IMPACT OF ROADS ON FARM SIZE, MARKET PARTICIPATION, AND FOREST COVER CHANGE IN RURAL GHANA

Thesis submitted by

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ABSTRACT

The research sought to find out: the degree to which improved roads influence farm size and market participation of different typologies of farmers; the factors that contribute to forest cover change; and the extent to which forest cover changes along roads. In answering these questions, rural areas in Ghana were used for the study.

Five districts in three regions of Ghana were mapped for the research. Ten communities from the five districts were selected for field survey; five with improved roads and five without improved roads. Thirty farmers were interviewed in each of the selected communities. Data on their farming operations, household characteristics, and other factors were sought and analysed using regression in SPSS. This provided the results for the farm size dynamics and farmers' market participation in rural Ghana. Satellite images for 1986, 2002, and 2015 were downloaded from Landsat archives, pre-processed, mosaicked, and used to analyse the contributory factors to forest cover change as well as the changing patterns of forest cover along roads in the study area. ArcGIS 10.2.1 and ENVI 5.3 software was used for the spatial analyses.

The regression results showed that improved roads reduce the rate of farm expansion net all other factors. Furthermore, improved road farmers have relatively small farm sizes than hinterland farmers. The rate of farm size reduction with time is higher at the improved road zone than in the hinterlands. Despite the relatively small farms of the improved road farmers, they sell 84% of their farm produce as compared to 31% of the hinterland farmers. The hinterland farmers grow mainly for consumption due to the challenges they face with transportation.

The spatial analysis showed that agriculture and settlements expansion were the main causes of deforestation in the study area. Within the 29-year period, more than 50% deforestation occurred along both the improved and unimproved roads. However, the extent of deforestation along the unimproved road was higher (62.8%) than along the improved road (7.5%) especially between 2002 and 2015. Deforestation along the improved road declined overtime while that along the unimproved road increased. This is because agricultural expansion was 63% higher along the unimproved road than the improved road for the 29 years and it kept on increasing overtime.

Agricultural transformation through the application of modern farm inputs should be recommended to the farmers such that they could increase their outputs on the existing

farmlands without increasing their farm sizes. This would lead to surpluses beyond the consumption of farm households. To encourage commercialisation of farm produce, roads in the hinterlands should be improved to avoid post-harvest losses resulting from the surpluses.

Improving the roads would attract more farmers since they could easily connect to the markets, attract more investors to the agricultural corridor, and enhance the creation of other non-farm jobs. Although, this might exert pressure on the existing farmlands and the forest, when farm intensification is practiced and strict environmental laws are enforced, agricultural production could increase with minimal threat to forest. Livelihoods of farmers would improve through the sale of the surpluses produced as well as the other non-farm jobs they might engage in resulting from the road's improvement. Improved roads could promote agricultural transformation, transform farmers' wellbeing, enhance community development, and conserve nature when environmental measures are adhered to.

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LIST OF ABBREVIATIONS

AGRA	Alliance for a Green Revolution in Africa
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization's Statistics
GDP	Gross Domestic Product
GSS	Ghana Statistical Service
HLC	Household Life Cycle
NTFPs	Non-Timber Forest Products
SSA	Sub-Saharan Africa
TEMA	Techiman Municipal Assembly
UNEP	United Nations Environmental Program

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Background to the study

Road infrastructure is a vital component in the development of nations. The contribution of roads to freight movement and human mobility in both developed and developing countries are self-evident (Badu et al., 2013; Bafoil & Ruiwen, 2010; Marko et al., 2011; McIntire, 2014). In developing countries, movement of people, goods, and service are mainly made by road. Roads in India for instance, carry more than two-thirds of freight and over 80% of all passenger traffic in the country; road transport contributes 4.7% to the Gross Domestic Product (GDP) of India (Gajendra, 2013). In Ghana, 92% of farmers transport their produce to the market by road (Angmor, 2012). The World Bank, the European Union, CADFund (China–Africa Development Fund), and other organisations invest in the agricultural sector of Ghana, yet roads connecting the agricultural corridors receive minimal attention in the investment agendas (Amanor, 2013; Mitric, 2013). Although, these investments are a boon to the economy given the fact that the agricultural sector employs 54.2% of Ghanaians and contributes 22% to the GDP of the country (GSS, 2015), roads are inevitable in Ghana's agricultural development (McIntire, 2014).

The rural dwellers in Ghana constitute 49.1% of the country's population, and 73.5% are farmers (GSS, 2013a). The quality of the roads (improved/paved or unimproved/unpaved) partly determines the kind of economic activities and the farming practices adopted in rural Ghana (Angmor, 2012). Out of the 24.2% of the poor people in Ghana, farmers in the rural areas constitute 78% (GSS, 2014f). These farmers are poor because they produce on subsistence basis due to the fear of post-harvest losses alongside other constraints. One reason could be the inability to convey harvested produce to marketing and manufacturing centers on time (Codjoe & Owusu, 2011). This constraint might stem from poor road networks which become inaccessible especially in rainy seasons (Badu et al., 2013). However, the impact of roads on farming activities in rural Ghana has received limited research in the refereed literature. The first part of this research seeks to examine the influence of roads on farm size and famers' market participation in rural Ghana.

Agricultural expansion is one of the major causes of deforestation in the tropics (Gibbs et al., 2010). Roads built through forest habitats lead to forest fragmentation (Laurance,

Laurance, & Goosem, 2009). Sloan and Pelletier (2012) projected forest cover change for Panama using 25 drivers. Four of these drivers related to distance to road types while seven related to farm activities and conditions. Their findings revealed that distance to roads, farm scale, proportion of agricultural land in forest, farm machines used, etc. determine the rate of deforestation. In Ghana, the main causes of deforestation are: farming, logging, and charcoal production (Ahenkan & Boon, 2011; Benhin, 2006; Boafo, 2013). Despite the research undertaken on the drivers of deforestation, the scale of farm expansion into forests and the spatial changes in forest cover with proximity to roads has not been researched in Ghana. The second part of the research examines the causes and extent of forest cover change along roads in rural Ghana.

1.2 Research questions

This research is based on the hypothesis that farmers that have access to improved roads are able to market their farm produce, access farm inputs, and intensify farming thereby reducing pressure on forests. The research provides answers to the following questions.

i. To what degree do roads influence farm size and market participation of different typologies of farmers?
ii. What factors contribute to forest cover change in Ghana?
iii. To what extent does forest cover change along roads in Ghana?

1.3 Justification for the research

Improved roads are promoters of rural development: increasing non-farm employment increasing farmers' income, and improving the livelihoods of rural people (Senadza, 2012). Improvement in road infrastructure in agricultural areas may have several multiplier effects (Nair & Kumar, 2006) which have not yet been fully examined. Through this research, how improved roads influence farmers to commercialise their produce would be known and it would serve as one of the documents concerning road infrastructure as a determinant of livelihood strategies and farming system dynamics. The findings would facilitate further research in the agriculture and road development and serve as one of the basis to encourage the development of transport corridors in agricultural frontiers in Ghana and other African countries.

According to Ackah (2013), about 80% of agricultural produce and other raw materials in developing countries are obtained from the rural areas. Most of these farmers, especially in Sub-Saharan Africa, produce to feed their households and they use forestlands as land banks to increase their production when the existing farmland loses its fertility (Owubah, Donkor, & Nsenkyire, 2000). This research would show the extent to which improved roads could transform agriculture to benefit farm households and the economy of Ghana while reducing pressure on forests. The findings of the research would serve as an advocacy for support from development partners who are interested in rural development to consider roads' improvement in line with agricultural transformation projects.

1.4 Scope of the research

The research covers five districts in three regions of Ghana (see chapter 3 for the details). The regions and their districts are: Brong Ahafo region (Techiman Municipality), Ashanti region (Offinso Municipality, Offinso North district), and Western region (Amenfi West district, Bibiani-Anhwiaso-Bekwai district). These districts are some of the major agricultural production corridors in Ghana. They produce all sort of food crops both for consumption and commercial purposes. This is largely attributed to the vast fertile lands in those areas.

There is a concentration of road networks in these five districts under study. The districts selected from Brong Ahafo and Ashanti regions have access to improved roads connecting them to other parts of the country while the districts in Western region shows the opposite scenario; this selection was done to make comparative analyses possible. Agriculture and related trade is the main economic activity in the study districts. About 70% of the active labour force is engaged in agriculture. The major food crops grown are yam, maize, cassava, cocoyam, and plantain. Vegetables such as tomato, eggplant, onion, groundnut, and okra as well as cash crops such as cocoa, cashew, and oil palm are also cultivated in the study districts.

1.5 Overview of research methods

Field survey was undertaken in 10 communities from the five selected districts. These communities were selected for two main reasons. First, they are located along the main roads connecting the districts. Second, they are among the communities that transport most of their agricultural produce to the central markets during the weekly market days. Three hundred farmers (30 from each community) were selected for interview. The selection criterion is detailed in chapter four. Questionnaires were used to obtain information from the farmers about their farming operation and some household variables. Geographical Positioning System (GPS) device was used to pick the locations/ communities of the various farmers for spatial analysis.

More than 70% of the households in each community were farmers at the time of the survey, hence, the main prerequisite for a household to be part of the sample was to be a farm household. Within each community, the first farm household was randomly identified through asking. Subsequent farmers were identified accidentally through asking or through the previous farmer interviewed until the required number of farmers for each community was reached. The interview was face-to-face with only the farmer. Linear regression was used to analyse the data obtained from the farmers. This was done to quantitatively determine the influence of roads on farm size and extent of commercialisation in the study communities. The details of the regression variables and results are stipulated in chapter four.

Forest cover change along roads in the study area was mapped using Landsat satellite images for the years 1986, 2002, and 2015 downloaded from the Landsat archives. These images were pre-processed, mosaicked, and subset with the map of the study area. The images were then classified into four main land uses: forest, agriculture, artificial surface, and bare ground/ dry grass. The classified images were used for spatial analysis using ENVI 5.3 and ArcGIS 10.2.1 software. The spatial analysis process and results have been detailed in chapter five.

1.6 Organisation of thesis

The thesis has been structured into six chapters. Chapter one presents the general overview of the research laying emphasis on the background to the study. The chapter then presents the objectives of the research, the scope, and methodology adopted for the research. It ends with the general organisation of the thesis.

Chapter two reviews literature on roads, agriculture, and forests in developing countries. The chapter discusses from various dimensions whether or not roads in forest frontiers are the main drivers of deforestation. The chapter also elaborates on the relationship between roads and agricultural development. It finally draws the nexus between roads, agricultural development, and forest conservation in developing countries.

Chapter three presents the profile of the study area. The chapter briefly describes Ghana, the study regions, and districts in the context of population, land area, vegetation and climate characteristics, and farming practices. The demographic, social, and economic characteristics of the farmers interviewed are also presented in chapter three.

Chapter four focuses on the quantitative aspect of the research. It uses regression techniques to analyse the degree to which roads influence farm size and market participation of the smallholder farmers interviewed. The chapter also presents the typology of the farmers using cluster analysis.

Chapter five details the spatial analysis aspect of the research. The chapter spatially presents the remaining forest cover in the study area over a 29-year period (1986-2015). It also presents the spatial drivers of forest cover change and the patterns of deforestation along roads in the study area.

Chapter six summarises the major findings of the research. It presents a summary of recommendations for roads improvement towards agricultural transformation while conserving forest and biodiversity. Areas of further research are highlighted and the conclusion of the research is presented in this chapter.

CHAPTER TWO

IMPACT OF ROADS ON FOREST AND AGRICULTURE IN DEVELOPING COUNTRIES: LITERATURE REVIEW

2.0 Overview of chapter

This chapter presents scenarios of the relationships between roads, forest, and agriculture in developing countries. The chapter partly lays emphasis on the objectives of the research stated in chapter one. That is, this chapter attempts to review relevant literature related to how roads influence farming and forest cover change especially in developing countries.

2.1 Introduction

Roads are one of the important infrastructural facilities that promote economic growth and development. In the developing world, where accessibility to areas of economic activities such as market centres mostly determine the livelihood strategies of people, roads are given high priority in development agendas (Duval, 2008; Simuyemba, 2000). Access to roads promotes efficient natural resource exploitation and human settlement development. These attributes of roads bring about economic development that may support poverty reduction (Laurance et al., 2006; Wilkie et al., 2000). In Africa for instance, some farmers have access to extensive areas of arable land but produce low agricultural output. One reason could be that most of these farmers have limited access to agricultural inputs and modern farming technologies due to inaccessible roads (Mueller et al., 2012). In such circumstances, road improvement (where roads exist), and construction of new roads to connect agricultural areas to market centers would be an enhancing factor to increase agricultural production (Laurance & Balmford, 2013; Weinhold & Reis, 2008). Farmers would also be able to transport agricultural produce to the market, and import fertilizers and other farm inputs. Agricultural extension agents would be able to extend modern farm practice training to farmers in remote areas. Accessibility to roads and its multiplier effects (employment generation, reduced transport cost, market opportunities, etc.) could enhance the livelihoods of farmers (Rudel et al., 2009), all other things being equal.

Roads do not always have positive attributes (Hoskin & Goosem, 2010). When inadequate before-, during-, and after-road environmental protection measures are put in place, roads could influence human activities that fragment forests, hence posing threats to ecosystems (Laurance et al., 2006). They could also encourage the spread of weeds and cause erosion if no maintenance measures are put in place. Roads are one of the major factors that influence land cover change and land use patterns across the globe. In the Brazilian Amazon for instance, more than 95% of deforestation takes place within 10km distance from roads (Laurance, 2013). Despite their negative attributes, once roads are extended into remote areas, they promote in-migration and enhance economic development through profitable human activities (Arima, Walker, & Perz, 2005).

There are different schools of thought concerning roads and their attributes. Some Environmentalists and Ecologists oppose expansion, extension, or construction of new roads especially in areas of rich biodiversity. The reason is that roads fragment forests, increase tree mortality, endanger wildlife habitat, and threaten the extinction of endangered species (Hoskin & Goosem, 2010; Laurance, Laurance & Goosem, 2009; Laurance, 2009; Laurance et al., 2014). Some Economists, Development Planners, and Sociologists on the other hand favour the expansion, extension, or construction of roads due to the various benefits the construction comes with: foster livelihood development, open access to job opportunities, promote extension of services into previously inaccessible areas, and enhance community development with its resultant poverty reduction (Laurance, Laurance & Goosem, 2009; Perz et al., 2012). Others also argue that roads trigger agricultural transformation through farm intensification which reduces the land area needed for more production, thereby releasing pressure on nature (Foley et al., 2013; Sayer & Cassman, 2013). These and other varied views on roads have created a fulcrum of disagreement on whether or not to favour roads construction, expansion, or extension.

Global road network is projected to increase by 60% by 2050 of which 90% is expected to occur in developing countries (Dulac, 2013). Most of these nations host vital biodiversity and ecosystem services (Laurance et al., 2014). Road construction in most developing nations is poorly planned and the rate of expansion poses a challenge to the capacity of environmental planners and resource managers (Fearnside & de Alencastro Graça, 2006). Although, roads benefit human and societal development in varied ways, poor planning for their expansion or construction could bring about negative environmental consequences. As global food demand is expected to double by 2050, the expected increase in road network is regarded as a prerequisite for increased agricultural production to meet the mid-century food demand (Laurance et al., 2014). Road expansion and construction do not facilitate agricultural production only, but also several other features such as access to natural resources (e.g. forests, minerals), transnational trade, and energy infrastructure development (Forman, 2002). Roads could therefore be thought of as both good promoter of development and an agent of environmental destruction based on how, why, and where they are constructed.

The benefits from forests to mankind and societies are enormous. Forests provide food and firewood to rural dwellers (Appiah et al., 2009). Most people living in forest fringe communities transport non-timber forest products (NTFPs) to the market for sale and this contributes between 20% and 40% to their household income (Shackleton, Shackleton, & Shanley, 2011). Timber and other wood processing industries depend on forests for their raw materials. Roads are used to transport these raw materials to the factory. The global community benefits from the recreational parks, biodiversity conservation, carbon storage, climate regulatory functions, and other ecosystem services of forests (Sayer & Collins, 2012). Without access to roads, the livelihood activities of rural dwellers and other forest related jobs might be in jeopardy.

Conserving forests while improving the livelihoods of forest- and forestland-dependents has been a major challenge to the global community (Sayer, Byron, & Petrokofsky, 2014). This is because the major economic activity undertaken by people in tropical developing nations, especially in the rural areas, is farming. Most agricultural activities are carried out in formerly forest or savannah areas, making the expansion of agriculture inversely related to the conservation of forest. However, farming can be practiced in such a way that it would have minimal negative impact on forest cover. Practising farm intensification is one of the means of increasing yield without expanding farm size. Farmers could even be encouraged to farm on deforested areas to grow trees amidst food crops as a way of forest regeneration. Roads in this case would play major role in agricultural production, and to some extent, forest regeneration as foresters could extend tree planting programs to farmers living in forest zones. This means that while the livelihoods of farmers are improved through access to improved roads, farm intensification, non-farm employment, and market opportunities, degraded forests could be regenerated through tree-crop planting programs.

This chapter seeks to review how roads influence agricultural activities and its consequence on forest cover in tropical areas. The chapter focuses mainly on research works related to road construction/expansion, forest conservation, and agricultural production in the Brazilian Amazon and African countries such Congo, Cameroon, and Ghana. Although, some other developing countries in Africa and the Asia-Pacific (e.g. Papua New Guinea, Indonesia) would be referred to at some point, the majority of the review focuses on research works related to the Brazilian Amazon and the Congo Basin. The reason is that, these two tropical zones have vast forest cover with rich biodiversity, and the rate of deforestation and biodiversity loss in these areas have been well researched.

The rest of the chapter is divided into four sections. The first part reviews research works on roads, forests, and biodiversity. This section assesses from different scenarios whether roads are the core cause of deforestation and biodiversity loss or other causative agents (factors) trigger the necessity for roads, thus, making roads indirect cause of deforestation. The second section focuses on the impacts of roads on agriculture. The third section presents the converging point between roads, forests, and agriculture. The final section suggests recommendations for environmental sustainability and agricultural production in the midst of roads improvement or construction.

2.2 Roads and forests in developing nations

The drivers of deforestation have been changing over time. In the 1980s and 1990s, forest cover loss was attributed to increasing human populations that were engaged in small scale subsistence farming (Rudel, 2005; United Nations, 2011). Although, this farming practice continues to be one of the drivers, industrial drivers of deforestation such as large scale (extensive) farming, plantation expansion, extensive logging, oil, gas, and mineral projects, have gained significant recognition (Butler & Laurance, 2008; Rudel et al., 2009). These drivers, which serve as economic activities for many people, fuel the proliferation of roads in forest frontiers (Laurance, 2013). Roads are required to transport farm produce to processing and marketing centers. Roads are required to transport logs to timber and wood processing industries for value addition. These economic activities would not survive without roads. Roads therefore facilitate the continued operation of the drivers of deforestation. However, stopping road development would put the livelihoods of the users, especially farmers, at risk.

Boakes et al. (2010) states that the best way to conserve biodiversity is to avoid building roads through the forest. Many roads have penetrated, and are continuously extending into most of the world's biodiversity-rich zones including the Amazon, the Congo Basin, New Guinea, and Siberia for various reasons (Laurance & Balmford, Fearnside & de Alencastro Graça, 2006; 2013). Roads open up the forest for exploitation at the expense of biodiversity conservation. However, it is not the construction of roads that poses the greatest threat to forest and biodiversity loss, but how and where it is constructed as well as the environmental management measures put in place before, during, and after the construction works (Suarez et al., 2009; Wilkie et al., 2000). Many road construction plans in developing countries are backed by weak environmental laws especially in remote areas (Fearnside, 2007; Reid & De Sousa, 2005). When environmental laws are strengthened, roads could still be constructed or expanded with minimal consequence on forest and biodiversity.

2.2.1 The Brazilian Amazon scenario

The driving forces of road construction in Brazil are based on regional and local agendas. The regional agenda for road construction is spearheaded by the government to improve accessibility to resource areas for national development purposes. In the local context, people extend roads to resource rich areas for their benefits (Wood, 2002). In the Amazon basin, governments build roads to enhance spatial connectivity of settlements and increase accessibility to markets by the working population. However, timber companies build secondary road networks to link the primary roads to forest areas for easy transportation of timber (Arima et al., 2005).

The Brazilian forest cover has decreased from 546,705,000ha in 1990 to 493,538,000ha as at 2015, representing 0.4% annual deforestation rate (FAO, 2015). The benefits from the Amazon have led to an increasing rate of logging annually. For instance, from 1996 to 1999, the annual rate of logging increased from 9,400km^2 to 23,400km^2, accounting for about 150% increase in forest clearing (Matricardi et al., 2001). Forest clearing through logging is accompanied by secondary road networks' expansion. It could be said that forest clearing in the Amazon has not been influenced by the existence of the main highways. The benefits derived from logging makes loggers construct secondary roads to link the main roads for their transportation purposes. Roads in the Amazon basin were constructed to facilitate movement between settlements, enhance livelihood development through engagement in myriad economic activities, and propel settlement development through the extension of other services and facilities to previously inaccessible areas.

Individual private interests linked to road construction in the Amazon then lead to deforestation. These private interests are effectively facilitated by the lack of or the weak enforcement of environmental laws.

The Transamazon Highway (Figure 2.1) for instance has experienced massive extensions by large logging firms after its construction in the 1970s (Arima et al., 2005). These firms construct secondary road networks to link their concession sites to the main highway. The road extensions are not necessarily problematic in themselves because they may improve accessibility for nearby communities. The problem lies in how these secondary roads are constructed, and the purpose for their construction. Since the loggers construct the secondary roads for their operations, logging becomes intensive along the roads causing serious impact on ecosystem services. Despite the negative impacts of the logging activities on biodiversity, which is almost always linked to the existence of the roads, other people's livelihoods are improved through the extension of the roads. Farmers along the secondary roads are able to access markets, and other people get employment from the logging firms as well. Roads construction is therefore not always detrimental to the environment; it depends on the objective with which they are constructed and how they are managed.

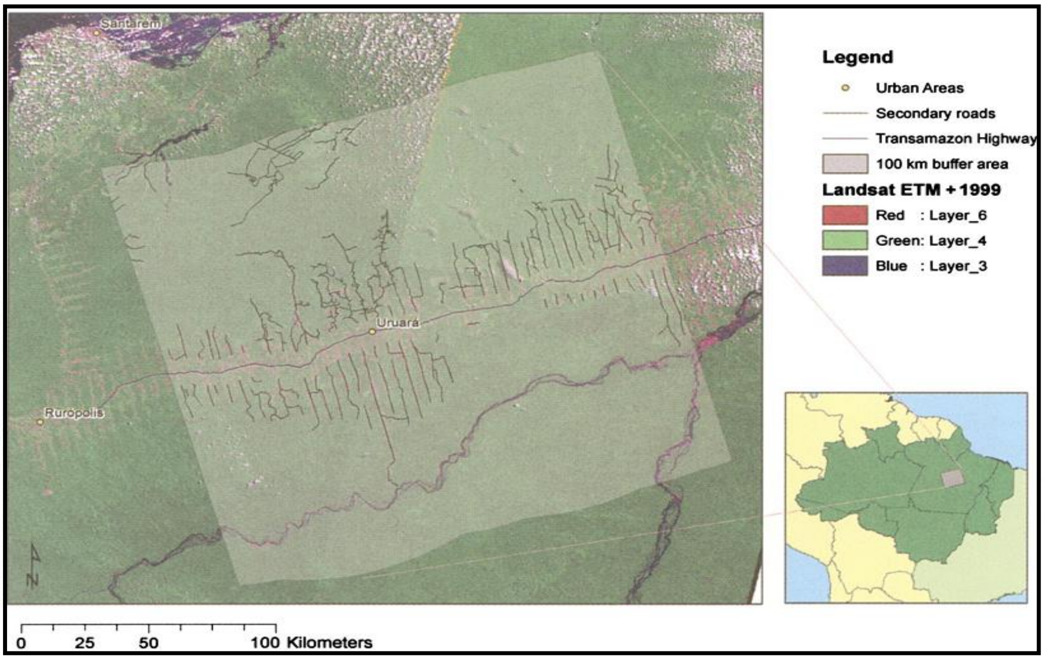


Figure 2.1: Secondary roads in a 100km buffer along the Transamazon Highway

Source: Adapted from Arima et al. 2005.

