in the vegetation cover by 2026. Results of the prediction analysis indicate three possibilities (no change, positive and negative changes). No change would occur by 2026 when protected forest and off reserve forest are not destroyed and remain stable. Positive changes such as increase in forest areas may occur when the people find alternative sources of livelihood and alternative energy sources. However, such a positive increase in forest vegetation is very unlikely to occur given the current social and economic difficulties facing the people. Any loss of forest lands may result in negative changes in the forest vegetation cover. Consequences of this deforestation would include the release of carbon dioxide into the atmosphere which may contribute to climate change. Positive changes in the woody vegetation areas and bare areas may occur when the forest vegetation cover is lost. Any of the three possible changes that may occur by 2026 would be largely determined by proximate and underlying driving forces of deforestation rather than natural driving forces of land cover change. Results of the household interviews indicate that population pressure, use of chemical fertilizers, woodfuel exploitation and income from farming are the key drivers of deforestation. According to responsents, these drivers are unlikely to stop in the future.

11.2 Recommendations

Change detection analysis from 1975 – 2001 show forest cover decline while increases occurred for woody/grass vegetation, settlements and bare areas. To address the decrease in forest cover, existing forests have to be protected against deforestation while planting of trees is encouraged and supported. Forest protection has to be done in partnership with local communities. In this regard new policy directives that seek to encourage community participation in forest resource management will make land owners feel part of the decision making process and consequently avoid forest vandalism. For example, a study in Nepal shows that involving local communities in conservation efforts contribute to the success of conserving protected areas. This is because local communities have a sense of ownership and derive various incentives from such projects to improve their social and economic lives (Bajracharya, *et al*., 2006).

Underlying driving forces of deforestation identified in the municipality such as population pressure, poverty, bribery, land tenure issues, policy matters and income factors can be addressed from various perspectives. Education on family planning and ways to reduce family sizes to avoid high living costs are important parts of many conservation programmes such as conservation Internationals programmes in Mexico and Philippines (Conservation International, 2005). Alternative rural livelihood projects of NGOs need to focus on strategies to reduce deforestation. Bribing of forestry officials can be tackled by paying adequate salaries to them to motivate them as a means of eliminating corruption.

Proximate driving forces of deforestation identified in this study such as wood energy exploitation and agriculture expansion can be addressed using different approaches. For example, given that wood energy serves as the basic energy source for the people of the study towns, it will not be easy to refrain from utilizing wood energy since it is the only affordable energy to the low income households. It will, however, be useful when fast growing tree plantations are planted to ensure sustainability in the

supply of wood energy as was carried out in Ghana, Cote d'Ivoire and Liberia (Parren and Graaf, 1995). Oil finds in commercial quantities in Ghana raises hopes of producing liquefied petroleum gas in large quantities that may be affordable enough for the poor to buy thereby reducing pressure on the forest. Improvement on the traditional stove technology such as enhancing stove enclosures has maximized heat transfer to cooking pots and this has reduced the quantity of wood energy used daily due to energy efficiency and in effect reduced pressure on wood energy resources (Kristoferson and Bokalders, 1991). Improvement in the agricultural technology such as planting high yielding seeds and simple soil fertility improvement techniques such as mulching may reduce pressure on forests (FAO, 2010).

11.3 Conclusions and future work

Global change has become a key environmental issue that is accelerating in recent times with increasing evidence of loss of forest lands and rise in the global temperature (IGBP, Science No. 4). Global environmental changes occur largely due to underlying and proximate driving forces of land cover change as opposed to natural driving forces. Planning of effective control measures to counter the accelerated pace of environmental change due to deforestation requires data such as the analysis of satellite images and socio-economic surveys of this study. Studies of this kind are useful for characterizing the nature of land cover changes and the inter-linkages among driving forces of land cover change. This may increase the knowledge base of researchers concerning the driving forces of deforestation in a tropical developing country such as Ghana, or apply such knowledge on a larger scale.