Research predicts that roads would be the greatest factor that would influence future deforestation trends in the Amazon (Nepstad et al., 2006; Soares-Filho et al., 2006). The reason authenticating this prediction is that, mining, logging, farming, hunting, and other infrastructure expansion occur along roads (Gibbs et al., 2010), all of which cause deforestation (see Plate 2.1). A point to note, however, is that all the factors of deforestation associated with roads occur for the purpose of livelihood development: farmers, loggers, miners, etc.

Plate 2.1: Forest clearing along roads in the Brazilian Amazon

Source: http://photos.mongabay.com/sat/americas/br_230-400.jpg (Accessed: 28/12/14)

Protection of forests and biodiversity is important for ecosystem services; arguably, at least as important as enhancing livelihood development. Many animal species are killed through collision with vehicles, and from human hunting for survival (Goosem, 2007). People need roads to travel to their work sites. Farmers need roads to transport their farm produce to marketing centers. With roads and effective environmental laws, human livelihoods especially farmers, would improve while forest and biodiversity are conserved.

2.2.2 The African scenario

Africa has been experiencing annual deforestation rate of 0.56% since 1990 (FAOSTAT, 2015). The causes of deforestation in the African continent are several but similar in almost all tropical African countries. In the 1980s, Stryker et al. (1989) found that the increased producer prices of export crops triggered the clearing of more forests for crop cultivation in Sudan. In the 1990s, Angelsen and Kaimowitz (1999) found that the increased prices of annual crops led to significant deforestation in Tanzania. Similar cases occurred in Cote D'Ivoire and Cameroon where increases in the prices of export and other cash crops contributed to the clearing of more forests (Gbetnkom, 2005; Sunderlin et al., 2000).

Increase in the prices of cocoa, coffee, food crops, and timber, and reduction in the prices of fertilizers in the 1990s caused more forest clearings in Ghana. Perhaps, the farmers had limited knowledge about agricultural intensification although they had access to subsidized fertilizers. Even before the 1990s, some studies show that devaluation in Ghana encouraged loggers to intensify tree felling to reap the most benefit from the timber industry (World Bank, 1994). Similar evidence were recorded in Malawi, Botswana, and Cameroon (Gbetnkom, 2005). None of these causes of deforestation were linked to road construction or expansion in the above-mentioned countries. This implies that agricultural activities contribute to deforestation more than the construction or expansion of roads in most African countries.

West Africa had vast area of tropical rainforest within the Guinean Forest Hotspot of Biodiversity at the beginning of the 20th century (Mittermeier et al., 2004). Unsustainable timber exploitation, expansion of tree crop farms, and slash-and-burn agriculture have destroyed a significant proportion of the tropical rainforest (Norris et al., 2010). In terms of moist tropical forests coverage in the world, Central Africa comes second to the Brazilian Amazon covering about 2,000,000km^2 (Verhegghen et al., 2010). The Central African forest zone provides home for about 12 million rural people, almost 80% of who are slash-and-burn cultivators (Duveiller et al., 2008). The livelihoods of these rural dwellers depend on the resources the tropical forests provide (Céline et al., 2013) as well as the forestland available to them for farming. These survival activities are major causes of deforestation in forest frontiers of Central Africa.

The Congo basin, well recognised in Central Africa for its forests and wildlife conservation, hosts the second largest primary forest in the world after the Amazon (Sanderson et al., 2002). Similar to other parts of Africa, the primary cause of deforestation in the Congo Basin is agriculture, mostly through shifting cultivation (Norris et al., 2010). It is predicted that agricultural land demand in the Congo Basin would double in the next 20 years; this is due to lack of incentives for agricultural intensification and the rate of population growth (Wilkie et al., 2000; Zhang et al., 2006).

This would happen at the expense of forest cover since slash-and-burn farmers do not have the capacity to convert non-forest lands to agricultural uses.

Forest lands provide suitable soil for farmers in the Congo Basin to undertake their activities. Once the fertility of the soil is lost, the farmers shift to another fertile forest land to survive. Although forest fragmentation is well evident along the road networks in the Congo Basin (Céline et al., 2013) the roads are not the main cause of forest fragmentation, but rather extensive agricultural activities (Rudel, 2005), logging, and mining exploration (Mazalto, 2009). As long as farmers in the Congo Basin do not have access to agricultural intensification programs, forest fragmentation would continue.

In the remote regions of the Congo Basin, where logging concessions are furthest away from ports, roads play a vital role to timber companies**.** The profitability of timber companies depends on the existence of high quality roads. Secondary roads become a prerequisite for timber companies to have easy access to their concessions (Wilkie et al., 2000). Logging roads constructed in the Congo Basin span 52,000km (Laurance et al., 2009). The construction of these secondary roads also enable nearby farmers to transport their farm produce with relative ease. Farming activities, mining explorations, and timber extraction, all started in the Congo Basin before the proliferation of secondary road networks (Duveiller et al., 2008). Roads are therefore seen as secondary factors of deforestation in the Congo Basin but a major factor in enhancing the livelihoods of dwellers in the forest frontier. Roads are very important in all economic activities. Roads construction however pose significant environmental consequences depending on the objectives for their use.

Aside from the deforestation in Africa and Brazil, many forests in the Asia-Pacific have been depleted through industrial logging, penetrating the forests with poorly planned roads. The unplanned nature of the roads cause several negative impacts on biodiversity like killing of animals by the roadside, fragmentation of the forest, and extinction of some species (Perz et al., 2008; Pfaff et al., 2007) which could have been prevented if proper environmental measures were put in place before, during and after the road construction.

The emergence of roads and their proliferation facilitated the phenomenon known as the Pandora's Box Effect (Laurance, 2009). Both legal and illegal mining activities are carried out near roads, and poorly planned secondary roads are constructed to the actual mining sites to facilitate transportation. Paved roads have much greater impacts on forests and wild life than unpaved roads (Fearnside, 2007; Soares-Filho et al., 2006). This is because paved roads provide all-year round access to forests, unlike unpaved roads that become inaccessible in the wet season. However, paved roads favour dwellers in the tropics since they can carry out all their economic activities with ease without any hindrances posed on them by road access. This review would argue that what is needed is strict enforcement of construction regulations and environmental laws, and not the cessation of road construction and/or improvement.

2.3 Roads and agriculture in developing nations

Agriculture is the predominant rural economic activity in most African countries. In Sub-Saharan Africa, about 70% of the active labour force is involved in Agriculture (AGRA, 2013). In rural Africa, 70% of the population rely on farm income for their survival while 30%-40% rely on other rural non-farm activities as a complement (FAOSTAT, 2015). However, agricultural development in rural Africa is constrained by poor infrastructure development, especially roads, which increases the prices of inputs such as fertilizers, discourages technology adoption, and results in poverty (Neumann et al, 2010).

Aside from employment creation for majority of the labour force, the agriculture sector contributes over 30% to the GDP of most developing nations (World Bank, 2015). Feeding a population of 5.5 billion in low income countries (Dethier & Effenberger, 2012) and ensuring continuous contribution to GDP of developing countries requires the agricultural sector to be transformed and one means is the improvement of infrastructure such as roads.

2.3.1 Farming practices in Africa

There is a myriad of farm practices in Africa: mixed cropping, mixed farming, mono cropping, commercial farming, subsistence farming, shifting cultivation, crop rotation, among others. Research shows that about 183 million hectares of land are under cultivation in Sub-Saharan Africa (SSA) while over 450 million hectares of additional suitable parcels have not been cultivated (Alexandratos & Bruinsma, 2012). Most of these lands are owned by smallholder farmers with average farm sizes of about 2 to 2.5 hectares (Salami, Kamara, & Brixiova, 2010). Population growth in most SSA countries has led to the expansion in cultivated lands and the reduction in average farm sizes. In countries such as Mali, Sierra Leone, Burkina Faso, Ghana, Malawi, Niger, Ethiopia, and Mozambique, the area under cultivation has expanded more than 50% between 1990 and

2011 (FAO, 2013). This cultivated area is mainly under smallholder agriculture with significant yield gaps due to rural infrastructure development constraints, high input prices, and low technology. Although, cultivated lands are expanding, average farm sizes are reducing (see Table 2.1).

Table 2.1: Agricultural lands and farm sizes for selected countries in SSA

Country	**Agricultural land in 2011[a]**	**Cultivated land in 2011[b]**	**% Change in cultivated land (1990-2011)**	**Mean farm size (Ha)[c]**
Mali	41,621,000	6,981,000	228.8	5.5
Sierra-Leone	3,435,000	1,235,000	98.9	-
Burkina Faso	11,765,000	5,765,000	61.2	5.5
Ghana	15,900,000	7,600,000	58.3	3.5
Malawi	5,580,000	3,730,000	56.9	1.0
Niger	43,782,000	15,000,000	53.3	4.0
Ethiopia	35,683,000	15,683,000	48.8	-
Mozambique	49,400,000	5,400,000	46.7	2.0

[a]Arable lands suitable for cultivation; [b]Arable lands cultivated; [c]AGRA Baseline studies, 2009-2010

Source: Adapted from Alliance for a Green Revolution in Africa (AGRA) (2013).

Smallholder farmers own 80% of all the farms in SSA and contribute up to 90% of agricultural production in some SSA countries (AGRA, 2014). Studies conducted in Botswana, Kenya, Malawi, and Zimbabwe showed that 76%, 85%, 90%, and 80% of the rural population respectively depends on subsistence agriculture for their livelihoods (Ngigi & Denning, 2009). About 175 million people in SSA are smallholder farmers of whom 70% are women (AGRA, 2014). These farmers normally grow on subsistence basis because they do not have access to financial and agricultural inputs needed to embark on intensive farming. Due to high transport cost resulting from poor road conditions, inaccessible roads, and other limitations, smallholder farmers in SSA mostly do not market their farm produce (AGRA, 2014). Since these hindering factors lock farmers in subsistence agriculture, rural poverty is 53% in SSA (Rosen & Shapouri, 2012). Rural poverty is also attributed to the decreasing farm sizes: the smaller the farm size, the lower the income of the household as not much produce are sold. Improving roads in rural SSA would serve as a fulcrum for agricultural and livelihood development through the marketing of farm produce, the ability to acquire farm inputs, and the capacity to intensify farming.

2.3.2 Influence of roads on farming in developing countries

The increasing world population especially in developing countries requires a corresponding increase in food production to meet the food demand of the people (Tilman et al, 2011). There are however biophysical and environmental concerns that limit yield increment. Agricultural expansion and intensification is limited by inadequate infrastructure, poor access to inputs, and institutional obstacles (Phalan et al., 2011; Sayer & Cassman, 2013). The ability to recognise the need for infrastructure development and improvement, and its associated improved access to farm inputs and modern technology would help meet future food demand for the growing global population. Roads are one of the main development factors through which all other enabling factors such as access to markets, financial institutions, and modern farm technology are made available to farmers. Financial institutions would not invest in areas with difficult road access. Agricultural extension agents would not be able to extend their training programs to areas that are inaccessible. Farmers in hinterlands with poor roads are discouraged from cultivating for commercial purposes since they cannot market their produce. Although, roads have other negative impacts, the benefits derived from roads in agricultural areas especially in SSA significantly outweigh the negative impacts depending on the underlying land use models and principles (Soares-Filho et al., 2006).

Roads are constructed to enhance growth and development in all productive sectors (Perz et al., 2008). Depending on the reasons for constructing the roads, they can be beneficial or detrimental (Perz et al., 2007). If the purpose of roads construction is to promote local and national development and enable people to improve upon their livelihoods such as farming, with minimal impacts on the environment, then roads become beneficial. In many African countries, farmers encounter huge post-harvest losses (~40%) due to inability to market their produce on time (Foley et al., 2013). In the rainy seasons, farmers in the hinterlands with unsealed/unpaved roads are unable to get vehicles to transport their produce to the market centers. Transport operators are not willing to go to such hinterlands as they consider the roads risky in the rainy season (see Plate 2.2). Farmers who manage to get their produce to market centers incur high transport cost which leaves them with almost no profit from their farming activity. Road building and agricultural expansion in most cases are directly related, causing forest fragmentation (Koh & Wilcove, 2008; Rudel, 2005). However with strict enforcement of environmental laws, improved farm technologies, farm intensification, land sparing, and land sharing practices, road building would have minimal environmental consequences but bring significant benefits to livelihood and community development.

Plate 2.2: Poor roads in rural Ghana

Source: Retrieved from google.com on 5/02/2016

https://www.google.com.au/search?q=poor+roads+in+Ghana&tbm=isch&tbo=u&source=univ&sa=X&ved=0ahUKEwjlp9HqieDKAhVGPKYKHSg4B-cQsAQIGw&biw=1280&bih=923

Access to improved roads could increase agricultural production in many areas in all continents with minimal environmental costs. Globally, 1.46 billion hectares of land (12.3% of global land area) stands potential for future increase in agricultural production (Laurance et al., 2014). These potential lands that are spread across all regions cannot be put into optimum agricultural use without roads because roads support all the enabling factors of agricultural production. Roads linking existing agricultural areas to market centers actually have the potential to reduce deforestation because farmers would be inclined to move towards already human dominated areas where they have easy access to most of the inputs for their farming activities (Laurance, Sayer, & Cassman, 2014; Weinhold & Reis, 2008). Farmers who have access to improved roads would mostly patronise agricultural intensification thereby producing more yields from the same piece of land without necessarily clearing additional lands for farming. This is because these farmers would have access to modern farm technologies through extension agents; farm inputs through marketing and credit facilities, and ready market for their produce. Farmers in the hinterlands with poor road access might face the opposite scenario.

2.4 Roads, agriculture, and forests: The nexus

The world is looking towards putting the remaining arable lands in the tropics into sustainable use to meet increasing agricultural demand (Gibbs et al., 2010). To meet the food demand by 2050, agricultural expansion, intensification and modernisation are required. This goal would not be fully realised without access to improved roads for transportation, marketing, and related purposes associated with agricultural activities. It is an established fact that agricultural expansion is a leading driver of deforestation (Balmford, Green, & Phalan, 2012; Godfray et al., 2010), but not all expansions lead to the loss of intact forests. Arable lands in Africa are mainly shrubs, pasture, logged or regrowing forests, and degraded lands that serve as potential lands for farming (Koh & Wilcove, 2008). When modern farm practices, land sparing, land sharing (Tilman et al., 2011), and growing of trees amidst food crops are encouraged, there is potential for both sustainable agriculture and sustainable forestry to emerge.

In the last two decades, agricultural activities in developing countries have increased by 3.3%-3.4% annually with gross deforestation increasing agricultural area by 0.3% in the same period (Angelsen & DeFries, 2010). This means that agriculture's role in deforestation is minimal in developing countries although higher in some specific countries. Providing roads in inaccessible agricultural should therefore have a minimal negative impact on forests but a significant positive impact on community integration and development, market operations, livelihood improvement, and overall national development. Agricultural production needs to increase to support the provision of food for the 923 million people who go hungry every evening (FAO, 2008) and keep pace with the increasing population. Access to markets, inputs, alternative sources of income to invest in farming, modern farm technology, among others would continue to be stifled if roads are not improved and extended to the hinterlands. Farmers would move from subsistence shifting cultivation, which increases deforestation, to commercial farm intensification once they have access to the aforementioned farming enabling instruments which come with roads access.

There are two major additional drivers of forest transition: higher non-farm wages and better employment opportunities that pull labour into other ventures more than agriculture while keeping few people in Agriculture to utilise the existing lands (Mather & Needle, 1998). When roads are extended to the hinterlands, investors come in with other non-farm activities, transport operators are able to carry out their freight activities effectively, and market opportunities emerge quickly. Initially, there would be urgency for farm expansion since commercialisation is possible. This expansion would reduce forest cover. But once other employment opportunities emerge and sustainable farm intensification is introduced, the rapid expansion of farms would slow down and gradually stabilise through intensification (Angelsen & Kaimowit, 2001; Rudel, 2005). Farmers would also be able to earn income from other non-farm activities. Livelihoods would improve, community development would follow, and forest cover would stabilise.

Development strategies, especially in Africa, could be carried out effectively with road access if not taking the highest priority, becoming part of the major priorities. Modern farming techniques are not new in this era (Fearnside, 2007; Reid & De Sousa, 2005; Suarez et al., 2009). Application of inorganic fertilizers, improved seeds, mulching, crop spacing, etc. in Sub-Saharan Africa have proven to double and in some cases triple crop yields on the same lands without farm land expansion (Perz et al., 2008; Pfaff et al., 2007). High yields must go with ready market to avoid post-harvest losses. Road extension to inaccessible areas and improvement of existing degraded roads would integrate farm areas to market centers, reduce transport costs, and hence increase the income levels of farmers.

In Ghana, the main causes of forest loss are logging, agricultural expansion, wild fire, mining, and in some areas charcoal production. In Cameroon and Indonesia, among the causes of deforestation are fuelwood extraction, wild fire, logging, and agricultural expansion mainly shifting cultivation (Benhin, 2006). In Papua New Guinea, subsistence agriculture and logging are the main causes of forest loss (Nelson et al., 2014). Wildfires, large-scale mining, and clearing for oil palm and exotic-tree plantations are also causing significant forest loss (Filer et al., 2009). Roads play a minimal role in deforestation in most African countries and other developing countries in the Asia Pacific. They do however pave way for intensive agricultural production. Since smallholder agriculture is the backbone of food security in African countries (Tscharntke et al., 2012), improving and extending roads to inaccessible agricultural areas would not only promote community integration, market opportunities, and national development, but would also ensure sustainable food security in Africa.

Although, tropical forests provide significant ecosystem services to rural dwellers and the world as a whole (Céline et al., 2013), if farmers do not have access to inputs, modern farm technology, and market opportunities, they would continue to practice shifting cultivation, thereby depleting the forest. Access to roads with all its multiplier effects is likely to help conserve forests while at the same time increase farm yields, all other things being equal. It is not only farmers who benefit from roads. Microeconomic studies show significant poverty reduction in communities and towns near to or that have access to improved roads (Gibson & Rozelle, 2003; Perz et al., 2012). Road networks have the potential to reduce poverty because they link towns and communities and support the distribution of goods, services and resources, thereby creating employment opportunities for most dwellers who were formerly not employed.

2.5 Implications for sustainable agriculture and forestry

Agricultural production to meet future food demands is a challenge to forest conservation especially amidst roads improvement. To increase agricultural production with minimal consequences on the environment requires a series of measures. Four main connected recommendations are suggested: Enforcement of environmental laws, agricultural intensification, farmer education on land sparing and land sharing, and tree-crop planting strategies.

2.5.1 Enforcement of environmental laws

Roads remain an integral part of economic development. However, when they are not planned and constructed properly, roads tend to be destructive agents to forest cover and biodiversity. Most highways especially in the Brazilian Amazon have led to deforestation since they were poorly planned and constructed. Avoiding roads in forest or rural areas as a means of conserving the forest would be detrimental to livelihoods and halt community development. Establishing and enforcing laws to protect forests along roads should have a high priority (Fearnside & de Alencastro Graça, 2006; Nepstad et al., 2006).

Evidence from Brazil shows that deforestation along highways with no protected areas is higher than those with protected areas (Butler & Laurance, 2008). In developing countries, it would be efficient to enact forest protection laws to govern the ecosystem first before road construction begins. This would ensure that activities of land grabbers would be minimised along roads passing through forest areas.

2.5.2 Sustainable agriculture through intensification

Once roads are provided to agricultural areas, market opportunities would expand leading to the desire to expand farm sizes at the expense of forests. To counteract this trend while meeting the increasing food demand, agricultural intensification should be supported (Godfray et al., 2010). Some institutions refer to this strategy as sustainable intensification (Tilman et al., 2011) where the same piece of land is farmed with modern technology such that yields would increase more than traditional methods of farming. In 2008, the Alliance for Green Revolution in Africa (AGRA) started the Soil Health Program (SHP) in some Sub-Saharan African countries including Ghana, Ethiopia, Mali, Mozambique, Nigeria, and Tanzania to improve soil fertility to increase yield (AGRA, 2011). As at 2012, over 900,000 farmers have benefited from this program in areas of appropriate fertilizer application, the use of improved seeds, seed planting techniques, among others (AGRA, 2012). Although, this was a pilot project, it might be possible to get most farmers in African countries to adopt farm intensification strategies once they know that the additional produce can be exported to markets at minimal cost.

In most cases, farmers are reluctant to practice modern farm technologies because of fear of post-harvest losses due to marketing difficulties. Most farmers encroach forests gradually to grow on subsistence basis rather than practising intensification that results in additional harvested produce rotting on the farm. If roads to agricultural areas are accessible, then farmers would have access to market ventures after harvest. Roads serve as one of the main decision parameters for farmers in terms of the farming systems they practice.

2.5.3 Farmer education on land sparing and land sharing

Farming does not mean no trees on the land. Farmers should be sensitised on land sparing and land sharing options as a means of conserving forest and enriching the soil at the same time. Agricultural lands are abundant in almost all developing nations, but they mainly consist of forests, wetlands or grasslands whose conversion would mean loss of biodiversity and ecosystem services (Garnett et al., 2013). The best way to farm in these areas is to practice wildlife-friendly farming: land sharing and land sparing. Land sharing means farming without cutting the trees on the farm land, while land sparing is farming intensively on one parcel of land and reserving land elsewhere for conservation (Phalan et al., 2011).

Both land sparing and land sharing approaches may be adopted as biodiversity conservation measures. These approaches do not guarantee total forest conservation but could reduce significantly the environmental impact of farming on forest cover. Establishing how land sharing could produce high yields and multiple ecosystem services should be a prior concern for both environmentalists and economists. How to balance the trade-off between yields and environmental services should also be considered in the context within which land sharing and land sparing are practiced (Garnett et al., 2013).

2.5.4 Tree-crop planting

Land has multiple competing demands the main two being forest conservation, and agricultural production (Godfray et al., 2010). So far as land sharing and land sparing could be practiced, farmers could also be motivated to grow trees in the midst of their crops as well. This would ensure that forest would regrow on degraded lands used for farming. Trees also enrich the soil so if they are planted with food crops, while ecosystem services are earned, high yields would be reaped through the soil enrichment (Fernández-Ondoño et al., 2010). Tree-crop planting has been practiced in some countries as agroforestry schemes with certification (Phalan et al., 2011) and is in a form of organic farming which provides varied benefits to community members.

Yield increase does not guarantee land sparing. Land sharing does not guarantee optimum biodiversity conservation on farm land (Angelsen & DeFries, 2010; Rudel et al., 2009). Both approaches require strategic design and management measures to be effective. Tree-crop planting approach however requires only trees seedlings to be provided to farmers and if possible, some incentives to motivate them to grow the seedlings. Once the trees start maturing, the farmers could again be given other degraded lands to farm on with the same condition of growing trees. Gradually, degraded areas would be forested while agricultural production still goes on with its enabling factors brought by roads. In Ghana, India, and other developing countries, land sharing, land sparing and tree-crop planting are being widely practiced to reconcile food production and biodiversity conservation (Phalan et al., 2011).