Understanding the dynamics of global environmental change problems and planning for the future requires modeling to make predictions on future environmental changes and trends. Application of predictive models to predict future environmental conditions such as application of the Markov model to this study is very timely as there is

a growing need for accurate predictive tools. Assessing the potential utility of Markov model in predicting land cover changes in the study area illustrates that models such as this can produce very different results depending on the temporal scale used and therefore requires careful interpretation. Nevertheless, the Markov model can complement or enhance other investigative tools such as the socio-economic based study conducted here.

Results of this study can be used to provide the framework for planning solutions to solve negative land cover changes in the future. Results of this study will contribute in part to address local and global land cover transition problems by highlighting both proximate and underlying causes. There are some limitations to this study such as difficulty in obtaining high quality satellite images for analysis. The scope of the study is broad; hence, it has not been possible to do detailed investigation on the key driving forces of land cover change. These key driving forces should be investigated in detail in the future as funding becomes available.

Furthermore, to avert further losses and disturbance of the forest ecosystem, there is a need to find alternative sources of employment for the local people so that there is not so much dependence on the forest cover for survival. There is also the need for the Municipal Forestry Commission to protect the existing forest reserves. Protecting the forest reserves requires logistical support and appropriate remuneration of the forestry staff in the Municipality. Clearing of woody areas for purposes of growing jetropha and other bio-fuel plants have the potential of contributing to further loss of the forest/woody vegetation cover, unless properly managed.

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APPENDIX A

University of the Witwatersrand, South Africa,
This questionnaire seeks information for academic purposes.
Respondents are free to respond to the questions or abstain

Underlying driving forces of deforestation

Population Dynamics

1. Do you consider the population of your town as increasing? Yes ☐ No ☐

2. If yes, what contributes to the population increase? (a) high fertility ☐ (b) immigration ☐ (c) both a and b ☐

3. Is population increase playing a role in deforestation in your town? Yes ☐ No ☐

4. If no, what do you consider as the main cause of deforestation?
……
……
5. Do you anticipate any increase in your farm size when your family size increases? Yes ☐ No ☐

6. If yes how much extra land will you need when you have a new family member?

(a) 0.5 acres ☐ (b) 1 acre ☐ (c) 2 acres ☐ (d) 3 acres ☐ (e) 4 and more acres

(f) no extra land is needed. ☐

7. What kind of land would you clear when your family size increases? Forest ☐ Savannah ☐

Social drivers

8. Is there any existing forest in your town/village Yes ☐ No ☐

9. If yes is the forest land increasing or decreasing?…….

10. What accounts for deforestation in this town/village?……
……

11. What are the indicators of deforestation in this town/village? ……..
……

12. List the effects of deforestation in your town/village

…….. ……

…….. ……

……. ……..

13. Can you estimate the deforestation rate in this town in acres? …….

14. Do you consider poverty as a possible factor that contributed to deforestation in 1975? Yes ☐ No ☐

15. Could poverty be the cause of deforestation from the 1991 to 2001? Yes ☐ No ☐

16. In an order of priority number from 1 to 4 basic needs that will be met when the forest is cut down. Food ☐ wood energy ☐ shelter ☐ cloths ☐

17. Has illegal logging contributed to deforestation from 1975 to 2001? (a) Yes ☐ (b) No ☐

18. Do you think the forestry commission is doing enough to check illegal logging? Yes ☐ No ☐

19. Do you think corruption such as bribing of forestry officials encouraged illegal logging from 1991 to 2001? (a)Yes ☐ (b) No ☐

Land tenure issues

20. Who has the right to own land in your house (a) Men ☐ (b) Women ☐ (c) Both ☐

21. Are you free to use the land you have for forestry projects (a) Yes ☐ (b) No ☐ If no give explanations to your answer ……

…….

22. What will happen if all citizens in your town grow at least 2 hectares of forest ten years? (a) The forest area will increase ☐ (b) Deforestation will be slightly reduced ☐

Policies and deforestation

23. Will you attribute encroachment on forest reserves/lands in this town to arbitrary forest demarcations in the past such as the forestry commission having the right to

trees on individual lands? (a)Yes ☐ (b) No ☐ Give explanations to your answer …….
……

24. Are you aware of any policy changes to the ownership, control and management of the forest reserves/lands in your town as of now? (a)Yes ☐ (b) No ☐

25. If yes state some of the policy changes you are aware of
……..
……..

26. Are these policy changes useful to you? (a) Yes ☐ (b) No ☐ If no Why ……..

27. Give suggestions for improving the current policy if any ……..
……

28. Will you attribute deforestation during the 1980s and 1990s to the Economic Recovery Programme and Structural Adjustment Policies of Government? (a) Yes ☐ (b) No ☐ Explain your answer?
……..
…….

29. Is land use such as the crops you grow favored by central government policy? Yes ☐ No ☐

30. Is land use such as the crops you grow determined by local economic demand? Yes ☐ No ☐

Technology and land use intensity

31. What are the existing high technological farming methods available to you? (a) tractor ploughs ☐ (b) weed killers ☐ (c) Other ☐
32. State how any of these technologies contribute to loss of forest or woody vegtation
……..
33. Do you apply chemical fertilizer to your crops Yes ☐ No ☐

34. Do chemical fertilizers have any negative effects on vegetation and soil? Yes ☐ No ☐ Explain your answer……...

Attitudes

35. Is the vegetation in your town burnt every year? Yes ☐ No ☐
36. If yes what causes the fire? (a) human beings ☐ (b) natural causes ☐

37. What are some of the human causes of bush fires? (a) burning of the land for crop cultivation ☐ (b) hunting for bush meat ☐ (c) fire from palm wine tapping ☐ (d) Others ☐

38. List some consequences of bush fires in your town ……..…….. …….. …….. …… ……..

39. What practical measures have been taken so far to minimize annual bushfires? ……..

Proximate Driving forces

Agricultural land use

40. How do you prepare your farm land for crop cultivation? (a) burning of the bush ☐ (b) clearing with a cutlass ☐ (c) plough direct with a tractor ☐

41. In which year did you clear the first forest land in your life time for crop cultivation…….

42. When was the last year you cleared a forest land for crop cultivation……..

43. Do you practice slash and burn farming? Yes ☐ No ☐

44. Do you leave the land to fallow after cropping to land for some number of years Yes ☐ No ☐

45. If yes for how many years? ……

46. What may be the motive for clearing forest lands from the 1970s to the 1990s.
(a) grow export crops ☐ (b) export timber ☐ (c) land for food crops
(d) Income for cloths and shelter ☐

47. Name the export crops cultivated during the 1970s and 1990s that you are familiar with ……. …….. …….. ……..

48. What kind of crops do you grow in your farm?
(a) Tree crops, give examples …….
(b) Cereals, give examples ……
(c) Root and tubers, give examples ……..…….

49. Do you notice any increase in forest cover due to activities of the forum project? Yes ☐ No ☐

Income levels and market opportunities for farm products

50. How much income do you earn from the sale of your farm product per market day……..

51. Is the income from farming a motivation for cutting more forest trees for crop cultivation? Yes ☐ No ☐

52. Is the income obtained from farming enough to cater for your basic needs such as (a) Food ☐ (b) shelter ☐ (c) cloths ☐ (d) school fees ☐ (d) travel costs (tick those that apply).

53. Which agricultural commodities are in high demand presently? List them.
…… ……
…… ……
…… ……

54. Are the above products in high demand because government policy favours their production as industrial raw materials? Yes ☐ No ☐

55. If no are the products in high demand because they are basic food stuffs?
Yes ☐ No ☐

56. Do you feel the promotion of these crops is contributing to deforestation?
Yes ☐ No ☐

Animal grazing

57. Why do you chose to raise cattle?…….
……..

58. Give an estimate of the size of your free range pasture field in hectares if you can……

59. Is your existing pasture land producing enough nutritious grass to feed your cattle
(a) Yes☐ (b) No ☐

60. If no, will you like to move to a more nutritious pasture land? Yes ☐ No ☐
61. How many cattle do you have in total?……

62. What kind of other grazing animals do you have apart from cattle?
(a) goat ☐ (b) sheep ☐

63. How do you feed the animals? (a) free range ☐ (b) pen/ranch ☐ (c) both ☐

Extent and nature of deforestation

64. What is your opinion about the nature of vegetation in 1975? (a) dense forest ☐
(b) savanna vegetation ☐ Your answer to this question may be by either personal observation or hearsay.