2.6 Concluding remarks

Agriculture is the backbone of most developing nations especially African. Agricultural growth is however stunted due to poor road infrastructure in farming areas. Farmers do not practice intensification because they lack the technological know-how due to inefficient agricultural extension services. Although agricultural extension agents are limited in some countries such as Ghana, inaccessible roads deter the available officers from going to most agricultural areas. As a result, traditional methods of farming, which is the main cause of deforestation, predominates. Investment in roads is a priority if agricultural, livelihood, and community development are to be the foci of development policies. Forest conservation is important to secure valuable ecosystem services but it cannot be achieved optimally when traditional farming methods are practiced (Gibbs et al., 2010). Roads are contingent to agricultural modernisation with minimal impact on forest cover through strict enforcement of environmental laws and farmer education.

There are vast expanses of non-forest lands available in developing nations that could be used to increase agricultural production with minimal impact on forests (Koh & Ghazoul, 2010). These lands are underutilised through traditional subsistence farming due to lack of inputs (e.g. fertilisers) and poor access to markets and modern farm technologies. All these challenges are rooted in inaccessibility. Market opportunities are available but most roads linking farming areas to market centers are inadequate and often impassable during the rainy season. Farmers prefer producing on subsistence basis to feed the family rather that going to a commercial scale that would merely result in produce rotting on the farm after harvest when there is no opportunity to get the produce to the market. However, the potential of modernising agriculture to improve farmers' livelihoods, develop communities, and raise national development exists. The pathway to realise this potential is to improve roads in farming areas.

Road development comes with several environmental impacts on ecosystems. There are also numerous benefits attached to roads such as employment generation, market integration, community development, and poverty reduction. Condemning road development at the expense of its benefits, especially in poor rural areas, is likely to result in spatial inequality and increase in poverty gap between rural and urban areas. What is needed are strict laws that would guide where, how and under what conditions roads should be constructed. Enforcing measures to protect forest areas before, during, and after road construction is a major strategy to minimise the impacts of roads on forests while maximising their benefits to mankind.

CHAPTER THREE

CHARACTERISTICS OF THE STUDY REGIONS, DISTRICTS, AND RESPONDENTS

3.0 Overview of chapter

This chapter presents an overview of Ghana, the study area. It attempts to look at the similarities between Ghana and what was found in the literature (chapter 2) in terms of agriculture and forest. The profile of the specific areas studied have also been briefly described.

3.1 Introduction to Ghana

Ghana is located in West Africa on latitude 8°00′N and longitude 2°00′W with a total land area of 238,537km^2. Ghana shares boundaries with three French-speaking countries: Togo to the east, Burkina Faso to the north and northwest, and Côte d'Ivoire to the west. The Gulf of Guinea lies to the south and stretches across a 560km coastline. The country has a population of 24,658,823 with population density of 103 persons/km^2, and 49.1% of the citizens live in the rural areas (GSS, 2013a). There are 10 administrative regions in Ghana (see Figure 3.1) which are divided into 216 political districts.

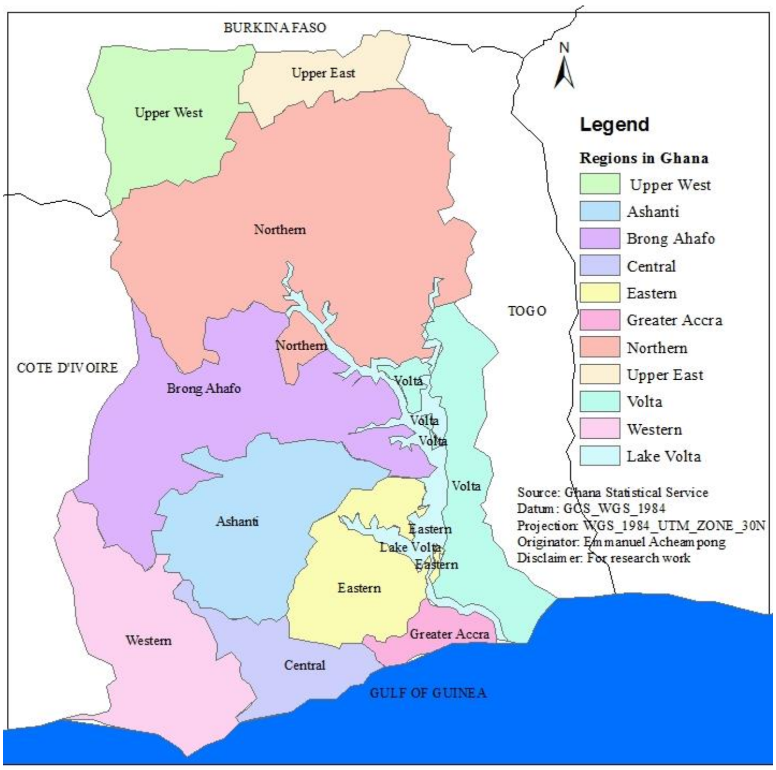


Figure 3.1: Administrative regions of Ghana

Source: Adapted from GSS, GHS, and ICF International, 2015

Table 3.1: Historical trend of Ghana's population

Year	Population	Growth rate	Percentage urban
1960	6,726,815	-	23.1
1970	8,559,313	2.4	28.9
1984	12,296,081	2.6	32.0
2000	18,912,079	2.7	43.8
2010	24,658,823	2.5	50.9

Source: Ghana Statistical Service, 2013a

Ghana has a tropical climate with temperatures and rainfall patterns that vary according to distance from the coast and elevation. The eastern coastal area is comparatively dry, the southwestern part is hot and humid, and the north of the country is hot and dry. The mean annual temperature is 26ºC. There are two wet seasons in the southern and middle parts of the country: the major one from April to June and the minor one from September to November. The northern part of the country has one rainfall season that begins in May, peaks in August, and lasts until September. Annual rainfall ranges from 1015mm in the north to about 2300 in the Southwest (GSS, 2013a).

3.2 Brief profile of the study regions

Three regions were selected for the study: Ashanti, Western, and Brong Ahafo (see Figure 3.1). These regions were selected because they contain the major agricultural production centers in the country and they are connected by major roads some of which are paved/sealed (improved) and others are unpaved (unimproved/earth roads). The following sub-sections describe the selected regions.

3.2.1 Ashanti region

The Ashanti region is the most populous region constituting 19.4% of the country's total population with 60.6% urbanised and having population density of 196 persons/km^2 (GSS, 2013b). Table 3.2 shows the trend of population growth in the region.

Table 3.2: Historical population trend of the Ashanti region

Year	Population	Growth rate	Percentage urban
1960	1,109133	-	25.0
1970	1,481,698	2.9	29.7
1984	2,090,100	2.5	32.5
2000	3,612,950	3.4	51.3
2010	4,780,380	2.7	60.6

Source: Ghana Statistical Service, 2013b

The region occupies a total land area of 24,389km^2, and is centrally located in the middle belt of Ghana between longitudes 0.15°W and 2.25°W, and latitudes 5.50°N and 7.46°N (GSS, 2005). It is the third largest region after Northern (70,384km^2) and Brong Ahafo (39,557km^2) regions. The region is made up of two vegetation zones; the wet, semi-equatorial forest zone covers more than half of the region while the savanna zone covers some portions of the north due to extensive agricultural and other human induced activities. The region has mean annual rainfall of 1270mm and two rainy seasons: April-August and September-November. The periods December to March and mid-August to mid-September are relatively dry. The mean daily temperature is 27°C. The climatic conditions of the region are suitable for the cultivation of most annual and tree crops. There are 412,055 agricultural households, representing 36.6% of the region's total households and 16.5% of the agricultural households in the country (GSS, 2013b).

The households are engaged in either one or more of the following activities: crop farming, tree growing, livestock rearing, and fish farming. Crop farmers constitute 96.8% of the agricultural households, and this is higher than the national average of 95.1%. There are 1,087,342 farms in the region, constituting 16.4% of the farms in Ghana. Cocoa farms represent the highest (22.1%) among the crops grown, followed by cassava (21.6%), plantain (20.1%), and maize farms (11.3%).

3.2.2 Brong Ahafo region

The Brong Ahafo, the second largest region in Ghana after the Northern region, occupies 16.6% (39,554km^2) of Ghana's land area. It is home for 9.4% of the country's population out of which 51.8% live in the rural areas. The region has population density of 58.4 persons/km^2 which increased from 45.9 persons/km^2 in the year 2000. Table 3.3 shows presents the population trend of the region.

Table 3.3: Historical population trend of the Brong Ahafo region

Year	Population	Growth rate	Percentage urban
1960	587,920	-	15.6
1970	766,509	2.7	22.1
1984	1,206,608	3.3	26.6
2000	1,805,408	2.5	37.4
2010	2,310,983	2.3	44.5

Source: Ghana Statistical Service, 2013c

The mean temperature of the region is 23.9°C and it has a double maxima rainfall pattern with annual rainfall averaging 1400mm. The main vegetation types in the region are the moist semi-deciduous forest mostly in the southern and south eastern parts, and the guinea savannah woodland predominant in the northern and north eastern parts. The moist semi-deciduous forest zone is conducive for the production of cash crops, such as cocoa and cashew. Other cash crops grown in the forest zone are coffee, rubber and tobacco. The main food crops grown are maize, cassava, plantain, yam, cocoyam, rice, and tomato.

Agriculture employs 68.5% of the active labour force in the region and they are engaged in the same agricultural activities as that of the Ashanti region. Crop farming employs 96.6% of the agricultural households in the region. Described as the 'bread basket' of Ghana, the region contributes about 30% of the local food requirements of the country (GSS, 2013c, p. 12).

3.2.3 Western region

The Western region houses 9.6% of Ghana's population (2,376,021) out of which 57.6% live in the rural areas. The region's population density is 99.3 persons/km^2, an increase of 23.5% from that of the year 2000 (GSS, 2013d). See Table 3.4 for the population trend.

Table 3.4: Historical population trend of the Western region

Year	Population	Growth rate	Percentage urban
1960	626,155	-	24.7
1970	770,087	2.1	26.9
1984	1,157,807	3.0	22.6
2000	1,924,577	3.2	36.3
2010	2,376,021	2.0	42.4

Source: Ghana Statistical Service, 2013d

The Western region is located in the south-western part of Ghana, and covers an area of approximately 23,921km^2, about 10% of Ghana's total land area. The relief of the Western region is classified as the forest dissected plateau falling between 240m and 300m above sea level with isolated hills (Dickson & Benneh, 2001). Aside from its mineral deposits, the region is the wettest part of Ghana with a double maxima rainfall averaging 1600mm per annum. The two rainfall peaks fall between May-July and

September-October; but practically, there is no month without rain in the region (GSS, 2013d). There are two main climatic zones: the south-western equatorial and the wet semi-equatorial, all characterised by moderate temperatures ranging from 22°C at nightfall to 34°C during the day. Relative humidity ranges between 70% and 80% all year round. The region has about 75% of its vegetation within the high forest zone of Ghana. The remaining vegetation is made up of the tropical rain forest, interspersed with patches of mangrove forest, high tropical forest, and semi-deciduous forest (GSS, 2013d).

There are myriad economic resources in the region. First, it produces over 50% of the total cocoa production in the country. Second, it is the highest producer of timber and the second highest producer of gold after Ashanti Region. Third, it is the only region that produces rubber, bauxite, and manganese in huge quantities and has recently been producing crude oil. However, agriculture remains the major economic activity in the region employing more than half of the households especially in the rural areas. The region has 46% (11,000km^2) of its land area suitable for agriculture. Four types of farming are practiced in the region. These are: crop, tree, livestock and fish farming. However, 90% of the agricultural households are crop farmers. There are 614,106 farms in the region and this is made up of 65 different crops. The predominant crops based on the number of farms are: cocoa (37.9%), cassava (23.1%), plantain (15.5%), oil palm (6.9%), cocoyam (2.9%), yam (1.9%), maize (1.9%) and coconut (1.9%) (GSS, 2013d).

3.3 Brief profile of the study districts

Five districts (in the three regions described in section 3.2) were selected for the study based on their similar characteristics in terms of the mixed vegetation cover, agricultural domination, rural nature, and condition of roads connecting them. The sub-sections describe the districts.

3.3.1 Districts with improved roads: Techiman, Offinso, and Offinso North

Techiman municipality has a population of 147,788 (6.4% of the Brong Ahafo region's population) with 35.5% living in the rural area. The municipality is situated in the central part of the Brong Ahafo region and lies between longitudes 1°49′E and 2°30′W and latitude 8°00N and 7°35′S (see Figure 3.2). It covers an area of 669.7km^2 with population density of 228 persons/km^2 (GSS, 2014e). Agriculture and its related trade is the main economic activity in the municipality. The major food crops grown are: yam, potato, maize, cassava, cocoyam, and plantain. Vegetables like tomato, eggplant, onion, and okra are also grown. Farmers also grow cash crops such as cocoa, cashew, mango, orange, cowpea, and groundnut. Rivers crisscross the municipality but agriculture is still rain fed with not many farmers applying modern farm techniques.

Techiman municipality is one of the agricultural production corridors in Ghana due to its vast fertile lands, especially in the southern part. The fertility of the soil has attracted migrant farmers especially from the northern part of the country to the municipality (TEMA, 2010). In the rural areas, 75.8% of the households are farmers but the agricultural households in the entire municipality is 46.2% (GSS, 2014e). Techiman municipality, Offinso municipality, and Offinso North district are connected by a major highway that links the south of Ghana to the north and the neighbouring countries.

Offinso municipality and Offinso North district are located in the Ashanti region of Ghana (see Figure 3.2). Offinso municipality has land area of 585.7km^2 with population density of 131 persons/km^2 while Offinso North district has land area of 945.9km^2 with population density of 60 persons/km^2. Both districts are rural and agriculture dominates the economy. Offinso municipality has 71.8% of rural population, and 67.7% of agricultural households out of which 97.2% are crop farmers (GSS, 2014b). The Offinso North district has rural population of 58.8% with 78.8% agricultural households almost all of whom are crop farmers (99.3%) (GSS, 2014c).

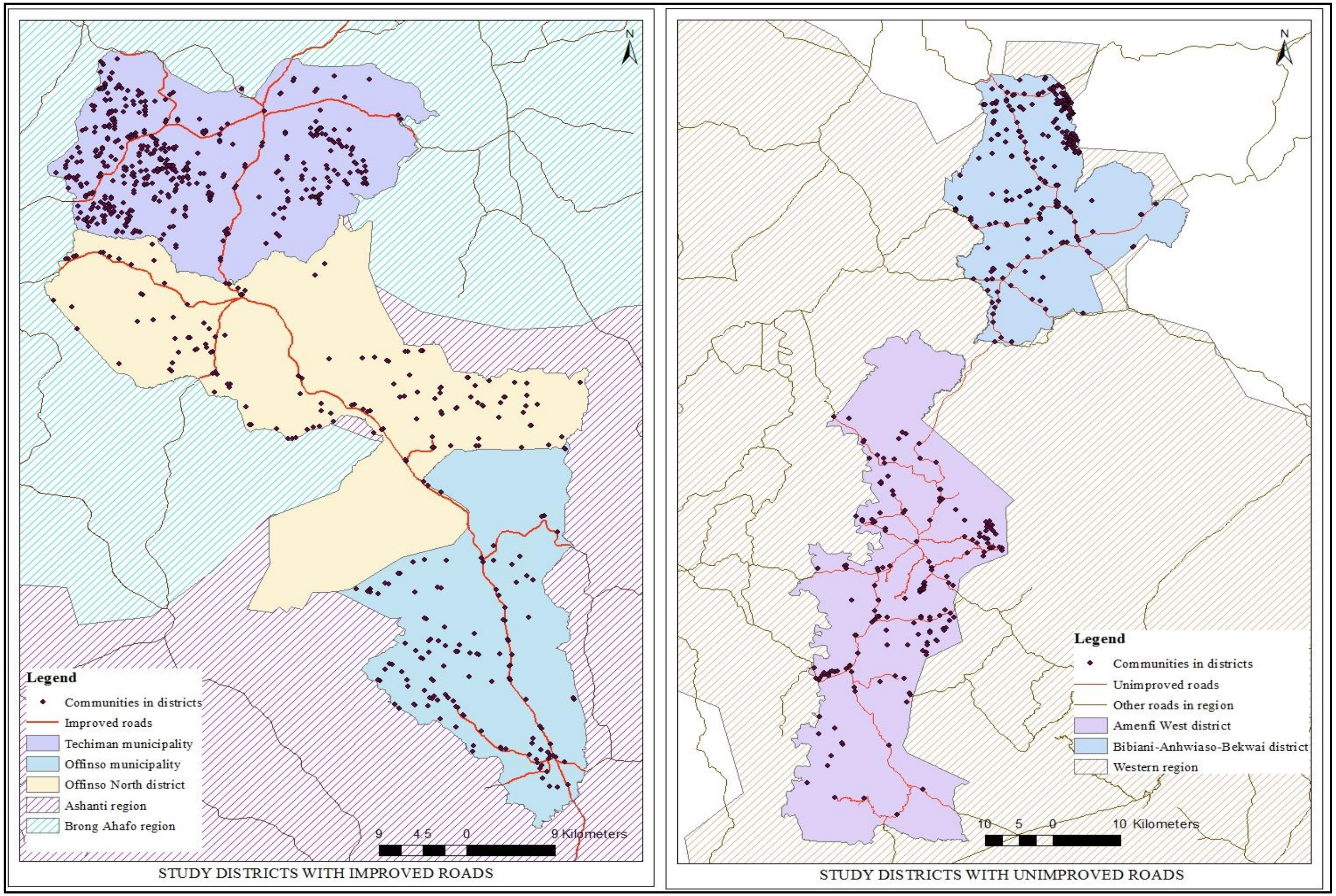


Figure 3.2: Selected districts along the improved and unimproved roads
Source: Resource Management Support Center, Forestry Commission, 2015

3.3.2 Districts with unimproved roads: Amenfi West and Bibiani-Anhwiaso- Bekwai

Both districts are located in the Western region of Ghana (see Figure 3.2) and they have similar characteristics as the region in terms of topography, vegetation, relief, soil type, and farming practices. The Amenfi West district has land area of 1,448.6km^2 and population density of 64 persons/km^2. The district has 59.7% of its population living in the rural areas and 71.6% of its households are engaged in agriculture (GSS, 2014a). Cash crops grown in the district are cocoa, oil palm, and rubber, and the major food crops produced include cassava, maize, rice, eggplant, and tomato. Most of the farmers use family labour and farmers' mutual help for their farming operations. Land acquisition is mostly on leasehold or share-cropping system. The farmers use traditional methods of farming. The practice of slash-and-burn, bush fallowing and shifting cultivation are the main methods used.

The Bibiani-Anhwiaso-Bekwai district on the other hand has land area of 833.7km^2 and population density of 148 persons/km^2. The rural dwellers constitute 71.5% of the district's population. Agricultural households in the district form 74.9% with 82.5% in the rural areas. Crop farmers dominate (98.2%) the agricultural households in the district (GSS, 2014d). There are two market centers in the district that operates on weekly basis, one on Wednesdays and the other on Fridays. Crops in the rural areas are transported to the markets on these days. Despite ready market for agricultural produce in these markets, most of the produce rot on the farm due to poor road conditions that make it difficult for drivers to transport the produce to the market especially in the wet season (GSS, 2014d).

3.4 Characteristics of the farmers (respondents)

Three hundred (300) farmers were interviewed in the five districts during the field survey (see chapter four section two for details on the selection process). This section presents the demographic, social, and economic characteristics of the farmers.

3.4.1 Demographic and social characteristics of the farmers

Men constituted 53.7% of the farmers interviewed. The significant number of women does not necessarily imply that the women farmers were the heads of their households at the time of the survey. A woman was interviewed based on any of the following considerations:

- The woman farms together with the husband but the man was not available at the time of the survey;
- The woman is a single parent and owns a farm;
- The woman is not married but has her own farm(s).

The results from the survey confirms the substantial involvement of women in agriculture in Ghana. Female heads of agricultural households constitute 28.6% of the agricultural households in the country (GSS, 2013a) while that of the study area is 28.7%.

The minimum and maximum ages of the farmers were 19 and 80 years respectively with the mean age being 43 years. Almost a third (32.7%) of the farmers were within the age range of 40-49 years while 31.3% were aged 30-39 years (see Figure 3.3). When compared to the national figures, the farmers within 30 and 50 years in the study area were 18% higher than the national average of 46% (GSS, 2013a) although both the national and study area figures portrayed the same trend. The majority of the farmers being in their middle ages (30-50) could influence labour-intensive farming since they have enough strength. The farmers above 60 years might face some challenges if they practice labour-intensive farming due to the vigorous nature of farming in Ghana.

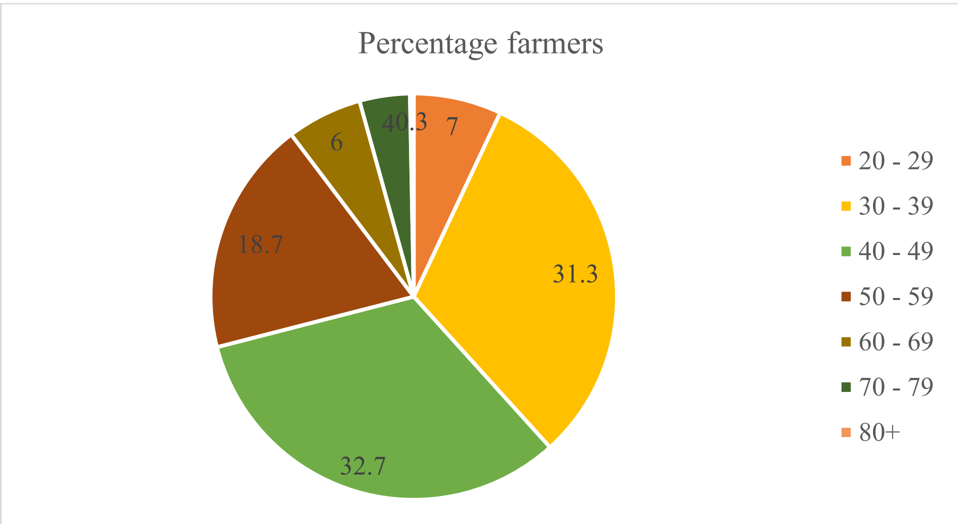


Figure 3.3: Age ranges of the farmers

Source: Author's field survey, June 2015

Married farmers formed 79.3% and those who were single, divorced, and widowed constituted 5.3%, 6.7%, and 8.7% respectively. The minimum and maximum household sizes of the farmers were one and 18 respectively with the mean size being six. More than half (54.7%) of the farmers had household sizes from four to six while 30.6% of the farmers had household sizes beyond six (see Figure 3.4). The relatively large household sizes could be due to the rural setting and the traditional methods of farming practiced in the study area where farmers need more household labour for their activities (GSS, 2013a).