65. Was the size of forest cover in your area in 1975 the same as it is at present?
Yes ☐ No ☐

66. If no what changes have taken place? (a) increase in forest size ☐
(b) decrease in forest size ☐

67. What was the general appearance of the vegetation cover in 2000/2001?
(a) limited forest ☐ (b) savanna ☐ (c) bare land

68. What was the general appearance of vegetation cover in 1991? (a) Forested ☐
(b) savanna ☐ (c) bare land

Woodfuel production and deforestation

69. Name the type of trees you cut to produce charcoal.
(i)……..
(ii)……
(iii)……
(iv)……

70. By what method do you cut a tree? (i) cut branches ☐ (ii) cut the stem ☐
(iii) uproot stumps. ☐

71. How do you obtain fire wood? (i) Dead wood ☐ (ii) live trees ☐ (iii) on farm lands ☐

72. What is the average number of living trees cut in a month for charcoal and fuelwood production? (i) 1 - 5 ☐ (ii) 6-10 ☐ (iii) over 10 ☐

73. How much do you sell (i) a maxi bag of charcoal,……. (ii) mini bag (iii) heap…… ….

74. Who are your customers? (i) Retailers/wholesalers ☐ (ii) Chop bars/restaurants ☐
(iii) Schools ☐

75. What is your main source of domestic energy for heating water and cooking?
(i) fire wood ☐ (ii) Gas ☐ (iii) Charcoal ☐ (iv) kerosene ☐

76. How many bundles of firewood do you consume in (i) a day ……
(ii) a week …….. (iii) a month ……(a bundle weights about 60 kgs)

7. What type of stove do you use? (i) Clay fan. ☐ (ii) Stones ☐ (iii) coal pot. ☐

78. How many bundles of firewood do you offer for sale in a week? …….

79. Do you anticipate the pace of deforestation to double in the next 10 years due to extraction of trees for wood energy? Yes ☐ No ☐

PERSONAL DETAILS

80. How old are you (i) 14 - 20 year ☐ (ii) 21 - 40 year ☐ (iii) 31 - 50 years ☐ (iv) over 50 years ☐

81. Sex Male ☐ (ii) Female ☐

82. Marital Status. (i)Married ☐ (ii) Single ☐ (iii) Divorced ☐

83. What is the size of your household? (i) 1-3 ☐ (ii) 4-6 ☐ (iii) 7-10 ☐

(iv) over 10 people. ☐

84. What is your level of education?

(i) None ☐ (ii) primary ☐ (iii) SSS/JSS (iv) post secondary ☐

(v) Vocational. ☐

85. What is your main occupation?

(i) Farming ☐ (ii) Trading ☐ (ii) Woodfuel Producer . ☐

(iv) Artisan/Driver. ☐ (v) Public Servant (vi)

Other…….

APPENDIX B

Hypothesis 1

H_o: Demographic pressure is not a key underlying driving force of land cover change transition.

H_i: Demographic pressure is a key underlying driving force of land cover change transition.

Significance level $\infty = 0.05$

Degree of freedom (df) = 2

Person product moment Chi square $X^2 = \sum \frac{(O - E)^2}{E}$

Where O = observed frequency and E = Expected Frequency.

Calculated value of X^2 = Critical value of $X^2 = 0.05 = 364.099$

Decision rule

If calculated value is less than the X^2 level of significance at 0.05 we do not reject the null hypothesis H_o.

If the calculated value is more than the level of significance at 0.05 reject the H_o, and accept H_i.

Is population increase playing a role in deforestation in your town?

	Observed N	Expected N	Residual
yes	255	100.7	154.3
no	45	100.7	-55.7
3	2	100.7	-98.7
Total	302		

Source: Field survey 2008

land cover and family size

	Observed N	Expected N	Residual
Forest	132	73.3	58.8
Savannah	159	73.3	85.8
5	1	73.3	-72.3
6	1	73.3	-72.3
Total	293		

Source: Field survey 2008

Test Statistics

	Is population increase playing a role in deforestation in your town	land cover and family size
Chi-Square(a,b)	364.099	290.031
Df	2	3
Asymp. Sig.	.000	.000

Source: Field survey 2008

Using the decision rule, $X^2 =$ 364.099 is more than the 0.05 hence the null hypothesis is rejected. In effect the alternate hypothesis is not rejected.