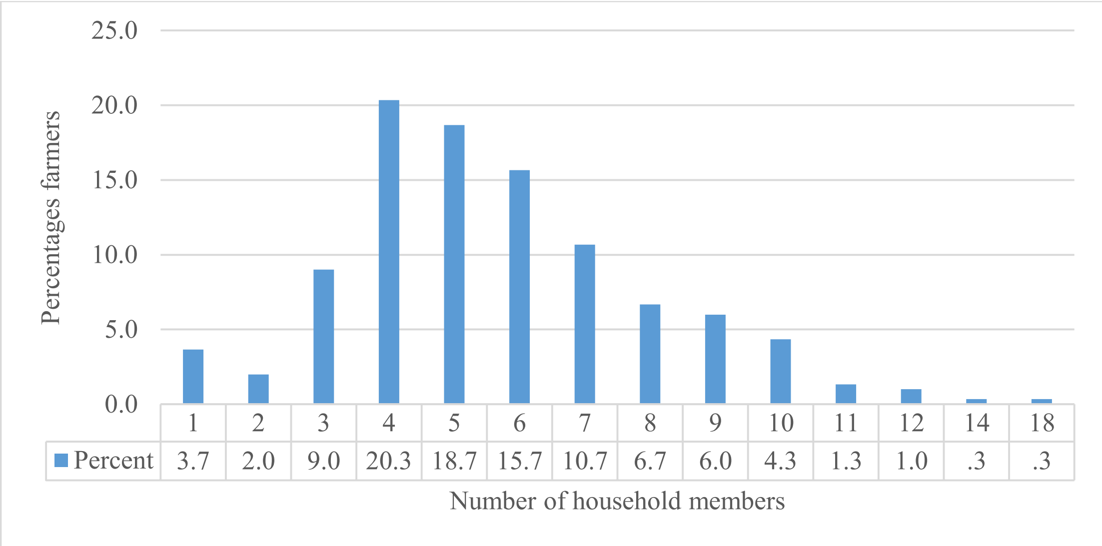


Figure 3.4: Household sizes of the farmers

Source: Author's field survey, June 2015

The minimum and maximum number of years a farmer has lived in their community was one and 71 years respectively and the mean years of stay was 24.1 years. A correlation between the number of years a farmer has lived in their community and the household size of a farmer indicated a positive relationship (see Table 3.1). The longer a farmer stayed in a community, the larger their household sizes all other things being equal.

Table 3.5: Correlation between years of stay in community and household size

Spearman's rho		**Years of stay in community**	**Household size**
Years of stay in community	Correlation Coefficient	1.000	.240**
	Sig. (2-tailed)	.	.000
	N	300	300
Household size	Correlation Coefficient	.240**	1.000
	Sig. (2-tailed)	.000	.
	N	300	300

** Correlation is significant at the 0.01 level (2-tailed).

Source: Author's field survey, June 2015

A third (33.3%) of the farmers had never been in school (see Figure 3.5). This implies that the application of modern farm technologies would be difficult for such farmers to practice when it involves reading. Such farmers might use farm inputs like fertilizers, weedicides, and pesticides based on their own experiences which might have negative effect on both the plants and the soil. Aside from soil fertility as the main determinant of crop yield, wrong application of farm inputs resulting from the inability to read and understand inputs indications could lead to variations in crop yields.

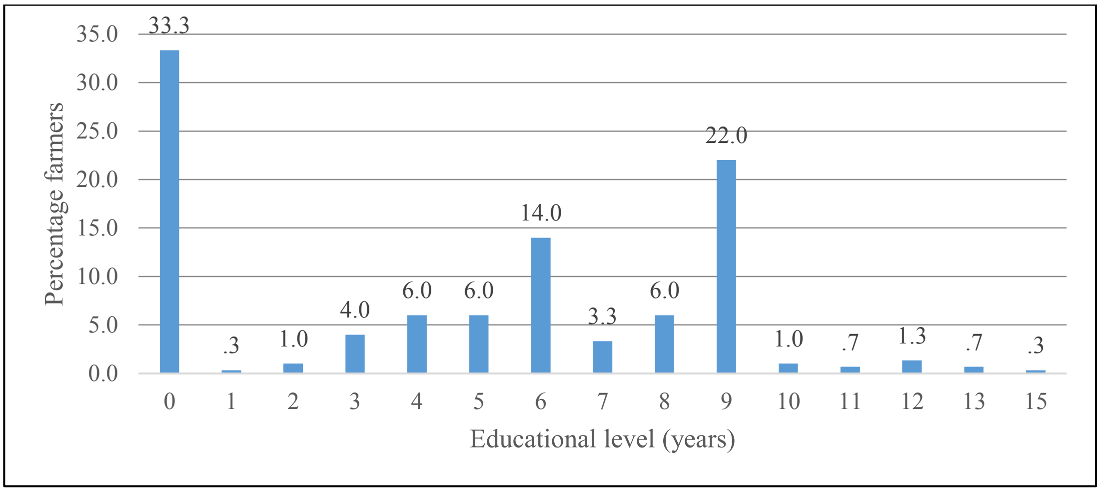


Figure 3.5: Educational attainment of the farmers

Source: Author's field survey, June 2015

A quarter (24.7%) of the farmers had no household member currently in school at the time of the survey, but these famers had literates in their households. Only 2% of the farmers had neither been to school before nor had a literate in their household. The presence of literates in the famers' household could enhance the practice of modern farm techniques if made available to the farmers. In most cases, farmer education programs are communicated to the farmers in their own languages, making it easier to practice. The farmers who did not attend school and those who reached up to grade six totaled 64.7%, but 80.7% of them had supported their household members to go beyond grade six. This portrays the importance of education to the farmers.

3.4.2 Economic characteristics of the farmers

Most of the farmers (70.7%) were not natives of the communities in which they lived. These farmers migrated to their resident communities for various reasons. The farmers who moved solely for farming purpose constituted 58.5% while the rest moved for various reasons one of which was farming. More than half (55.2%) were farmers in their previous residential areas before moving to the study communities to continue farming and other activities. That is, the migrant farmers who still had farming only as their occupation increased from 55.2% to 58.5% after realising that farming was lucrative in their new areas.

Out of the 300 farmers (both natives and migrants), 43.3% were solely farmers, 46.3% were farmers in addition to one other economic activity, and 9.3% and 1% had three and four additional economic activities respectively. These economic activities included: carpentry, charcoal production, driving, masonry, teaching, dress making, mechanical works, other manufacturing works (local drinks, soap, clothes, sandals, basket weaving etc.), and trading in agricultural and non-agricultural goods. The varieties of works of the farmers reflected in their households as well. The number of different jobs in the farmers' households ranged from one to ten (see Table 3.2).

Table 3.6: Number of other economic activities of the farmer households

Number of activities	Number of households	Percentage
1	76	25.3
2	84	28.0
3	74	24.7
4	34	11.3
5	18	6.0
6	6	2.0
7	2	.7
8	5	1.7
10	1	.3
Total	300	100.0

Source: Author's field survey, June 2015

The study did not investigate the profitability of the other jobs in the farmers' households. Nonetheless, the presence of multiple jobs in most of the farmers' households might serve as safety nets in times of risks or shocks that might occur, all other things being equal.

3.5 Roads in the study area

The study area has two types of road networks: improved/paved and unimproved/unpaved (see Figure 3.2). The Western region is recognised as having majority of the unimproved roads in Ghana. The Amenfi West and Bibiani-Anhiawso-Bekwai districts in the Western region portrays this feature. Over 90% of the main roads connecting the communities in these districts are unimproved. The Amenfi West district for instance has 900km length of road network but only 40.9km of it has been improved (paved/sealed) (GSS, 2014a).

Samatex Company Limited, one of the main timber production and processing companies in Ghana, is located in the Amenfi West district. According to the Amenfi Forest Service Division, most of the roads within the two districts were constructed by Samatex and the Ghana Cocoa Board due to the cocoa and timber production functions of the area. According to the residents in Amoaku, Bisaaso, and Mumuni (study communities in the Amenfi West district), the road connecting them to other parts of the region was last graded in 2009 and has been left to deteriorate to the current state (see Plate 3.1). The road has been graded five times since 1990 with the objective to sealing it but has never been realised.

Plate 3.1: Unimproved roads in the study area

Source: Author’s field survey, June 2015

The roads in Techiman and Offinso districts are however improved. The main road connecting the districts to the other regions was paved/sealed in the 1990s and has remained in good condition since then. Most of the secondary road networks are also improved enabling all year round accessibility (see Plate 3.2). The Techiman municipality, for example, has a total of 419km of road networks all of which are accessible throughout the year.

Plate 3.2: Improved roads in the study area

Source: Author’s field survey, June 2015

CHAPTER FOUR

EFFECTS OF ROADS ON FARM SIZE AND MARKET PARTICIPATION

4.0 Overview of chapter

This chapter analyses the degree to which roads influence farm size and market integration in rural Ghana. The chapter utilises the data obtained from the 300 farmers described in chapter three. The economic, social, and demographic characteristics of the farmers are presented in chapter three. The type of roads accessed by the farmers have also been briefly described in chapter three.

4.1 Introduction

Agriculture is an important economic sector in Africa. About 70% of the active labour force in Sub-Saharan Africa (SSA) are farmers but due to the subsistence nature of farming, production is mostly for household consumption (FAO, 2012). 60% of farmers in SSA consume their own farm produce partially or entirely. 75% of cereals and all root crops consumed in Africa are produced within the continent by both small- and large-scale farmers (AGRA, 2013). Agriculture in Africa is constrained by poor infrastructure, especially poor quality and extent of roads which increases the prices of inputs such as fertilizers and limit access to markets for farm produce. Poor communications are obstacles to technology uptake, training and extension of education and these factors combine to limit farmer innovation (Badu et al., 2013). In Africa, roads are the main means through which farm products are transported to the market (Angmor, 2012; Bafoil & Ruiwen, 2010). Farm size and the integration of farms into the cash economy are influenced by roads that connect farmers to markets (Masters et al., 2013). However, the degree to which improved roads influence farm size and commercialisation of agriculture varies from place to place and few empirical studies have been published. This research statistically tests the degree of influence that improved roads have on farm size and market participation in rural Ghana.

Global population is projected to exceed 9 billion by 2050 at which time Africa will have 25.5% of the world's people (FAOSTAT, 2015). Some authors predict that global food demand will increase by 70-110% as a result of population growth and changed diets (Laurance et al., 2014). 1 billion hectares of land would need to be converted to agriculture by 2050 to meet this growing food demand (Edwards et al., 2014). However, agricultural production could increase through intensification, innovation, and improved transport and farming systems (Masters et al., 2013). Food needs could be met by producing more food on existing farmlands using modern agricultural techniques. Improved transport (especially roads) could make a major contribution to improved farm productivity enabling food needs to be met without increasing the need for land. The degree to which improved roads influence farm size and commercialisation will determine future land demand. Farm size and productivity is of interest because almost all farmlands are derived from forests; expanding agriculture means loss of forests and biodiversity (Gibbs et al., 2010).

Farm size dynamics are linked to the household life cycle (HLC); smallholder households with different age structures farm different sized plots of land (Perz et al., 2006). The HLC theory holds that farm sizes increase and then decrease over one generational period (Leonard, Deane, & Gutmann, 2011). Young farmers with small household sizes and less capital migrate to new farming areas to farm on initially small land parcels. These farmers expand their farms as their household sizes expand. Farm sizes begin to decline as household members grow and leave to start their own farms. The presence of a successor influences the current farmer's decision to maintain, reduce, or transfer farmland to other farmers. Farmers without a successor often retire on their farm, gradually disinvesting and reducing farm size (Van Vliet et al., 2015). Migration to cities reduces the trend for farm subdivision.

The HLC theory does not address the question of how other factors such as access to improved roads and farm inputs influence farm size. Limited access to inputs resulting from financial constraints and lack of non-farm income could lead to reduced farm size and the persistence of subsistence farming (Van Vliet et al., 2015). Rural areas with high transport costs resulting from, among other factors, unimproved/unpaved roads, tend to have small farms and practice subsistence farming (Gockowski et al., 2014; Hazell et al., 2010). This situation prevails in most SSA countries where mean farm sizes are less than 5ha (Sayer, 2010). In some SSA countries, the area under cultivation has expanded by 50% between 1990 and 2011 (AGRA, 2013) but mean farm sizes are declining and farmers have little option other than continuing subsistence cultivation.

Subsistence farmers suffer financial and agricultural input constraints which prevent them from intensifying their production. Large household size often exacerbates this problem (Wiggins, 2009). Evidence however shows that access to improved roads increases market integration by enabling smallholder farmers to transport a larger proportion of their produce to markets (Hazell, 2013). Researchers state that road condition, distance to market, travel time to the market, household size, labour availability, and farming experience, influence the commercialisation of agriculture (Ouma et al., 2010; Sebatta et al., 2014).

There would appear to be a relationship between market participation and improved roads although this has yet to be statistically established in the context of Ghana. Road quality is one indicator of road transport cost known to influence agricultural development (Angmor, 2012; Christ & Ferrantino, 2011). Previous research has related farmers' market participation to road distance and condition by arguing that farmers in the hinterlands with poor or no roads fail to commercialise their produce due to high transport costs especially during the wet seasons. (Ouma et al., 2010; Sebatta et al., 2014). The intensity of this effect has not been determined and may vary for different crops. The degree to which improved roads influence farm size, a proxy for deforestation, has not been statistically tested (Masters et al., 2013). This study seeks to test the influence of roads on i) farm size, and ii) farmers' market participation, in rural Ghana.

The rest of the chapter is divided into four sections. Section 4.2 details the methods used to test how road quality (improved/unimproved) influences farm size and market participation, and it explains the criteria used to assess road quality. Section 4.3 presents the findings on the contribution of road quality to farm size dynamics and commercialisation of agriculture. Section 4.4 discusses roads and their relationships with farm size and commercialisation of agriculture in rural Ghana. Section 4.5 presents the conclusion of the chapter.

4.2 Materials and Methods

This research was carried out in two areas in rural Ghana with similar biophysical conditions. In the first area communities had roads that were paved and in the second roads were unsealed. Farmers were interviewed and data on their household demographics, farming operations, travel time, and road distance to the nearest central market were obtained. The travel time and distance were cross-checked independently by the interviewer. Road quality, a continuous variable, was assessed as the speed travelled by a car and the time required to access the nearest market. Absolute distances from the farmers' house to the market were used to control for the fact that a distant community and close community may have other differences beyond road quality. Multiple regression was used to test the effect of road quality, household variables, and other factors on farm size and farmers' market participation.

4.2.1 Study area, design and sampling

The research covered five districts in three regions of Ghana (see Figure 4.1). These districts were selected because they contain some of the major agricultural production corridors in Ghana. They produce various food crops both for household consumption and regional and national markets.

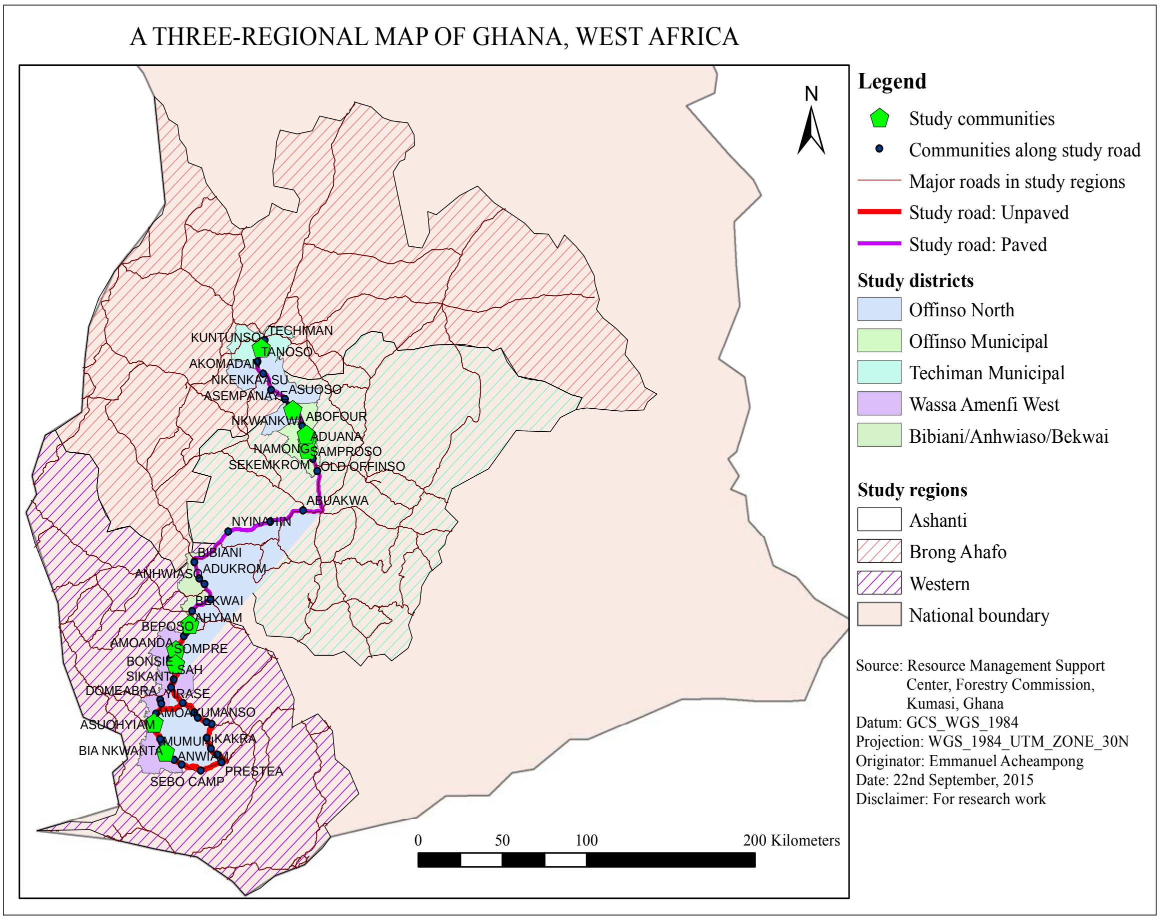


Figure 4.1: Study regions, districts, and communities in Ghana

Source: Resource Management Support Center, Forestry Commission, 2015

Ten communities from the selected districts were surveyed, five of which have their main roads unimproved (unpaved/unsealed) while the other five have improved/paved roads (see Table 4.1). About 70% of the active labour force in the study area are farmers (GSS, 2013a). A minimum sample of 269 farm households was sought in order to afford confident statistical inferences to the agricultural population at the 95% confidence level

(Krejcie & Morgan, 1970) (see appendix 1). Equal samples of 30 farmers from each of the 10 communities were selected to facilitate comparative analysis between the two types of communities, namely areas with and without access to improved roads, having 150 respondents each (see Table 4.1).

Table 4.1: Study Communities and sampled farmers

No.		**Total Population**		**Total**	**Farm**	**Sampled**
		2010	2014*	**Households**	**Households**	**farmers**
Unimproved road communities						
1	Amoaku	559	688	172	120	30
2	Mumuni	724	833	174	121	30
3	Kofi Gyan	497	532	130	91	30
4	Bonsie	1014	1164	238	166	30
5	Adebewura	1069	1347	228	159	30
Improved road communities						
6	Anyinasuso	1789	1877	299	208	30
7	Sampronso	1779	1866	287	200	30
8	Koforidua	1965	2061	299	208	30
9	Kuntunso	1606	1684	267	186	30
10	Nkwankwa	1195	1279	221	154	30
Total		12197	13331	2315	1612	300

*Projected from 2010 using annual growth rates for various communities

Source: GSS, 2014, Authors' construct, 2015.

A 'snowball' sampling technique was employed in each community in addition to random sampling. That is, in the situation where the farmers randomly surveyed also know other farmers, the interviewers were directed to those farmers. The selection of the farmers was random without any specific conditions related to, for instance, the types of crops they grow, their farm sizes, etc. Data were collected on household demographics, farming operations, farm produce marketing, and non-farm employment (Table 4.2). Total farm size was calculated by adding the sizes of the number of individual plots each farmer was cultivating. Net farm income was obtained by deducting the overall expenses on farm (cost of: fertiliser, weedicides, pesticides, hired labour, and transport) from the gross farm income. Road distances from each community's center to the market, and from each farmer's house to the community center were recorded using a GPS device.

These distance measures were used to compute the distance from each farmer's house to the nearest market. Information on the time taken by each farmer to reach the market was provided by farmers and verified using the average of 14 different travel times recorded by the interviewers from each community. The travel time reported by each farmer was rounded to the nearest travel time recorded by the interviewers in each community such that each farmer had a unique mean travel time from house to market, regardless of whether the farmer used the market. Each community used a single road to access market so no confounding factors such as travelling on a different road were encountered to influence road quality measurements.

Table 4.2: Minimum, maximum, mean, and standard deviations of the variables

Variables	**N**	**Minimum**	**Maximum**	**Mean**	**Std. Dev.**
Distance to market (km)	300	4.00	28.80	12.70	8.09
Road quality (km/h)	300	27.65	91.25	52.32	18.15
Total farm size in 2014 (ha)	298	0.4	12.1	3.81	2.21
Percentage sales per cropping season[a]	256	0.00	100.00	59.93	34.24
Non-farm employment per farmer (no.)	300	1	4	1.68	0.68
Household size (no.)	300	1	12	5.63	2.33
Years of farming	300	1	40	15.95	9.02
Number of plots farmed as at 2014	300	1	5	1.88	0.82
Number of crops grown as at 2014	300	1	6	2.78	1.07
Labour hired per cropping season (no.)	292	1	11	4.59	2.45
Frequency of labour hired per cropping season	292	1	6	3.11	.97
Household labour[b]	300	1	6	2.20	.80
Farm profit (2014)	293	20.00	100.00	78.01	13.94

[a]Farm produce sold per cropping season; [b]Household members used for farming.

Source: Authors' field survey, June 2015

4.2.2 Data analysis

A typology of the farmers in the study area was derived using k-means cluster analysis with three distinct clusters defined by the researchers and employing a maximum of 10 iterations and convergence criterion of zero (see Table 4.3). Variables in Table 4.2 that give the maximum distinction were used to cluster the farmers in order to identify subsistence, commercial, small-scale, large-scale, and hinterland farmers (Emtage, Herbohn, & Harrison, 2006).

Table 4.3: Types of farmers in rural Ghana based on cluster analysis

	Means of variables		
Cluster variables	Type 1	Type 2	Type 3
Road quality (km/h)	68.98	70.10	35.01
Average distance to market (km)	8.50	9.10	16.56
Total farm size in 2014 (ha)	5.0	2.9	4.0
Years of farming	26	10	15
Percentage sales per cropping season	78.0	84.0	31.0
Labour hired per cropping season	6	5	4
Number of cases (n=300)	63	87	150

Source: Cluster analysis results from survey data, June 2015

Multiple regression analysis was used to test the effect of road quality on farm size and market participation net of all other household and non-household factors/variables (see Tables 4.4 and 4.6). Prior to running the regression tests, the data were checked for normality and homogeneity of variance and the data that required correction were log-transformed (Zar, 1999). The models were then checked for multiple collinearity problems using the collinearity statistics (Variance Inflation Factor, and tolerance). Multiple collinearity was not a problem as the highest VIF was 1.8, less than the critical value of 10 and the lowest tolerance was 0.7 (Gujarati & Porter, 2009).

4.3 Results

From Table 4.3, the three types of farmers are; the most experienced, labour-intensive large-scale commercial farmers (Type 1); the young, labour-intensive small-scale commercial farmers (Type 2); and the experienced, medium-scale subsistence farmers (Type 3).

a. Type 1 farmers have access to improved roads and they travel about 9km at 70km/h to access the market. They have farmed more than 20 years, own large farms, hire more farm labourers, and sell 78% of their farm produce.

b. Type 2 farmers travel distances and speeds similar to type 1 farmers to access the market. Type 2 farmers have the least number of years farming experience and the smallest mean farm size, but the highest proportion of sales and least hired labour. The similarities observed between type 1 and 2 farmers are because both have access to improved roads.

c. Type 3 farmers travel the longest distance at the lowest speed on an unimproved road to access a market. They have more farming experience and larger farms than type 2 farmers but hire the least number of labourers and sell only 31% of their farm produce.

These three types of farmers can again be categorized into two broad types based on road quality, distance travelled, and percentage sales. Type 1 and 2 farmers form one broad category: commercial farmers with improved roads and short distances to market; we refer to them as "improved road farmers". Type 3 forms the second and opposite category: subsistence farmers with unimproved roads and long distance to market; we describe them as "hinterland farmers". The influence of improved roads, the most significant variable influencing farm size and commercialisation is analysed and discussed in the next sections.

4.3.1 Influence of improved roads on farm size

Various factors influence farm size (Gockowski et al., 2014). From Table 4.4, five of the predictors have significant correlation with farm size ($F_{(10,279)}$= 21.214, $P<0.05$, R^2=0.432, N=289). Despite road quality being the fourth significant predictor, it is the only variable that reduces the rate of farm expansion net all other factors. Labour usage, years of farming, and number of plots possessed correspond to the HLC theory; road quality however correlates negatively with farm size (t=-2.449, $p<0.05$, p=0.01).

Table 4.4: Regression: influence of road and other variables on farm size

Predictor variables	Standardised coefficients (Degree of influence on farm size)	P-values
Average distance to market (km)	.077	.139
Household size	-.037	.524
Household labour	.071	.197
Labour hired per cropping season	.214	.000***
Frequency of labour hired	.089	.058
Years of farming	.346	.000***
Non-farm employment per farmer	-.036	.496
Number of plots farmed as at 2014	.334	.000***
Percentage sold per cropping season	.132	.012**
Road quality (km/h)	-.151	.013**

Dependent variable: farm size (ha)

$F_{(10,279)} = 21.214$, $P<0.05$, $R^2=0.432$, N=289

***Significant at p<0.005; **Significant at p<0.05

Source: Regression results from survey data, June 2015

The HLC theory states that farm sizes increase and then decrease with time (Leonard et al., 2011). A comparative analysis of the trend in farms expansion showed that since the beginning of farming, 84% of the improved road farmers have not expanded their farms beyond 100% as compared with 68% of the hinterland farmers. On the contrary, 32% of the hinterland farmers have expanded their farms beyond 100% as compared with 16% of the improved road farmers (see Figure 4.2).

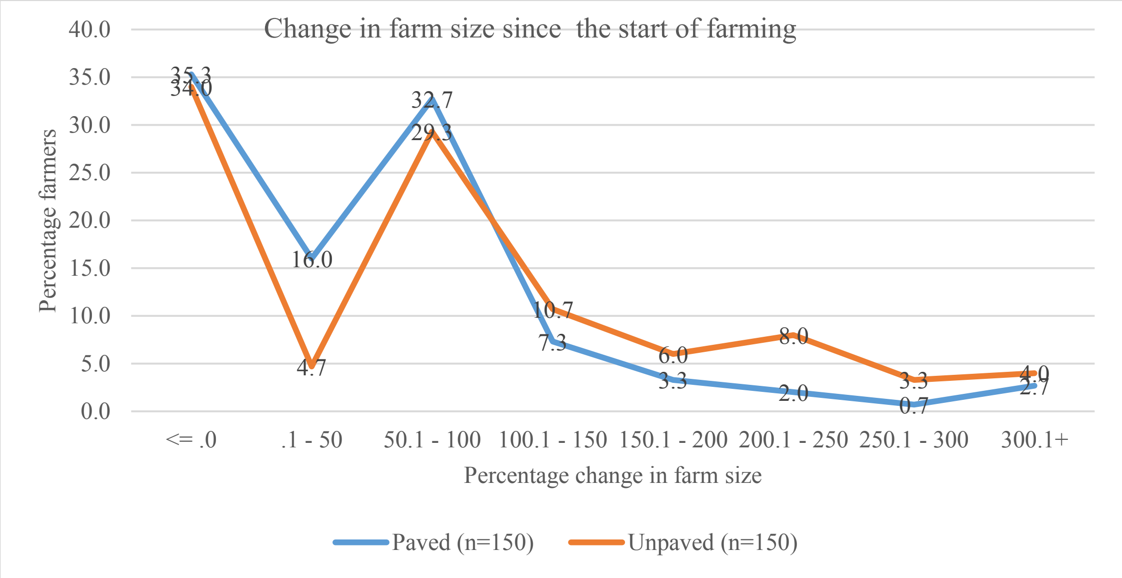


Figure 4.2: Trends in farms expansion

Source: Authors' field survey, June 2015

Prior to the year 2000, the mean size of a hinterland farm was 3.7ha while that of an improved road farm was 4.6ha. By 2014, the mean farm size had declined by 18.9% and 45% for hinterland and improved road farmers respectively. Although this confirms that mean farm sizes are declining in Africa (Masters et al., 2013), farm sizes of improved road farmers were declining more rapidly than those of hinterland farmers (see Table 4.5).

Table 4.5: Farm size changes with time

Changes in farmlands		**N**	**Min.**	**Max.**	**Sum**	**Mean**
Overall farmlands (ha)	Total	300	.4	20.6	1168.3	3.89
	Improved road	150	.4	20.6	570.6 (48.8%)	3.80
	Unimproved road	150	.8	10.1	597.6 (51.2%)	3.98
Farmlands as at the year 2000 (ha)	Total	115	.4	20.6	472.5	4.11
	Improved road	56	1.2	20.6	256.2 (54.2%)	4.58
	Unimproved road	59	.4	9.7	216.3 (45.8%)	3.67
Farmlands from 2000 to 2014 (ha)	Total	242	.4	17.4	695.8	2.88
	Improved road	116	.4	17.4	314.4 (45.2%)	2.71
	Unimproved road	126	.8	10.1	381.3 (54.8%)	3.03

Source: Authors' field survey, June 2015

Although other factors might account for farm size dynamics (see Table 4.4), road quality appears to be the most significant factor that reduces the rate of farm expansion, all other things being equal.

4.3.2 Influence of improved roads on commercial farming

Finance, agricultural inputs, and transportation factors are found to influence agricultural commercialisation (Wiggins, 2009). This confirms the results in Table 4.6; road quality has the highest significance of increasing farmer's market participation (t=6.869, p<0.005, p=0.000) followed by net farm income some of which is used to purchase farm inputs, the third enabling factor of farm commercialisation.

Table 4.6: Regression: influence of road and other variables on commercial farming

Predictor variables	**Standardised coefficients (Degree of influence on commercialization)**	**P-values**
Average distance to market (km)	-.063	.283
Household size	-.099	.105
Household labour	-.080	.201
Net farm income for 2014	.399	.000***
Total farm size in 2014	.269	.000***
Number of plots farmed as at 2014	-.158	.007
Non-farm employment (No.)	.015	.798
Farm inputs used (amount)	.297	.004***
Road quality (km/h)	.433	.000***
Dependent variable: Farmers' market participation		
$F_{(9,281)}$ = 11.120, P<0.005, R^2=0.263, N=290		

***Significant at p<0.005

Source: Regression results from survey data, June 2015

There are some farmers who grow only cocoa, a cash crop which has to be processed industrially before it can be consumed. When these farmers are excluded, only one hinterland farmer sells all his farm produce while 37.4% of the improved road farmers sell all their farm produce. While 25.7% of the hinterland food crop farmers consume all their farm produce, only 2% of the improved road farmers do same. Even when all farmers are considered (see Figure 4.3), more improved road farmers commercialise their farm produce than the hinterland farmers. The principle cash crop grown by hinterland farmers is cocoa, everything else is grown for consumption.

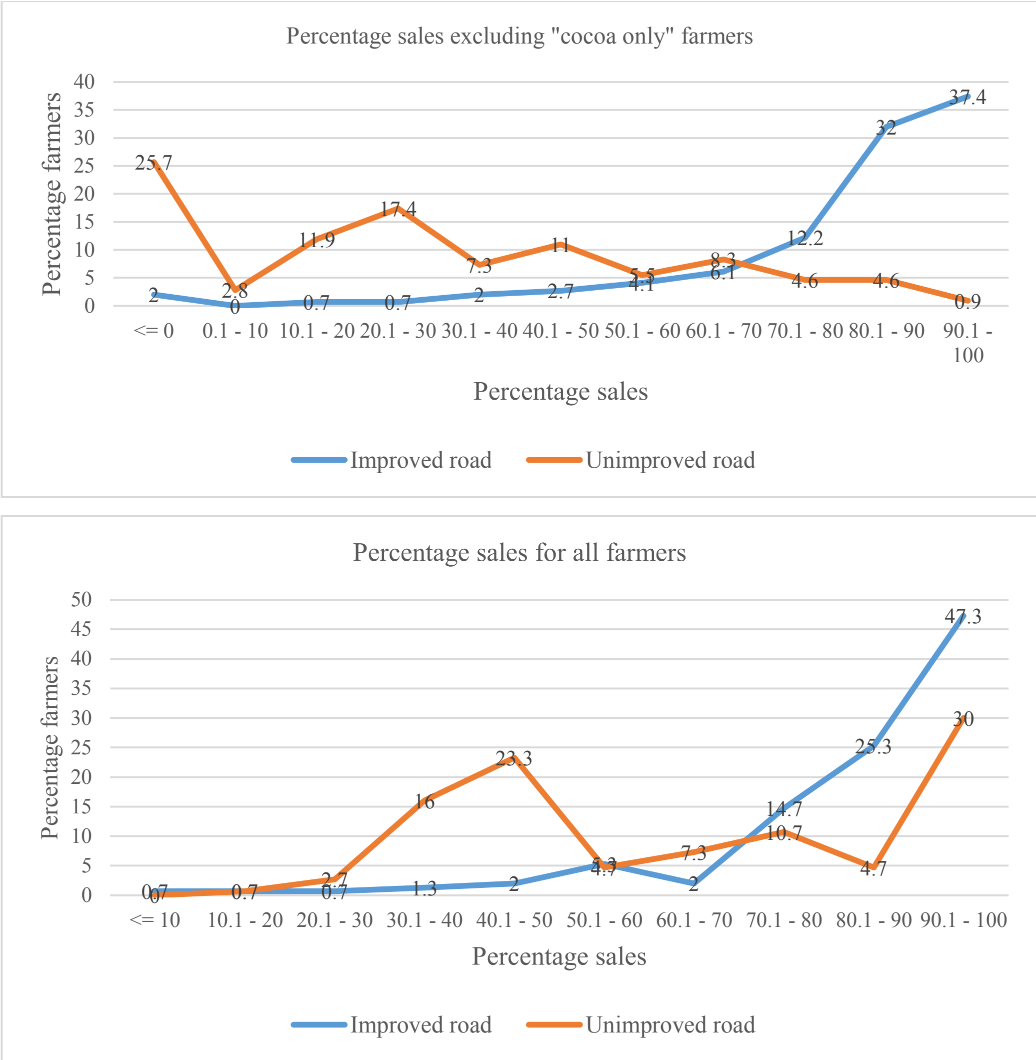


Figure 4.3: Degree of market engagement of hinterland and improved road farmers
Source: Authors' field survey, June 2015

Improved roads provide easier access to markets for famers. These markets are located alongside the main road and vehicles pass frequently, often stopping to buy agricultural produce before they continue their journey. Improved road farmers therefore have access to both daily and weekly markets. This encourages the farmers to sell most of their produce regardless of farm size. The hinterland farmers however have access to only weekly markets, about 29km away from their communities. Vehicles move at approximately 34km/h due to the nature of the road (see Plate 4.1). Once a farmer misses the last vehicle, they have to wait till the next market day, a situation that does not favor perishable farm produce.

Plate 4.1: Improved and unimproved roads in rural Ghana

Source: Authors' field survey, June 2015

4.4 Discussion

Improved roads have the capacity to decrease the rate of farm expansion since farmers do not have to depend solely on natural soil fertility to increase agricultural production. Improved road farmers have access to fertilizers and pesticides. Improved roads increase the probability that farmers will market their produce irrespective of farm size. Income from sales is used to purchase farm inputs.

4.4.1 Roads and farm size

Evidence from other parts of Africa shows that farms in accessible areas are relatively larger and more integrated into markets (Masters et al., 2013; White & Roy, 2015). This contrasts with the situation described in this study where farms are larger in the hinterlands than in the improved road zones and the rate at which farms expand is higher in the hinterland than the accessible areas. The explanation for this unexpected finding is that farmers in Ghana are migrating to improved road areas with good market access (Kuemmerle et al., 2013). Three-quarters (75.3%) of the improved road farmers are migrants as compared to 23.3% in the hinterlands. These migrants do not own land but cultivate on land leased from local residents. As more farmers move into the accessible areas competition for land intensifies and leased lands become increasingly smaller since only a finite areas of land is available (Table 4.5). In the hinterlands however, farmers sharecrop land that is owned by local members and intercrop cocoa with food crops. The standard arrangement allows them to retain ownership of half of the land when the cocoa trees reach maturity. Hinterland farmers grow food crops mainly for consumption and when the cocoa canopy closes they are obliged to seek new land to cultivate food crops. This practice of sharecropping is driving the expansion of farm size and contributes to deforestation in Ghana (Damnyag et al., 2011).

Security of land tenure is weaker in the hinterlands than in the improved road areas. In Ghana, there are three main land tenure systems: public, stool, and freehold lands. The lands in both improved road and hinterland areas are mainly freehold and individual families have title. Some land is administered under the “stool” system where it is administered by traditional authorities. Resident farmers in both areas own freehold land through inheritance. Before freehold land is transferred to a new owner, the land has to be registered in the new owner’s name (Obeng-Odoom, 2012). All the migrant farmers in the hinterlands own some farlands but none of them has official documentation confirming their ownership rights; this makes it difficult to prove ownership, especially when the owner dies. Farmers who need more lands for food crops due to the cocoa canopy shading-out subistence crops sometimes encroach adjoining forest. Forest protection laws are difficult to enforce in hinterland areas (Damnyag et al., 2011). Conversely, none of the migrant farmers in the improved road areas owns their farmland. These farmers are land insecure; they either sharecrop or hire the land annually for farming. This explains why they grow only annual marketable food crops. The farming practices and the land tenure complexities determine the rate and extent at which forests are converted to farms in Ghana.

Finally, no improved road farmer relies solely on agriculture for his or her livelihood. While 76% of improved road farmers engage in at least two economic activities, 64.7% of the hinterland farmers rely solely on farming. Reliance on subsistence crops exerts more pressure on forest cover. The presence of the improved roads enables farmers to participate in other businesses. Non-farm income contributes 45% to the income portfolio of the improved road farmers as compared to 10% of the hinterland farmers. The livelihoods of the improved road farmers are more secure as they have alternative economic activities during the non-farming season. Improved road farmers are also more food secure and have better nutrition than the hinterland farmers since they are able to purchase more diverse and nutritional foods using non-farm income. Improving roads in agricultural areas could therefore promote livelihood diversification, enhance food security, and serve as a pathway out of poverty (Foley et al., 2011) while minimizing threats to forests and biodiversity.

4.4.2 Roads and farm commercialisation

Commercial farming is mostly linked to large farms as farmers produce beyond their households' consumption level (Sebatta et al., 2014); however, there are other more significant factors influencing the shift to commercial farming than farm size. Improved roads, access to farm inputs and farm profitability all drive commercial integration (see Table 4.6). Improved roads provide a ready market for farm produce irrespective of farm size. Although, the improved road farmers have relatively small farms (see Table 4.5), they sell 84% of their farm produce compared to only 31% for the larger-scale hinterland farmers. This suggests that improved roads could significantly increase smallholder farmers' income ($t=3.892$, $p<0.005$, $p=0.000$). Hinterland farmers rarely market any produce other than cocoa due to high transport costs resulting in little or no profit (Ouma et al., 2010). For instance, transporting 50kg bag of maize over the same road distance would cost a hinterland farmer three times as much as transporting the same produce on an improved road. High transport costs and post-harvest losses from untimely marketing of perishable food crops constrain hinterland farmers to subsistence cultivation (Barrett, 2008). Agriculture in the hinterlands could be transformed through improved roads.

Access to markets for farm produce is equally important as access to sources of farm inputs. Agricultural transformation in this part of Ghana appears to be strongly linked to improvement of roads. Improved road farmers are able to commercialise their farm produce and they produce more using farm inputs. No improved road farmer travels more than 10km to access farm inputs while hinterland farmers have to travel up to 50km. Second, the improved road farmers combine farm and non-farm income to buy inputs. With the exception of larger cocoa farmers, no hinterland farmer applies inputs to food crops because they could not afford to do so. Their subsistence cultivation does not provide any income to purchase farm inputs. The only means of increasing production is to expand farms into forests (Gibbs, 2010). Improving existing roads could generate non-farm employment opportunities leading to diversified income sources, some of which could be used to intensify farming thereby sparing forest and biodiversity (Perz et al., 2012).

4.5 Conclusion

Farm expansion does not necessarily increase production, and large farms do not necessarily provide higher yields. Agricultural intensification increases production irrespective of farm size (Sayer et al., 2015); the surplus provided by intensified systems can be marketed through improved roads. Ghana's agricultural land has been increasing by 1% annually, yet agriculture's contribution to GDP has declined from 41.5% in 2004 to 20.7% in 2014 (World Bank, 2015). This trend portrays a decrease in production perhaps resulting from inefficient or limited use of farm inputs and poor infrastructure development (FAOSTAT, 2015; World Economic Forum, 2015).

Improved roads might allow hinterland farmers to transform from subsistence to commercial farming (Barrett, 2008). Improved roads might also attract more investors thereby creating more non-farm jobs, implying that farmers might no longer need to depend solely on farm produce for their livelihoods. Farmers would be able to derive income from non-farm employment (Kokoye et al., 2013). Agricultural extension officers would also be able to visit farmers via improved roads. Farmers' access to improved roads and knowledge about modern farm technology would enhance the transition from subsistence to commercial farming, hence leading to agricultural transformation (Figure 4.4). Improved road access might improve the enforcement of forest protection regulations. There is a significant literature claiming that increased road construction poses a threat to tropical nature (Laurance et al., 2009). This study suggests that improved roads in Ghana have the potential to reduce the pressure for forest conversion and can provide a positive force for the conservation of forests and biodiversity.

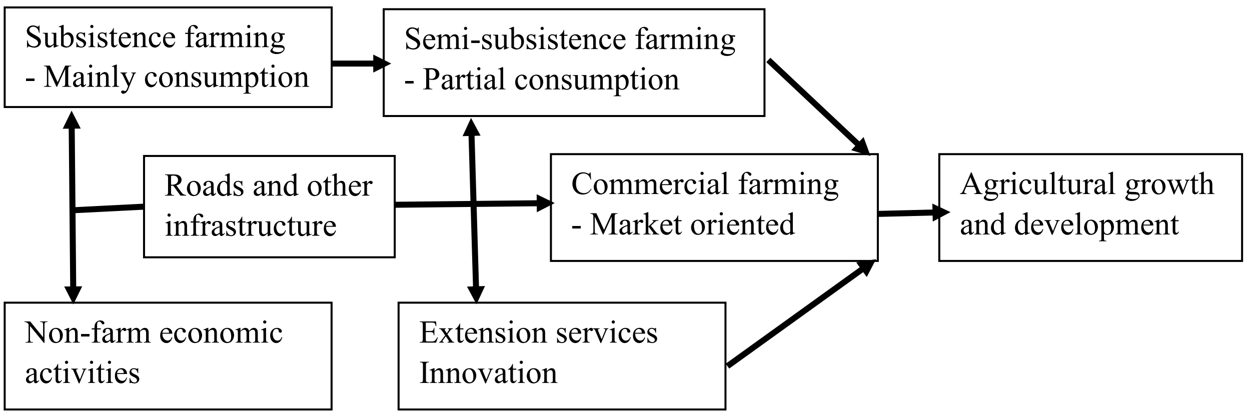


Figure 4.4: Subsistence to commercial farming transition through improved roads

Sources: Authors' construct, August 2015.

CHAPTER FIVE

REMAINING FOREST COVER AND CAUSES OF DEFORESTATION IN GHANA: A 29-YEAR SPATIAL ANALYSIS

5.0 Overview of chapter

This chapter is a continuation of the analysis in chapter four. While chapter four presents the influence of roads on farm size, chapter five examines the influence of roads of forest cover in the study area. The chapter first presents the status of forest in the study area, and then the causes of deforestation. The chapter finally looks at whether or not roads influence forest cover change in the study area.

5.1 Introduction

Deforestation has been a significant contributor to greenhouse gas (GHG) emissions; it emits 15% to 25% of annual GHG worldwide (Damnyag et al., 2013). Out of the total emissions, 18% to 20% comes from developing countries (Hansen, Lund, & Treue, 2009). As a result, mechanisms to curb deforestation has been a prerequisite to achieving global emissions reduction targets (Angelsen et al., 2012). Since the 1980s, there has been rapid changes in tropical countries' forest cover resulting in loss of biodiversity and other ecosystem services (Hansen et al., 2008). These changes have been caused mainly by human-induced factors although natural factors might have accounted for some of the changes. Researchers have been assessing and monitoring the potential impacts of forest cover change globally and recommending strategies for mitigation and management (Bodart et al., 2011). Global forest management strategies might however not be feasible for all countries due to context-specific agents of deforestation and patterns of forest cover change. Mapping national forest cover and assessing the extent and patterns of change, and the factors contributing to forest cover loss would guide the local strategies towards forest management. This research maps the extent of, the contributory factors to, and the effects of roads on forest cover change in three regions of Ghana over a 29-year period (1986-2015) using Landsat satellite imagery.

Forest covered 31% of the global land area in 2010. However, between the periods 1990-2000 and 2000-2010, there has been 0.20% and 0.13% annual rate of forest cover loss respectively (FAO, 2010a). African forest covered 23% of the continent's land area in 2010 and has experienced annual deforestation rates of 0.56% and 0.49% for the same periods 1990-2000 and 2000-2010 respectively. The net annual loss for West Africa has been 0.46% from 1990 to 2010 recording no decrease in the rate of deforestation (FAO, 2010a). Before the 2010 statistics of Food and Agriculture Organisation of the United Nations (FAO), it was reported that West and Central Africa has the highest rate of deforestation in the African ecoregion, recording annual net loss of 0.6% from 1990 to 2000, and 0.5% from 2000 to 2005 (FAO, 2007). Although, there are some differences in the deforestation rates recorded by FAO, evidence show that deforestation is reducing in Africa, especially the West and Central ecoregion. Mapping forest cover trends within countries could help track the patterns of change and the contextual factors of deforestation, and this would inform what and where management strategies should focus (Hansen & Loveland, 2012).

Human-induced factors are increasingly altering forest cover nationally and globally. In North America for instance, logging and fire have been recognised as the major causes of deforestation (Hansen et al., 2010). In the Asia Pacific, fire, logging and plantation expansion have been dominating the causes of forest cover loss for years (Indarto, Kaneko, & Kawata, 2015; Katovai, Edwards, & Laurance, 2015; Nelson et al., 2014). In some parts of Africa, pastoralism, shifting cultivation, and permanent tree crop planting have altered the forest cover to the extent that the landscape has turned into a mixture of human-induced changes and natural vegetation (Vittek et al., 2014). Brink and Eva (2009) demonstrated this physical alteration to forest cover by highlighting areas of agricultural expansion and wood and shrub lands reduction in the Somalia-Masai ecoregion using Landsat imagery. From the above evidence, there seem to be national variations in the causes and patterns of forest cover loss. Mapping Ghana's forest cover would help identify the spatial differences in deforestation with its associated contributory factors over a period of time.