APPENDIX C

Factor analysis

For this analysis, 7 factors were used such as (F1, F2, F3, F4, F5, F6 and F7). These factors were questions posed to the respondents in the field and the answers given provide basis for the analysis. The question numbers were represented by Q3, Q35, Q66, Q51, Q36, Q44 and Q54.

1. F1 = Q3. Is population increase playing a role in deforestation in your town?
2. F2 = Q35. Do chemical fertilizers have any negative effect on vegetation and soil?
3. F3 = Q 66. How do you obtain firewood?
4. F4 = Q51 Is income from farming a motivation for cutting more forest trees for crop cultivation?
5. F5 = Q 36 Is the vegetation in your town burnt every year?
6. F6 = Q 44 Do you practice slash and burn farming?
7. F7 = Q 54 Are agricultural product being produced in high demand because government policy favors their production?

Communalities

Communalities show the level of variance a variable has with all other variables being considered. The communalities also determine which of the variables share common relations. The higher the communality value the better the association with other variables. A cut off point of 0.5 was set for the communalities and the following are the outcome.

Communalities Table

	Initial	Extraction
Is population increase playing a role in deforestation in your town	1.000	.551
chemical fertilizer use on crops	1.000	.725
how firewood is obtained	1.000	.879
Income and motivation for cutting trees for crop cultivation	1.000	.574
Burn vegetation every year	1.000	.541
Practice slash and burn farming	1.000	.704
are agric products in high demand because of favorable govt. policy	1.000	.694

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	1.278	18.264	18.264
2	1.207	17.241	35.505
3	1.152	16.458	51.962
4	1.031	14.722	66.685
5	.877	12.526	79.210
6	.783	11.189	90.399
7	.672	9.601	100.000

Extraction Method: Principal Component Analysis.

Component Matrix(a) Table

	Component			
	1	2	3	4
Is population increase playing a role in deforestation in your town	.518	-.184	.401	-.298
chemical fertilizer use on crops	.363	.631	-.019	.442
how firewood is obtained	-.212	-.164	.404	.802
Income and motivation for cutting trees for crop cultivation	.596	-.003	.466	-.035
Burn vegetation every year	.575	-.349	-.192	.227
Practice slash and burn farming	.385	.125	-.723	.133
are agric products in high demand becasue of favorable govt. policy	-.018	.781	.226	-.179

Extraction Method: Principal Component Analysis.
a 4 components extracted.

APPENDIX D

Hypothesis 3

H_o: Land use in H_o Municipal District is not determined by local economic demands; but central government economic policies.

H_i: Land use in H_o Municipal district is determined by local economic demands and not central government economic policies.

Significance level $\infty = 0.05$

Degree of freedom (df) = 2

Person product moment Chi square $X^2 = \sum \frac{(O - E)^2}{E}$

Where O = observed frequency and E = Expected Frequency.

Calculated value of X^2 = Critical value of $X^2 = 0.05$ = ….

Decision rule

If calculated value is less than the X^2 level of significance at 0.05 we do not reject the null hypothesis H_o.

If the calculated value is more than the level of significance at 0.05 reject the H_o, and accept H_i.

	Observed N	Expected N	Residual
yes	230	150.5	79.5
no	71	150.5	-79.5
Total	301		

Source: field survey 2008

Test Statistics

	crops and government policy	crops and local economic demand
Chi-Square(a,b)	200.753	83.990
df	1	1
Asymp. Sig.	.000	.000

Source: Filed survey 2008

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6.204(a)	2	.045
Likelihood Ratio	5.843	2	.054
Linear-by-Linear Association	3.842	1	.050
N of Valid Cases	296		

Source: Field survey 2008

Using the decision rule, $X^2 = 6.204$ is more than the 0.05 hence the null hypothesis H_o is rejected. In effect the alternate hypothesis is not rejected (but accepted).