Ghana has been experiencing forest cover loss since the 1980s. The country recorded annual deforestation rates of 1.82% (135,395ha), 1.89% (113,595ha), and 2.10% (113,595ha) for the periods 1990-2000, 2000-2005, and 2005-2010 respectively (FAO, 2010b). Report from the United Nations Environmental Program (UNEP, 2009 cited in Damnyag et al., 2011) also put Ghana's annual deforestation rate at 127,000ha from 1990 to 2005. Other researchers have also reported 135,400ha of forest cover loss for Ghana between 1990 and 2005 (Amissah, Kyere, & Agyeman, 2010; Owusu, Fosu, & Burger, 2012). Although, there are some inconsistencies in the results as for instance FAO's (2010) figures are based on estimates from 1989 secondary data and 1996 national forest inventory data interpolated and extrapolated to arrive at the 1990, 2000, and 2005 estimates of forest cover (FAO, 2010b); the overall rates portray a trend of increase in deforestation in Ghana. The International Tropical Timber Organisation (ITTO, 2005 cited in Boafo, 2013) states that Ghana's forest cover could completely disappear in 25 years if the present rate of decline is not addressed. Knowledge about the remaining forest cover and the spatial dimensions of forest cover change is required to rational measures towards deforestation mitigation.

The significant contribution of forest resources to the livelihoods of forest dependent communities as well as Ghana's economy has made its decline one of the topmost environmental issues in the country. Forest resources provide livelihood support to more than 2.5 million people in the country and contribute 6% annually to the GDP of the country (Appiah et al., 2009; Boafo, 2013). This implies that the decline of the resource does not affect the livelihoods of the dependents only, but also to some extent, the economy of the country.

Forest cover decline due to several factors, one of which is agricultural expansion (Foley et al., 2011; Mithal et al., 2011). However, the extent to which agricultural expansion and other factors cause deforestation in Ghana has not been spatially established. Most research have been focusing on reporting the trends in deforestation in Ghana but failing to report on the factors contributing to the forest cover loss especially agriculture (Alo & Pontius Jr, 2008; Oduro et al., 2015). Some researchers have reported the causes of deforestation from the views of community members but no spatial analyses have been performed to assess the dominance of the causative agents (Damnyag et al., 2012; Damnyag et al., 2013). Other researchers have demonstrated land cover transitions in some areas in Ghana but were not specific on the transition between forest and agricultural lands (Kumi-Boateng, Mireku-Gyimah, & Duker, 2012). It is therefore imperative to map the land cover and assess the extent of forest cover lost to the major deforestation agents.

Research in other tropical developing countries have also demonstrated that the proliferation of roads in forest areas contributes to deforestation. For instance, more than 95% of deforestation in the Amazon has occurred within 10km of road (Laurance, 2013). On the other hand, accessibility to roads also promote livelihood development through agricultural transformation as farmers get connected to markets and input suppliers with ease (Masters et al., 2013). The purpose of constructing, the condition of the road, and the environmental laws in place might perhaps influence the human activities that take place along the road. There has however been limited research spatially depicting the influence of roads on human activities such as agriculture, and forest cover change in Ghana. Mapping land use along roads in rural/ forest frontiers in Ghana would inform researchers and policy makers on the patterns of land cover change along different categories of roads, mainly improved and unimproved roads.

Based on the above discussions, this research through the use of Landsat satellite images for three different years, namely, 1986, 2002, and 2015, provides answers to two questions:

i) What factors contribute to forest cover change in Ghana?
ii) What is the influence of roads on forest cover change in Ghana?

The rest of the chapter is divided into four sections. The first section presents the methods used to process satellite images and report the results. The second section elaborates on the remaining forest cover and the extent to which agriculture has influenced deforestation. It also elaborates on forest and agricultural land use change along improved and unimproved roads. The third section discusses the trend in forest cover change, and the fourth section presents the concluding remarks on the remaining forest cover in the study area.

5.2 Methods

Landsat satellite images for the years 1986, 2002, and 2015 covering the study area were downloaded from the Landsat archives. These images were pre-processed, mosaicked, and subset with the map of the study area. The final image for each year was classified and used for the spatial analysis. The following sub-sections detail the methods.

5.2.1 Study area

Three regions of Ghana were used for the study. These are: Brong-Ahafo, Ashanti, and Western regions (see Figure 5.1). These regions lie between latitudes 4°44′37″N and 8°45′42″N and longitudes 07°27′08″W and 3°12′28″W (http://glovis.usgs.gov). The area falls within two vegetation zones: the Moist Evergreen Forest (High Forest Zone) with increasing density towards the south and the Moist Semi-deciduous Forest with decreasing density northwards. Characterised by double maxima rainfall, March-July and

August-November, the annual rainfall ranges between 1270mm and 1600mm per annum (Asare et al., 2014). For detail description of the study regions, see chapter 3 section 2.

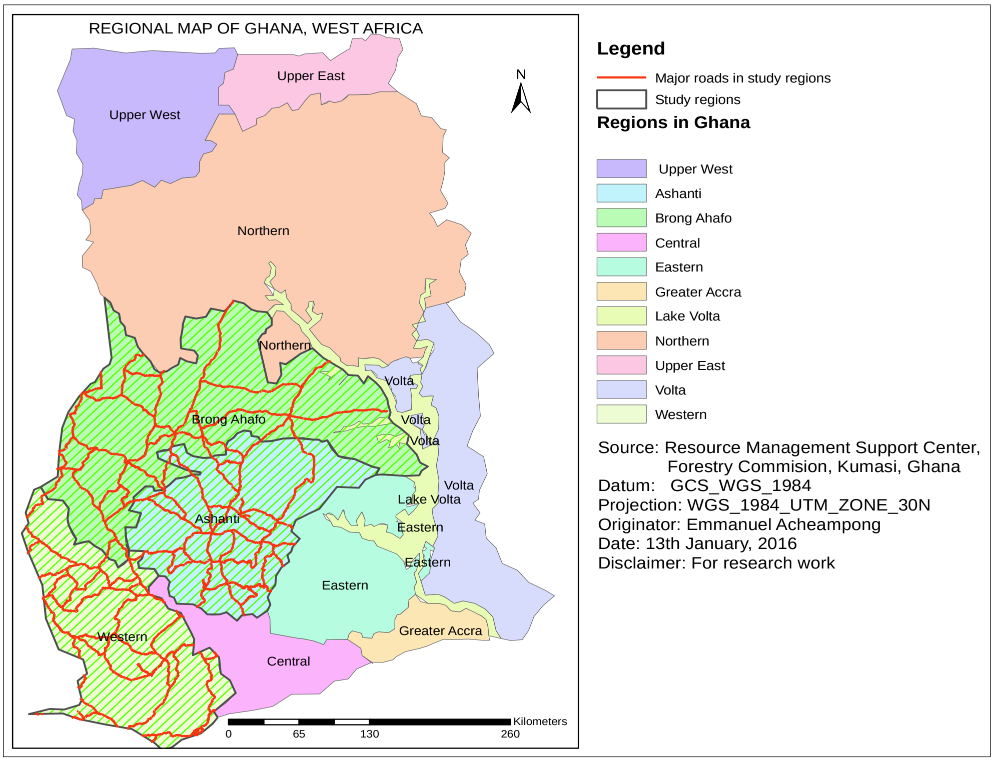


Figure 5.1: Study regions in national context

Source: Resource Management Support Center, Forestry Commission, 2015

5.2.2 Satellite data acquisition and image pre-processing

Landsat satellite images were acquired from the United States Geological Survey's (USGS) National Center for Earth Resources Observation and Science (http://glovis.usgs.gov) at 30m spatial resolution. Satellite images from three different dates- 1986 from Landsat 5TM, 2002 from Landsat 7ETM SLC-on, and 2015 from Landsat 8 OLI/TIS- were downloaded from Landsat archives. Based on image availability and quality (that is, minimum/no cloud cover), the acquired images have dates between December and February of the respective years, representing the end of the wet season for maximum vegetation discrimination (Bodart et al., 2011; Vittek et al., 2014). Six reflective spectral bands (bands 1-5, 7) of the Landsat images were pre-processed and used for spatial analysis.

The Landsat images that were selected have been geometrically corrected and georeferenced by the USGS to the Universal Transverse Mercator (UTM) projection of the study area (WGS 1984 UTM Zone 30N). Radiometric and atmospheric corrections have however not been performed on these images. Radiometric calibration was therefore performed to correct the differences arising from varied illumination conditions and the use of different platforms and sensors (Chander, Markham, & Helder, 2009). First, the digital numbers (DN) of each band were converted to at-sensor spectral radiance and finally to top-of-atmosphere (ToA) reflectance using FLAASH module in ENVI 5.3 software and employing a single scale factor.

Four Landsat scenes located at paths 194 and 195 and rows 55 and 56 were combined to form the study area. That is, four images were pre-processed for each of the years: 1986, 2002, and 2015. The radiometrically and atmospherically corrected images were mosaicked using the seamless mosaic tool in ENVI 5.3 and applying the nearest neighbour algorithm such that a single image was formed for each reference year. The mosaicked image for each year was subset with the shapefile of the study regions to constrain the analysis to the study area.

5.2.3 Image classification and change detection

Supervised classification was performed to categorise the features in each image into five distinct classes based on the spectral reflectance of the features and the familiarity and knowledge of the researcher about the area (Appiah et al., 2015). These classes are:

a. Forest: Both dense/closed forest including reserves, and less dense forest (off-reserves);
b. Agriculture: All food crop farms and cash tree crop farms such as cocoa, oil palm, citrus, mangoes, and cashew farms;
c. Artificial surfaces: All settlements including villages, towns, and cities, and other surfaces such as roads;
d. Bare ground/Dry grass: Areas with no vegetation cover or with few dry grass;
e. Water bodies.

For each land cover class, a minimum of 30 polygon-based training samples were randomly developed for each year and divided into two; half was used for calibration and the other half for validation. Polygon-based training samples were used due to their effects on heterogeneous land cover (Basnet & Vodacek, 2015). The spectral signature of the trained classes was generated for each year to assess the level of separability between the classes. Quantitative separability measures was also computed for each year using both the Jeffries-Matusita and Transformed Divergence separability measures both of which reported 1.999 as the minimum separability measure between the classes and 2.0 as the maximum (Appiah et al., 2015). With the assessed training classes, the images were classified using the Minimum Distance algorithm. Post classification refinement was performed using the Majority/Minority Analysis algorithm with a kernel size of 5x5 for moderate refinement. This refinement was done to avoid problems with conversion of raster classified images to vector files for incorporating into a Geographic Information System (GIS) software (Lillesand, Kiefer, & Chipman, 2008).

The classified images were validated using ArcGIS 10.2.1 software with the random validation data. Post classification accuracy assessment for each year was computed using the Confusion Matrix/Error Matrix module in ENVI 5.3 to assess the degree of correctness of the thematic/classification maps, that is, the extent of correspondence between Landsat imagery and ground truth data (see Table 5.1). The accuracy assessment was presented in the form of a matrix showing four features. First, the overall accuracy, which measures the overall level of agreement between the classified image and the reference data. The second feature, kappa coefficient, performs a similar function as the overall accuracy measure and it is considered as a better indicator of accuracy (Tan et al., 2013). The user's accuracy shows the probability of any classified pixel in the Landsat image to represent the correct class based on the ground truth data. The producer's accuracy on the other hand shows the probability that a pixel of a known class from the calibration sample is classified into the correct class in the satellite image (Basnet & Vodacek, 2015). Table 5.2 shows the overall accuracy, kappa agreement, producer's accuracy, and the user's accuracy for the images classified for each year. The class "water" was removed from the accuracy assessment matrix because it was not visually seen well in the satellite images for training samples to be randomly spread across the entire images.

Table 5.1: Confusion/Error Matrix for 1986, 2002, and 2015 image classification

Classified data	**Ground truth/reference data (pixels)**				
1986	Agriculture	Forest	Artificial	Bare ground	Total
Agriculture	633	0	54	0	687
Forest	27	1061	0	0	1088
Artificial	0	0	771	0	771
Bare ground	0	0	0	552	552
Total	660	1061	825	552	3098
2002	Agriculture	Forest	Artificial	Bare ground	Total
Agriculture	527	0	10	0	537
Forest	136	1520	0	0	1656
Artificial	11	0	752	2	765
Bare ground	0	0	12	403	415
Total	674	1520	774	405	3373
2015	Agriculture	Forest	Artificial	Bare ground	Total
Agriculture	2166	1162	0	0	3328
Forest	300	8150	0	0	8450
Artificial	0	0	4028	16	4044
Bare ground	0	0	8	2575	2583
Total	2466	9312	4036	2591	18405

Source: Author's image processing results, January 2016.

Table 5.2: Accuracy assessment results for the classified images

1986	**User's accuracy (%)**	**Producer's accuracy (%)**	**Total accuracy (%)**
Agriculture	92.1	95.9	Overall accuracy = 97.4
Forest	97.5	100.0	
Artificial	100.0	93.5	Kappa coefficient = 0.96
Bare ground	100.0	100.0	
2002	User's accuracy (%)	Producer's accuracy (%)	Total accuracy (%)
Agriculture	98.1	78.2	Overall accuracy = 94.9
Forest	91.8	100.0	
Artificial	98.3	97.16	Kappa coefficient = 0.93
Bare ground	97.1	99.5	
2015	User's accuracy (%)	Producer's accuracy (%)	Total accuracy (%)
Agriculture	65.1	87.8	Overall accuracy = 91.9
Forest	96.5	87.5	
Artificial	99.6	99.8	Kappa coefficient = 0.88
Bare ground	99.7	99.4	

Source: Author's image processing results, January 2016.

Normalised Difference Vegetation Index (NDVI) was created from the image of each year and change detection performed using the NDVI images through the Change Detection Difference Map tool in ENVI 5.3. Post classification change detection statistics was then computed using the classified images such that quantitative analysis could be performed alongside the visual interpretation of the difference images. The most popular post classification change detection approach is the bi-temporal change analysis of classified maps and this was adopted (Mayes, Mustard, & Melillo, 2015; Song et al., 2015). The change detection was carried out for 1986-2002, 2002-2015, and 1986-2015.

To assess the land cover change along the roads in the study area, two main roads were used: an improved major road connecting three districts, and an unimproved major road connecting another three districts. The improved road spans 206.3km while the unimproved road spans 226.9km (see chapter three section five for details of the study roads). A 10km and 20km buffer distances were created along the roads and overlaid on the classified land cover maps such that the land cover changes for the reference years within the 10km and 20km distances from the roads could be determined. Figure 5.2 shows the flow chart for the image pre-processing, classification, and change detection process.

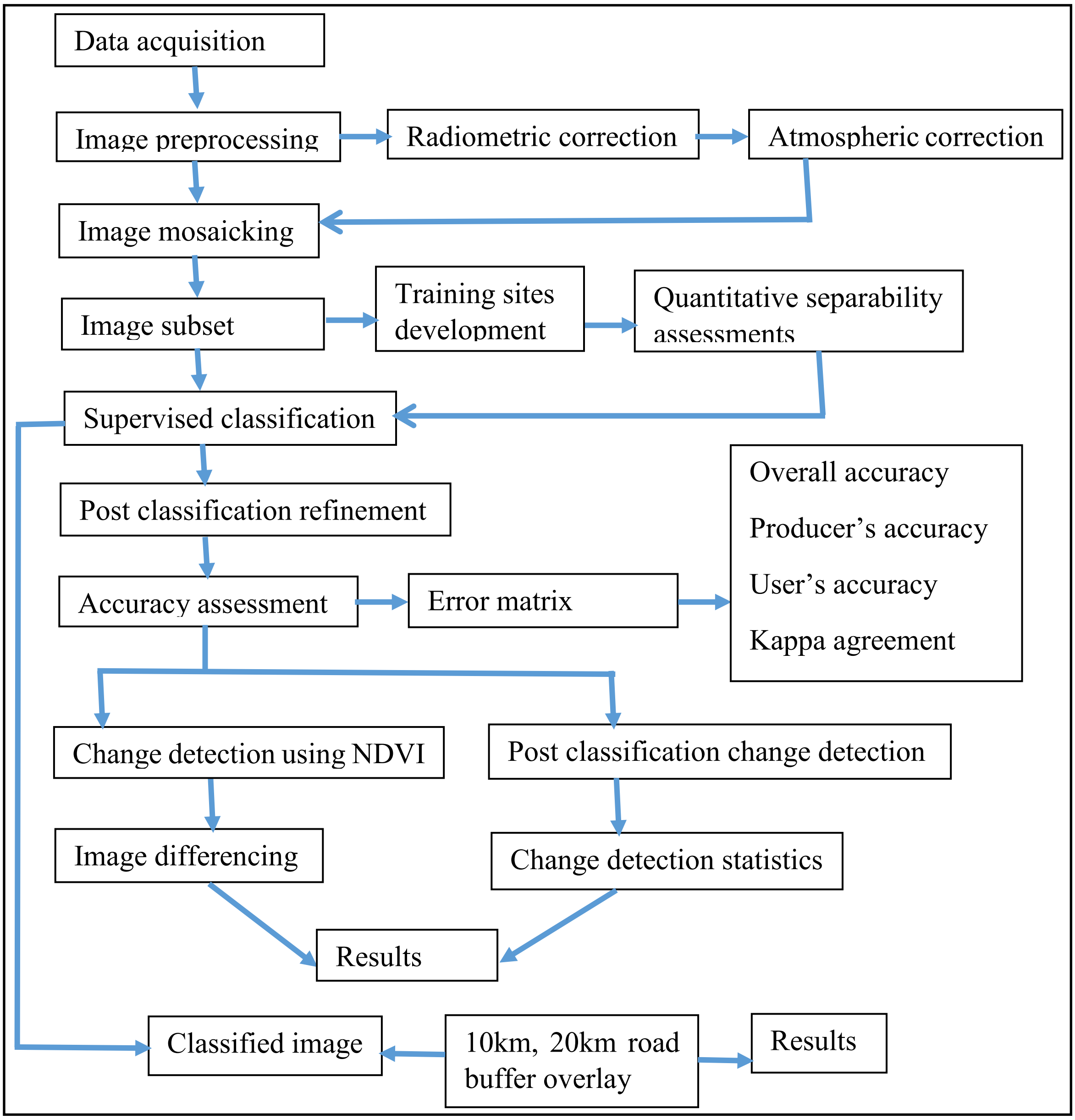


Figure 5.2: Image pre-processing, classification, and change detection stages

Source: Author's construct, January 2016

5.3 Results

With reference to Tables 1 and 2, the land cover types were classified well with overall accuracies of 97.4%, 94.9%, and 91.9% for the reference years 1986, 2002, and 2015 respectively with their corresponding kappa coefficients of 0.96, 0.93, and 0.88. The minimum classification accuracy threshold acceptable is 85% (Anderson et al., 2004 cited in Basnet & Vodacek, 2015). Based on the results from the image processing, all the classification accuracies were higher than the 85% minimum threshold. Despite the variations in the user's and producer's accuracy results, the vegetation cover (agriculture and forest) which is the focus of this research has all the accuracy results except one higher than 90%, implying that analysis could be performed with these results.

The results presentation is divided into four parts. The first section presents the state of land cover as at 1986, 2002, and 2015 showing four main classes of land cover: forest, agriculture, artificial surfaces, and bare ground/dry grass. The second section lays emphasis on vegetation cover change (forest and agricultural lands) from 1986 to 2015. The third section details forest conversion to other land uses between 1986 and 2015. The final section presents the spatial relationship between forest cover change and the two categories of roads under study.

5.3.1 Status of land cover, 1986-2015

Monitoring and modelling of any land cover begins with mapping that specific land cover. Land cover continues to change due to the dynamism of nature and human activities (FAOSTAT, 2015). However, the rate at which different land cover types change vary across countries (Indarto et al., 2015; Katovai et al., 2015). The study area covered 73,598.25km^2. As at 1986, forest constituted almost a third (31.3%) of the total land of the study area while agriculture covered more than half (56.9%) of the land area. Artificial surfaces (settlements) formed 1.5% while a tenth of the study area was either bare ground or covered by dry grass (see Figure 5.3).

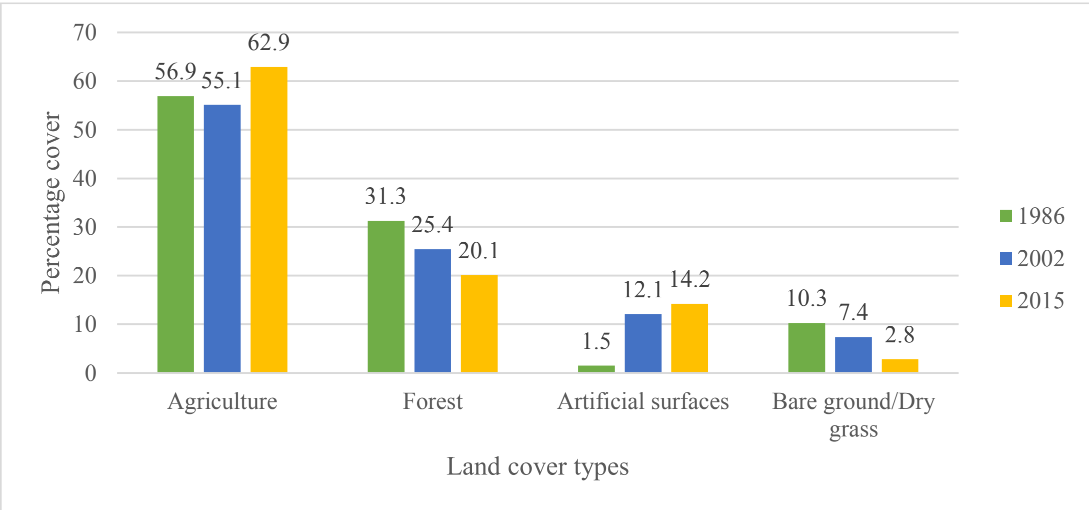


Figure 5.3: State of land cover, 1986-2015

Source: Author's image processing results, January 2016.

As at the year 2002, the land cover has undergone significant changes. The area covered by forest has reduced from 31.3% to 25.4%. Although agriculture was still occupying more than half of the land area, its coverage has reduced by 1.8%. A significant feature was the substantial increase in the development of artificial surfaces in the study area within the 16-year period, increasing its coverage from 1.5% to 12.1%. By the end of 2015, agriculture has covered almost two-thirds (62.9%) of the land area while forest cover has reduced to one-fifth of the land area (20.1%). Figure 5.4 shows the status of the land cover types classified in 1986 and 2015.

A noticeable trend was that while artificial surfaces and agricultural land cover have been increasing over the 29-year period, forest cover and bare ground/dry grass have been decreasing significantly. The rest of the analyses would focus on vegetation cover change especially forest cover, the focus of the research.

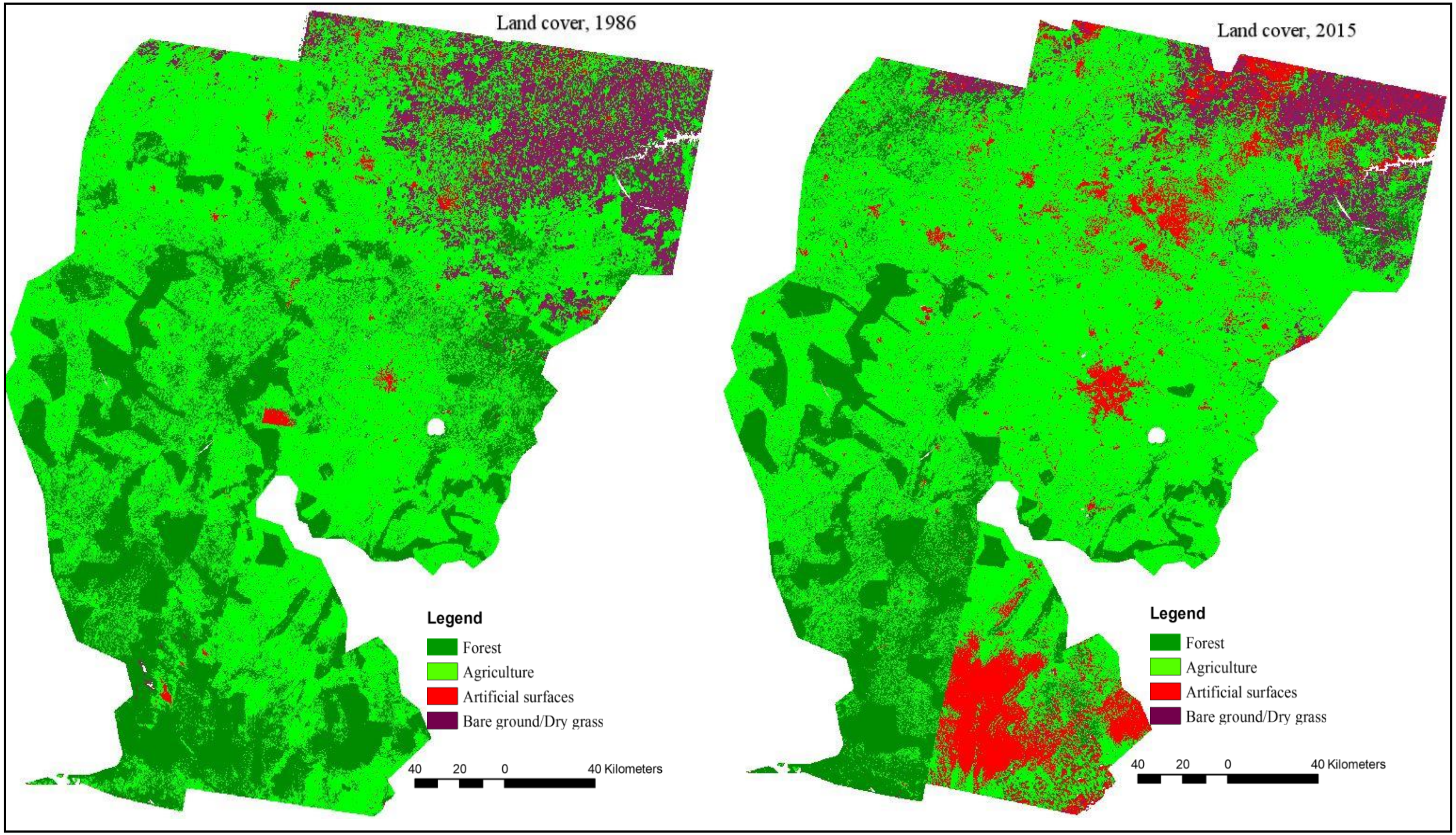


Figure 5.4: Land cover status, 1986 and 2015

Source: Source: Author's image processing results, January 2016.

5.3.2 Vegetation cover change, 1986-2015

Forest and agriculture have been identified as the most dominant vegetation cover in tropical developing countries (FAOSTAT, 2015). As a result, these land uses have been experiencing the most effects in terms of vegetation cover change. That is, whether there is a loss or a gain in vegetation cover, forest and agricultural lands reflect most of the change. Most research reports forest cover change by showing the declining trend only but fail to report the forest cover gain perhaps because there have been insignificant gains (Alo & Pontius Jr, 2008; Brink & Eva, 2009).

Results from the image processing showed two scenarios for vegetation cover in the study area: a loss and a gain in both forest and agricultural land cover at the same time. Between 1986 and 2002, there was a loss of 51.1% of forest cover. Within that same period, forest cover increased by 33.3%. Due to the greater loss than the gain, forest cover recorded a net loss of 17.8% for the 16-year period, that is, 1.1% annual deforestation (see Table 5.3). Between 2002 and 2015, the forest cover change statistics was similar to that of 1986-2002. Almost the same gain as that of the previous (33.4%) was recorded but the loss of 2002-2015 was greater than that of 1986-2002 by 1.6%. As a result, the net forest cover loss for the period 2002-2015 was also higher than the previous results by 1.5%. The 13-year period therefore recorded an annual deforestation of 1.5%, higher than the 1.1% of the previous 16-year period. The image processing results from the two extreme years (1986 and 2015) reported 19.1% and 52.8% forest cover gain and loss respectively. The 29-year period recorded a total deforestation of 33.7% with 1.2% annual deforestation rate.

Table 5.3: Vegetation cover change in the study area, 1986-2015

	Area and percentage change, 1986-2002					
Cover type	Gain (km^2)	Gain (%)	Loss (km^2)	Loss (%)	Net (%)	Annual (%)
Forest	7417.23	33.3	11389.50	51.1	-17.8	-1.11
Agriculture	13394.70	33.0	14356.13	35.3	-2.3	-0.14
	Area and percentage change, 2002-2015					
Forest	6119.6	33.4	9655.63	52.7	-19.3	-1.48
Agriculture	17246.55	43.5	10579.16	26.7	16.8	1.29
	Area and percentage change, 1986-2015					
Forest	4258.03	19.1	11769.26	52.8	-33.7	-1.16
Agriculture	14673.94	36.1	9019.48	22.2	13.9	0.48

Source: Author’s change detection results using image difference, January 2016

Agricultural land use also experienced losses and gains between the various periods. There was a gain of 33% and a loss of 35.3% of agricultural land cover between 1986 and 2002 resulting in a net loss of 2.3% for the 16-year period. The second analysis period (2002-2015) reported a gain of 43.5% and a loss of 26.7%, hence recording a net increase in agricultural land cover by 16.8% representing 1.3% annual increase for the 13-year period. Overall, agricultural land has increased by 13.9% over the 29-year period with an annual rate of increase of 0.5%. While forest cover has been declining since 1986 by 1.2% annually, agricultural land on the other hand has been increasing by 0.5% annually for the same period. The results from the deforestation rate when compared with the rate of increase in agricultural land cover showed that other factors accounted for deforestation in the study area.

5.3.3 Spatial factors contributing to deforestation

Several factors cause deforestation in tropical countries. These factors could be spatial, for instance, agricultural expansion, settlements expansion, excessive logging, and mining (Pielke et al., 2011). There could also be non-spatial factors, for example, population growth, and climate change such as severe and long term drought (Sassen et al., 2013). Only the spatial factors that caused deforestation in the study area was reported here using the image processing results and the factors were constrained to the classes/feature categories used for the image processing.

The main factors of deforestation in the study area were agricultural expansion and artificial developments (settlements/villages/towns expansion) and other factors that led to bare grounds (see Table 5.4). From 1986 to 2002, only 48.9% of forest cover retained its natural status; more than half was converted to other land uses. Agricultural expansion was the main cause of deforestation in the study area. Out of the 11,389.5km^2 of forest converted to other land uses between 1986 and 2002, agricultural expansion contributed to 94.9% while the remaining 5.1% was attributed to artificial developments and other factors. Agricultural expansion remained the main cause of deforestation from the year 2002 to 2015 portraying a similar trend as that of the previous period. More than half (51.1%) of the original forest cover as at the year 2002 has been converted to agriculture by the end of 2015, leaving forest cover remaining intact to be 47.3% for the 13-year period. Between 2002 and 2015, agricultural expansion constituted 96.9% of the deforestation in the study area.

Aggregately, agricultural expansion, artificial developments, and other factors have caused the conversion of 52.8% of the forest cover that remained intact as at the year 1986. Although artificial developments accounted for some deforestation for the 29-year period, agricultural expansion caused 81.8% of deforestation within this period. This shows the significant role agriculture has played in forest cover loss in the study area.

Table 5.4: Forest conversion to other land cover types

	1986-2002		2002-2015		1986-2015	
Cover type	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
Forest*	10898.67	48.9	8660.28	47.3	10518.91	47.2
Agriculture	10803.42	48.4	9358.0	51.1	9633.73	43.2
Artificial surfaces	240.34	1.1	250.32	1.3	1950.86	8.8
Bare ground/Dry grass	350.74	1.6	47.31	0.3	184.68	0.8
Total converted	11389.5	51.1	9655.63	52.7	11769.26	52.8

*Remaining forest cover at the end date

Source: Author's change detection results using image difference, January 2016

5.3.4 Effects of roads on forest cover change

In developing countries, land cover along roads vary based on the activities along the roads and the condition of the roads. Land cover within 10km distance from the study roads from 1986 to 2015 have been presented in Figure 5.5. Forest covered more than two-thirds (71.3%) of the 10km buffer of the improved road zone as at 1986 at which time the road has not been improved/paved. At the same time, forest covered 53.2% along the unimproved/unpaved road. By the year 2002, forest has declined to 32.1% of the land cover along the improved road while it increased to 65.8% along the unimproved road. Forest cover continued to decline as previously along the improved road. By the year 2015, it has reached 29.7% of the land cover. Along the unimproved road however, a significant decline was recorded. Unlike the increase in forest cover experienced from 1986 to 2002, as at 2015 forest cover constituted a quarter (24.5%) of the land cover along the unimproved road.

Agricultural land cover portrayed an increasing and decreasing trend along the improved road section of the study area but an opposite trend along the unimproved road zone for the three census years. Artificial developments continued to increase in both zones but was dominating the land cover along the improved road more than the unimproved road section of the study area.

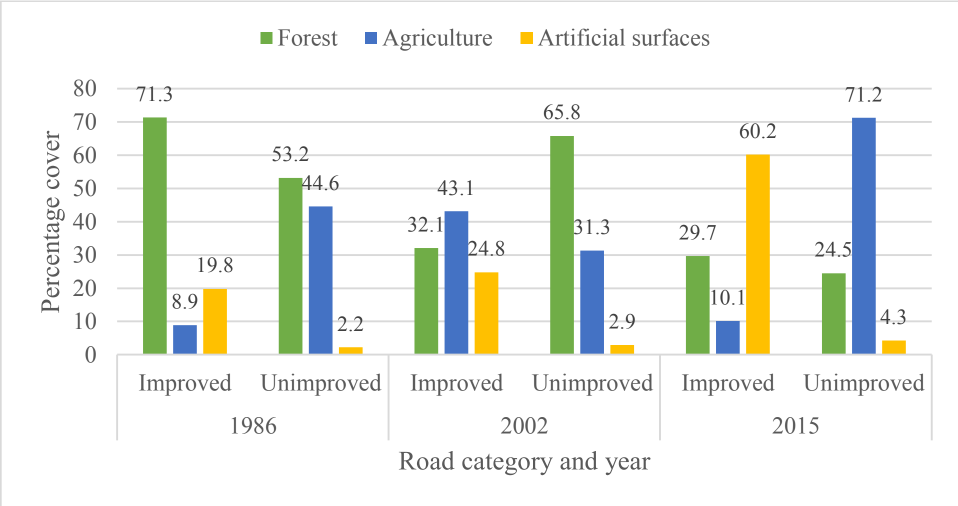


Figure 5.5: Land cover within 10km distance from a road, 1986-2015

Source: Author's change detection results using image difference, January 2016

With reference to Figures 5.5 and 5.6, more than half (55%) of forest cover was lost between 1986 and 2002 within 10km distance along the improved road while there was forest cover gain of 23.7% within 10km distance of the unimproved road within the same period. Between 2002 and 2015 however, both road zones experienced deforestation. Less than 10% deforestation occurred along the improved road as compared to 62.8% of deforestation along the unimproved road. Within the 29 year period (1986-2015) over 50% deforestation occurred along both roads. However, between the two intervals (1986-2002 and 2002-2015), unpredictable change occurred especially along the unimproved road; forest cover increased by 23.7% within a 16 year period (1986-2002) and suddenly decreased by 62.8% within a 13-year period (2002-2015).

Agricultural land change also showed opposite trends for the two categories of roads for the two census years. While agriculture expanded by 384.3% along the improved road, it declined by 29.8% along the unimproved road between 1986 and 2002. A decline of 76.6% was recorded along the improved road contrary to an increase by 127.5% along the unimproved road, all within the same period of 13 years (2002-2015). Contrary to forest cover, there was an expansion in agricultural land use within the 29-year period (1986-2015) for both road categories. However, the rate of agricultural expansion along the unimproved road section of the study area was 63% higher than along the improved road zone.

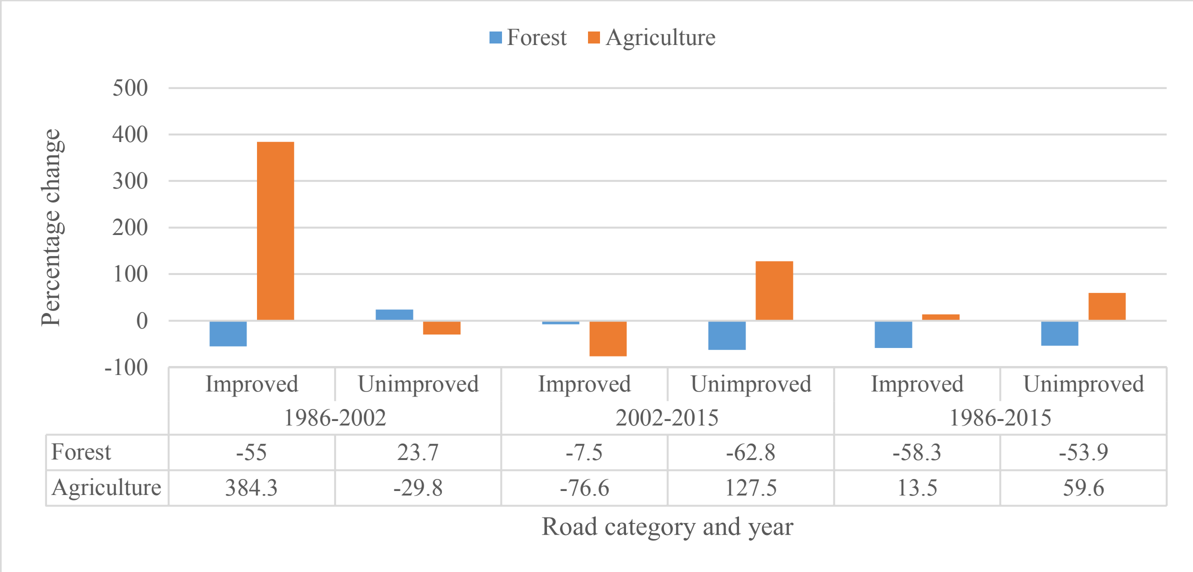


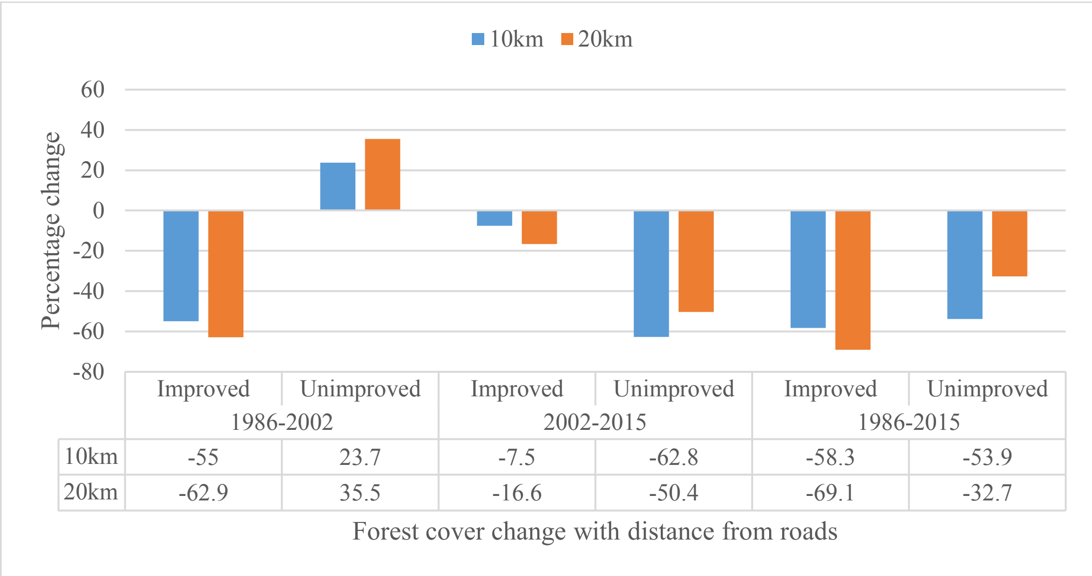
Figure 5.6: Vegetation cover change within 10km distance from a road, 1986-2015

Source: Author's change detection results using image difference, January 2016

A comparison of the land cover change along the 10km distance with a 20km distance buffer of roads showed significant differences in the magnitude of change but the direction of change remained the same (see Figure 5.7). Along the 20km distance of the improved road, there was 62.9% deforestation. That is, the additional 10km distance away from the improved road experienced 7.9% deforestation as compared to 55% deforestation within the first 10km distance within the same period, 1986-2002. Between 2002 and 2015 however, deforestation within the additional 10km distance away from the improved road was 1.6% higher than the first 10km distance buffer. Aggregately from 1986 to 2015, the recorded deforestation rate within the additional 10km distance buffer was 10.8% as compared with the 58.3% deforestation within the first 10km distance buffer along the same road.

Along the 20km distance of the unimproved road, a gain of 35.5% forest cover was recorded between 1986 and 2002. This represented 11.8% forest gain in the additional 10km distance buffer as compared to the gain of 23.7% along the first 10km distance within the same 16-year period. Between 2002 and 2015, the additional 10km distance buffer along the unimproved road experienced 12.4% reforestation, making the aggregate forest gain to be 21.2% from 1986 to 2015.

The difference between the 10km and the 20km buffer along the two roads is that deforestation reduces with distance to the improved road, a phenomenon similar to what has been observed elsewhere (Goosem, 2007; Laurance, Laurance, & Goosem, 2009). What was however realised from the image processing was that forest cover increases farther away from the unimproved road.

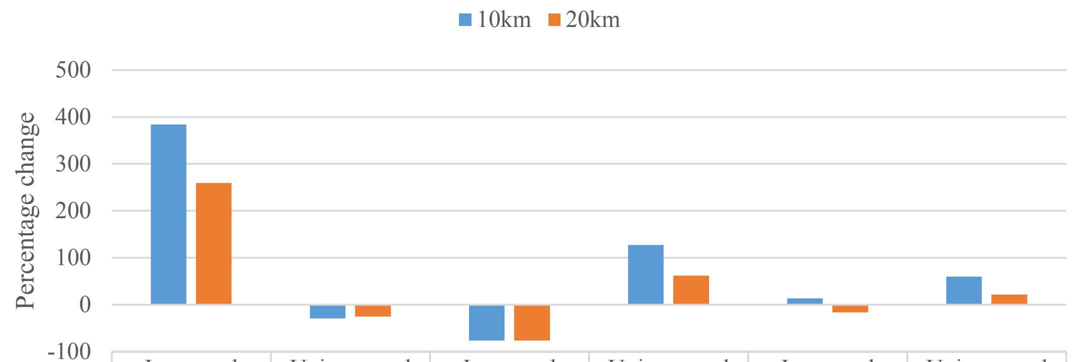


	Improved 1986-2002	Unimproved 1986-2002	Improved 2002-2015	Unimproved 2002-2015	Improved 1986-2015	Unimproved 1986-2015
10km	-55	23.7	-7.5	-62.8	-58.3	-53.9
20km	-62.9	35.5	-16.6	-50.4	-69.1	-32.7

Figure 5.7: Forest cover change within 10km and 20km distances from roads

Source: Author's change detection results, January 2016

With reference to Figure 5.8, agricultural land use reduced by 124.9% within the additional 10km distance buffer along the improved road from 1986-2002 but basically did not change between 2002 and 2015. Along the unimproved road, agricultural land use experienced an initial expansion of 4.7% from 1986 to 2002 but declined significantly by 65.5% from 2002 to 2015 within the additional 10km distance buffer. It can generally be said that agricultural land cover decreased farther away from the additional 10km buffer from both improved and unimproved roads in the study area, but the rate of decline was higher along the unimproved road than the improved road.



	Improved	Unimproved	Improved	Unimproved	Improved	Unimproved
	1986-2002		2002-2015		1986-2015	
10km	384.3	-29.8	-76.6	127.5	13.5	59.6
20km	259.4	-25.1	-76.8	62	-16.7	21.3

Agricultural land use with distance from roads

Figure 5.8: Agricultural land use change within 10km and 20km distances from roads

Source: Author's change detection results, January 2016

5.4 Discussion

Forest resources have been playing significant roles in livelihood diversification and nature dynamics. A change in its cover (loss or gain) therefore has impacts on forest-derived services and products in different dimensions. Deforestation for instance, caused by different factors threatens series of ecosystem and other services such as climate regulation, biodiversity conservation, water catchment protection, and livelihood support to forest dwellers (Sassen et al., 2013). This section discusses forest cover change and its impacts, the proximate cause of forest cover change, and the future of the remaining forest cover in the study area.

5.4.1 Forest cover change, 1986-2015

Forests have been a major source of carbon sequestration, aiding in reducing GHG emissions (Mithal et al., 2011). Over 80% of global carbon dioxide (CO_2) is stored in forests (Neale & Kremer, 2011; Pan et al., 2011). Tropical countries with increasing forest cover through afforestation or reforestation contribute to global emissions reduction, one of the focus of the Kyoto Protocol (Fang et al., 2014). Countries with increasing deforestation however increase global CO_2 emissions, a phenomenon receiving several attention about how it could be controlled. Based on the results from the image processing, Ghana's forest cover has been declining since 1986 in an increasing trend (see Table 5.3). Forest cover decreasing by 33.7% over a 29-year period implies a significant reduction in the carbon stock in living biomass and a corresponding increase in CO_2 emissions. This increasing trend of deforestation corresponds with the fact that carbon stock in Ghana's forest has declined from 454.8 to 307.2 million metric tonnes; this represents 32.5% forest decline or 1.6% annual deforestation over a 20-year period (1990-2010) (FAO, 2010a). The continuous decline of Ghana's forest would imply significant contribution to climate change with its associated effects on biodiversity and other ecosystem services.

Ghana's deforestation rate does not affect climate change only but also biodiversity. About 30% of Ghana's land area forms part of the Guinea Forest Region of West Africa, one of the 34 World Biodiversity Hotspots severely threatened (Arcilla, Holbech, & O'Donnell, 2015). Research has shown that 85% of Ghana's Guinea Forest Region has been degraded through human activities (Dowsett-Lemaire & Dowsett, 2014). As a result, avian community dynamics, population, and species composition have changed. For instance, through logging and other anthropogenic effects between 1993 and 2010, forest understory bird species abundance declined more than 50% in the Guinea Forest Region of Ghana (Arcilla et al., 2015). In addition, between 1993 and 2006, forest cover loss resulted in the extinction of 125 butterfly species, representing 25% of its original fauna, in a section of the study area (Larsen, Aduse-Poku, & Sáfián, 2009). The sustainability of biodiversity in Ghana is contingent upon the regulation of human-induced activities within the forest. Strict enforcement of environmental laws is key to effective regulation of human activities that trigger deforestation and subsequent biodiversity loss (Edwards et al., 2014).

Herbal medicine plays an imperative role in the health status of rural Ghanaians, especially forest dwellers. Almost all the medicinal requirements of forest dependent communities are derived from herbs, roots, and backs of trees from the forest. Traditional Birth Attendants (TBAs) and herbal practitioners in rural Ghana rely mostly on natural plants for their medical applications (Ahenkan & Boon, 2011; Asase & Oppong-Mensah, 2009). However, biodiversity-unfriendly practices have been causing the gradual extinction of the natural plants used for medical applications and research purposes (Awanyo, 2007). The continuous development and promotion of herbal medicine depends on the survival of the natural plant species. This could be achieved through deforestation mitigation strategies and/or effective forest conservation practices.

Ghana's forest areas are home to more than 10% (2.5 million people) of the population in the country. These dwellers secure their livelihoods mostly through the collection of non-timber forest products (NTFPs) although they engage in other economic activities. In their research from three forest districts in Ghana, Appiah et al. (2009) found that forest resources contribute 38% to the income of the dwellers. In Northern Ghana, over 600,000 women collect about 130,000 tonnes of nuts annually 40% of which is exported, generating US$30m to the national economy (Osei-Tutu et al., 2010). These benefits accrued from forest resources in Ghana are also generated in other tropical countries. For instance, in Nigeria, Ethiopia, Sudan, Togo, and South Africa, marketing of wild foods from forests value between 15% and 40% of rural household income (Kalaba, Quinn, & Dougill, 2013; Pouliot et al., 2012; Yemiru et al., 2010). Forest resources could serve as safety nets for rural dwellers in off season times for their usual economic activities (Paumgarten & Shackleton, 2011). However, this potential poverty reduction role that forest resources play particularly for forest dependent communities would gradually seize if the current trend of deforestation is not curbed.

5.4.2 Contributory factors to forest cover change

The causes of deforestation have been the subject of numerous studies across the tropics. Population growth coupled with increasing rural poverty, resulting in agricultural expansion, has been dominating the global discussion on the causes of deforestation in the tropics (Sassen et al., 2013). Between 1986 and 2002, 48.4% of the natural forest in the study area was converted to agricultural land use. Between 2002 and 2015, over half (51.1%) of the existing forest cover was converted to agriculture. Forest conversion to agriculture has been on the increase over the 29-year period (1986-2015). Although other land uses (such as settlements development, mining, logging, etc.) accounted for deforestation, none of them could be compared to the rate at which agricultural expansion has caused forest loss in the study area. As at the year 2015, only 47.2% of the natural forest remained intact while agricultural expansion has resulted in the clearance of 43.2% of the original forest cover since 1986.

Agricultural expansion at the expense of forest cover has been attributed to the growing of commercial crops such as cocoa, oil palm, cashew, and citrus in the study area. For instance, before the 1990s, cocoa was planted under partially cleared forest such that the remaining trees would provide shade for the cocoa trees (Anglaaere et al., 2011). After the 1990s, farmers especially migrants have been practising cocoa farming with total forest clearing (Ruf, 2011). The economic gains from these commercial crops drive their expansion thereby causing more forest and biodiversity loss especially in areas with weak enforcement of forest/environmental laws. A major challenge for conservationists and agriculturalists in the forest frontiers of Ghana has been how to balance the economically-driven agricultural expansion with conservation priorities in order to maintain ecosystem integrity and species viability (Asare et al., 2014).

The dominance of subsistence slash-and-burn crop farming has also contributed to the expansion of farms in the study area. None of the farmers in the study area who grow on subsistence basis practice farm intensification. As a result, when the current farmland loses its fertility through continuous cropping for some years, the only option to get a fertile land is to encroach the forest. This confirms the study of Owubah et al. (2000) that farmers at forest fringes use forest lands as land banks to increase agricultural production to support their livelihood. There could be a reason for encroaching the forest for agricultural purposes, for instance, inadequate funds to purchase agricultural inputs such as fertilisers to intensify farming; this should not guarantee total clearing of forests. Forest-farm friendly practices such as land sharing and land sparing could be carried out to ensure that as forest dwellers get their daily food needs, the forests would also be conserved.

Agricultural lands are abundant in almost all developing nations including Ghana, but they mainly consist of forests, wetlands and grasslands whose conversion would mean loss of biodiversity and ecosystem services (Garnett et al., 2013). There is however a high probability for land sharing to be successful in Ghana since most of the rural dwellers are subsistence farmers who produce mainly for household consumption, just as other smallholder farmers in Sub-Saharan African countries (Laurance, Sayer, & Cassman, 2014). However, practising land sharing requires education, training and strict environmental laws enforcement due to the conservation needs attached to it (Phalan et al., 2011). Degraded and fragmented areas of forests could be given out to farmers to interplant their food crops with specific quantities and types of endangered tree species on the given land. Establishing how land sharing could produce high yields and multiple ecosystem services should be a prior concern for both environmentalists and economists (the educators). How to balance the trade-off between yields and environmental services should also be considered in the context within which land sharing should be practiced (Garnett et al., 2013).

Although, the increasing global population with Africa experiencing the most brings forth an increasing demand for food, exerting more pressure on agricultural production. Some researchers argue that to meet the global food demand by 2050, agricultural production would have to increase by 70-110%, implying that about 1 billion hectares of land would have to be converted to agriculture (Edwards et al., 2014). However, agricultural expansion means loss of forest cover, a phenomenon that has been experienced in the study area over the 29-year study period. An alternative to increasing yield without expanding farms would be to intensify farming (Sayer et al., 2015). A study conducted by Alliance for a Green Revolution in Africa (AGRA) (2013) in some West African countries showed that agricultural intensification has doubled and in some occasions tripled smallholder farmers' output. In the case of Ghana, agricultural land has been expanding by 1% annually between 2004 and 2014 with no significant yield increase but rather a decline in Agriculture's GDP from 41.5% to 20.7% in the same period (World Bank, 2015). Agricultural intensification could contribute to the conservation of the remaining Ghana's forest and biodiversity. At the same time, the food requirements of the country would be met and the surplus could be marketed and added to the households' income.

5.4.3 Effects of roads on forest cover change

Forest cover along both roads have been decreasing since 1986. However, within 10km from both roads the rate of decline was higher along the unimproved road than the improved road especially between 2002 and 2015. This contradicts with some research that the construction of paved roads in forest areas lead to severe deforestation (Laurance, 2013). It might depend on the purpose for constructing the road; if it was for timber extraction, then deforestation would increase as timber contractors would extend secondary networks of roads to their concessions to enhance timber extraction (Arima et al., 2005). The roads in the study area were constructed to link communities and enhance easy access to other areas. The current improved road was unpaved just as the unimproved road as at 1986. The road was improved/paved in the late 1990s. The previous status (prior to the improvement) might have reflected the 55% deforestation that occurred between 1986 and 2002. After the road was upgraded, forest cover along it declined by 7.5% as compared to a 62.8% decline along the unimproved road between 2002 and 2015. It might be that the initial 55% deforestation prior to the road's improvement might have cleared most of the forest within the 10km distance from the road, there was still a significant decline in the rate of deforestation within the second study period (2002-2015).

As at 1986, the current unimproved road was narrow with forest all along. Not much human activities such as farming was taking place at that time. As a result, forest cover along the unimproved road did not decline between the years 1986 and 2002 but rather increased. According to the Forest Service Division of the study area, Samatex Company Limited, a timber company owning a major concession in the area expanded the road in the early 1990s by grading but it was still earth. The company graded the road to enhance their transportation of timber. This road has remained unimproved/earth to date and 62.8% of the forest cover along the road has been lost within 13 years (2002-2015) as compared with 7.5% along the improved road. The overall deforestation within the 10km of the improved road is 4.4% higher than along the unimproved road over the 29-year period (1986-2015). Nevertheless, with the current trend of annual deforestation, the remaining forest cover along the unimproved road is at a higher risk of being cleared than that along the improved road.

5.4.3.1 Causes of deforestation along the study roads, 1986-2015

In general, several factors cause deforestation as discussed previously. The factors however vary along roads in forest frontiers depending on the functions of those areas. The image processing results showed that two main factors have caused deforestation in the study area over the 29-year period. These two factors are: agricultural expansion and settlements growth. Between 1986 and 2002, agricultural land use increased by 384% along the improved road (it should be noted that the road was improved in the late 1990s) while it declined by 29% along the unimproved road. Between 2002 and 2015 however, the trend changed; along the improved road experienced a decline in agricultural land use while the unimproved road recorded an increase in agricultural land use (see Figure 5.6). This results partially contradicts with the findings of Masters et al. (2013) that access to roads increase agricultural activities (if taking to be expansion) although the quality/condition of roads and the contextual land tenure systems were not considered in their research. Settlements continued to expand along both roads. However, the rate of expansion along the improved road was higher than along the unimproved road.

The increasing expansion of agricultural and settlement land uses corresponded with the decline of forest cover along both roads. At the improved road section of the study area, forest transition to agriculture was not as high as what was experienced along the unimproved road. This is because land tenure system at the improved road zone started getting stricter as more people migrated to the area from the late 1990s when the road was improved. The in-migration happened for two reasons. First, the area offers fertile land for agricultural production. Second, the main road that connects Ghana to the northern, western, and eastern neighbouring countries (Togo, Burkina Faso, and Cote D'Ivoire) passes through the study area. There is therefore ready market for agricultural produce in almost all the communities along the road. The increasing population of migrant farmers without land titles in the study area has led to the lease of lands to these farmers on annual and produce sharing arrangements. An interview with 150 farmers at the improved road zone revealed that the mean land size leased to a migrant farmer was 1.2 ha (3 acres). The lease arrangement could either be annual hiring or sharecropping. This implies that almost no migrant farmer could own a land for farming at the improved road zone. This traditional land regulation by the owners has resulted in minimal expansion of agricultural land. Additionally, forest guards have been patrolling the forest areas ever since the road was improved and there have been strict laws and penalties against forest encroachment.

Unlike the improved road section of the study area, agricultural land use along the unimproved road has been expanding due to two phenomena. First, the land tenure arrangements for farmlands permit migrant farmers to own a portion of the land leased out to them. Generally, landless farmers could arrange with resident land owners to lease out their lands to them for farming purposes. The norm in the study area with unimproved roads was that a land owner would lease their land to a migrant or resident farmer on condition that the farmer would grow cocoa in addition to their food crops. According to the farmers, it takes about four to five years for cocoa seedlings to mature. The farmer would however grow and harvest their food crops on annual basis. After four years when the cocoa starts yielding fruits, the cultivated land is shared between the farmer and the land owner. The portion that would be given to the farmer would become their property but no official land documents would be added. Cocoa trees at a point form canopy.

When this happens, food crops would no longer grow well within the cocoa farm due to the shade. The farmer would have two options; either clear some portions of cocoa for food crops (which rarely happens), or search for another uncultivated land that could be leased out to them under the above same or similar arrangements. This land tenure system has been practiced in the study area since the 1980s and has been one of the underlying factors of agricultural expansion in the study area.

The second agricultural expansion phenomenon is the clearing of adjacent forests to cultivate food crops. The farmers use the nearby forest as land banks to increase their farm outputs when the current farmland loses its fertility, or when cocoa takes over the land. Since the area is often not "motorable" especially during the raining season, the forest guards are not able to patrol the demarcated forest areas as frequent as the improved road zone. As a result, the smallholder farmers take that opportunity to gradually clear portions of the forest close to their farms for food crop cultivation. Similar scenarios have been observed in some other forest areas in Ghana (Damnyag et al., 2013; Owubah et al., 2000). According to the Forest Service Division (at the unimproved road study area), how to prevent smallholder farmers from clearing the forest has been their major challenge for years. This is because in most cases, the foresters would see the cleared forest at the time the land has already been cultivated, making it impossible to stop the clearing in the first place. This might imply that there is no effective monitoring of the forest perhaps due to the condition of the road. Although, improving the road might lead to in-migration of landless farmers into the area with its associated environmental consequences, it might lead to more effective monitoring of the forest.

5.5 Remaining forest cover in Ghana: Concluding remarks

Through the image processing, it has been identified that agriculture has been dominating the land cover in the study area and depicting an increasing trend over the 29-year study period. This conformed to the country's profile that agricultural land use covered 66.8% of Ghana's total land area (FAOSTAT, 2015). Unlike agricultural land use, forest cover in the study area has been declining throughout the study period. The initial coverage of 31.3% as at 1986 was in conformity with the reports of the Food and Agriculture Organization (FAO) (2010b) although their figures was for the year 1990 which were extrapolated from some years before and after 1990.

Forest cover has been declining at an increasing rate annually. Although each of the study periods recorded a loss and a gain, the intensity of the annual losses has reflected the increasing decline over the 29-year period. Agricultural expansion has contributed significantly to the forest cover loss in the study area. This might result from several factors one of which is the loss of soil fertility rendering the existing farmlands incapable of producing the required yield. It might also result from an increase in population in the study area, putting more pressure on the existing farmlands as new farmers emerge. The population growth may also render the existing agricultural land unable to sustain the food demands of the population based on the existing farm practices. But agricultural expansion leading to deforestation would not necessarily increase production. Agricultural intensification has been recognised as one of the most effective ways of increasing farm production with minimal effect on the terrestrial environment (Sayer & Cassman, 2013).

Agricultural intensification could offer a wide range of benefits. First, it could save the forest and biodiversity from extinction since farmers would no longer depend on forest as a source of fertile land for agricultural production. Second, the food needs of smallholder farmers would be met and the surpluses could be marketed to increase the income portfolio of farm households. Third, agricultural intensification could gradually migrate smallholder subsistence farmers to commercial farmers without expanding their farm sizes. Promoting agricultural intensification in the study area could therefore be a significant pathway out of poverty (Foley et al., 2013) and forest and biodiversity conservation strategy. These benefits could be realised optimally when roads within forest areas of Ghana are improved.

Roads could be detrimental sometimes especially when strict before, during and after construction environmental management measures are not strategically adhered to (Boakes et al., 2010; Laurance & Balmford, 2013). Roads connecting farming areas to urban and marketing centers however play vital roles in the rural development and agricultural transformation of communities (Perz et al., 2012). Without improved roads, the benefits of agricultural transformation (increased and sustained food production) would be counteracted by massive post-harvest losses since harvested produce would not be transported to demand centers on time due to road conditions. With improved roads and effective implementation of environmental laws, agricultural transformation through intensification could be achieved which would improve the livelihoods of smallholder farmers while ensuring the sustainability of forest and biodiversity.

CHAPTER SIX

SUMMARY OF MAJOR FINDINGS, RECOMMENDATIONS, AND CONCLUSION

6.1 Introduction

This chapter outlines the major findings from the research under three main objectives: the influence of roads on farm size, farmers' market participation, and forest cover change. Recommendations for agricultural transformation and forest conservation with roads improvements are suggested. Areas that require further research have been outlined. The chapter ends with the general conclusion of the research.

6.2. Major findings

The research was carried out with three questions:

- To what degree do roads influence farm size and market participation of different typologies of farmers?
- What factors contribute to forest cover change in Ghana?
- To what extent does forest cover change along roads in Ghana?

The findings are summarized based on the above research questions.

6.2.1 Influence of roads on farm size in rural Ghana

- Two broad farmer types are evident in rural Ghana. These are; improved road farmers and hinterland farmers.
- Improved roads reduce the rate of farm expansion net all other variables (see Table 4.4).
- Improved road farmers have relatively small farm sizes (mean farm size is 2.71ha as at 2014) than hinterland farmers (mean farm size is 3.03ha as at 2014).
- The rate of farm size reduction with time is higher at the improved road zone than in the hinterlands.

6.2.2 Influence of roads on farmers' market participation in rural Ghana

- Improved roads have the highest probability to influence farmers to commercialise their produce (see Table 4.6).
- The mean proportion of produce sold by an improved road farmer is 84% while that of a hinterland farmer is 31% (see Table 4.3).

- When cocoa farmers are excluded, 37.4% of the improved road farmers sell all their farm produce while only one hinterland farmer sells all his farm produce. The hinterland farmers grow mainly for consumption due to the challenges they face with transportation.
- The improved road farmers have access to daily markets along the road within their communities and weekly central markets with the farthest distance being 10km. The hinterland farmers have access to only weekly markets which is about 29km from the farming areas with poor road condition.

6.2.3 Causes of deforestation in rural Ghana

- Forest, agriculture, and settlements constituted 31.3%, 56.9%, and 1.5% respectively of the total land in the study area as at 1986. Forest, agriculture, and settlements constituted 20.1%, 62.5%, and 14.2% respectively as at the year 2015.
- Net forest cover loss from 1986 to 2015 was 33.7% with annual deforestation rate of 1.2%.
- From 1986 to 2015, 52.8% of forest in the study area was converted to other land uses.
- Agricultural expansion resulted in the deforestation of 94.9% of the forest cover lost between 1986 and 2002 while settlements expansion and other minor factors caused the remaining deforestation. Between 2002 and 2015, agricultural expansion caused 96.9% of the deforestation in the study area.
- Agriculture and settlements expansion were the main causes of deforestation in the study area.

6.2.4 Forest cover change along roads in rural Ghana

- More than 50% deforestation occurred along both the improved and unimproved roads over the 29-year period.
- Within 10km from the roads, deforestation was higher along the unimproved road than the improved road, especially between 2002 and 2015 (62.8% for the unimproved road and 7.5% for the improved road).
- While along the improved road experienced a decline at a decreasing rate overtime, along the unimproved road experienced deforestation at an increasing rate overtime. This is because agricultural expansion was 63% higher along the unimproved road than the improved road for the 29 years.

6.3 Recommendations

Agriculture should be transformed through the use of modern farm practices. All the farmers in the study area farm from their own experiences. None of the farmers in the hinterland who grow only food crops apply inputs such as fertilizers to their crops. They rely on the natural soil fertility for their production, partly because they produce mainly for consumption. Although, some of the improved road farmers apply fertilizers and pesticides to their food crops, they do it with no prescribed indications as to the quantity and frequency with which to apply.

Agricultural transformation requires effective farmer training through on-farm demonstrations by agricultural extension officers. Field demonstrations could be done on community basis so that the farmers would know the best practices to adopt. It would also help the farmers to consult their fellow farmers when they encounter difficulties in applying certain methods since they would all be given the same training at a point in time. Field demonstrations should be done at the beginning of the cropping seasons. This would help the farmers to remember most of the techniques they would be applying since they would be farming in that same season.

Farmer education could also be carried out through radio programs so that farmers in remote areas where the demonstrators might not be able to travel due to road conditions could benefit through the radio. In rural Ghana, over 90% of the populace have radio features on their cell phones, use radio sets at their homes, work places, and even on the farm, and this has proven to be one of the effective ways to disseminate agricultural information to farmers (Adei, Amponsah, & Acheampong, 2015). Once the farmers begin to practice modern farm methods, farm size expansion as a means to increase production would be minimal.

Farmers should be encouraged to minimise slash-and-burn agriculture. They should be educated about the dangers of slash-and-burn such as the spread of fire into the forest, killing of micro-organisms in the soil, and burning of endangered tree species on the farmland. Farmers should be sensitised on the role of composting and mulching in soil enrichment and water conservation.

Tree-crop planting should be practiced in the communities closer to the forests and where portions of the forests have been degraded. Farmers who are willing to engage in tree-crop planting projects should be apportioned some deforested areas to interplant their food crops with specific tree seedlings. The types of trees to grow, the forest areas to use, how to grow the trees, and the land tenure for the farmers to grow their crops should be decided by the Forest Service Division in charge of the particular forest area and communicated to the willing farmers. The trees' maturity period should be about five years after which the farm would exit the land. This would ensure that the farmers' livelihoods are improved for at least five years while reforesting a degraded land at the same time. The farmers that would be involved in the tree-crop planting project should be encouraged to leave their previous farmlands to fallow for at least two years since they have an alternative source of feeding. This would enable the farmlands to regain their soil fertility before the farmers return to them.

When farmers adopt modern techniques to increase their production, the surplus would have to be sold. Roads in the hinterlands should be improved so that farmers would not have to encounter post-harvest losses resulting from transportation difficulties. When the roads are improved, investors would be attracted to the agricultural corridor. New employment opportunities would emerge. Rural farmers would no longer depend on farming only for their livelihoods, but would also have other non-farm economic activities as a complement.

6.4 Areas of future research

This research has shown that farmers in the hinterlands expand their farms more than the improved road farmers. Research is required to assess the yield per hectare of land in relation to the use of farm inputs at both the hinterlands and the accessible areas in the study region.

It was found from this research that land tenure system for farming in the hinterlands is different from the improved road zone. The hinterland migrant farmers could own their farmlands through share cropping and some conditions while the improved road farmers could only share crop but not own the farmlands through share cropping. Further research would have to be carried out to assess the different land tenure systems for farming and their effects on farm practices and crops grown.

Improved roads are said to attract investment opportunities, which create myriad jobs and enhance community development. This implies that residents at well-connected areas might engage in more than one economic activity. The probability of farmers participating in non-farm enterprise and its intensity in the study area warrants future research.

6.6 Conclusion

Agriculture is the major economic sector in the study area. Crop farming is done mostly in forest frontiers, making it a threat to forest cover. Traditional methods of farming are used, and this constraints farmers to subsistence cultivation. Farmers' livelihoods could be improved through the transition from subsistence to commercial farming. Agricultural commercialisation comes through intensification: producing more on the same piece of land. The surplus could then be marketed to increase the household's income.

To promote agricultural commercialisation, farmers would have to be connected to the outputs markets and inputs sources through improved roads. Improved roads would also attract more farmers and put more pressure on the existing farmlands and the forest cover. However, the application of modern farm techniques and strict enforcement of environmental laws would help increase yield on existing farmlands while protecting the forest.

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APPENDIX

A. Sample size calculation

$s = [z^2*N*P (1-P) / [e^2*(N-1) + z^2*P (1-P)]$, where:

s = sampled farmers; N = total farmers in the study area

z = standard score at specific significant level; P = probability of selecting a farmer

e = error margin

$s = [1.96^2*1612*0.7 (1-0.7) / [0.05^2*(1612-1) + 1.96^2*0.7 (1-0.7)] = 269.0101 = 269$ farmers.

B. Household questionnaire

VERBAL INFORMED CONSENT

PRINCIPAL INVESTIGATOR: **EMMANUEL ACHEAMPONG**
PROJECT TITLE: **IMPACT OF ROAD INFRASTRUCTURE ON LIVELIHOODS AND LAND USE IN RURAL GHANA**
SCHOOL: **EARTH AND ENVIRONMENTAL SCIENCES**

Good day, my name is Emmanuel Acheampong and I am a student at James Cook University, Australia. I am studying **"the impact of road infrastructure on livelihoods and land use in rural Ghana"** with the focus on farmers**.** I will appreciate it if you can spare about 30 minutes of your time to answer a few questions.

- The project is purely for academic purpose and the results will be used for academic reports.
- Taking part in this study is voluntary and you can stop taking part in it at any time without explanations or prejudice and to withdraw any unprocessed data you have provided.
- Any information you give will be kept strictly confidential and that no names will be used to identify you in this study without your approval.
- With your consent, this interview will be audio-taped.

Do you consent to participate in this project?

RESPONDENT'S ID:………………………………….

PART A: HOUSEHOLD CHARACTERISTICS

1. Age…………………………………………………………………………………
2. Gender a) Male b) Female
3. Educational attainment (e.g. primary 4/year 4/ grade 4)…………………………
4. Marital Status a) Married b) Single/Never married c) Divorced d) Widowed
5. Hometown ………………………………… District ………………………
6. How long (e.g. 30 years) have you lived in this community? ………………
7. Where were you living previously (if applicable)?...
   i. What work were you doing in you previous place?..
   ii. Why did you move to this town?..
   ....
8. How many people have left your household for the past 5 years?.......................
   i. Where have they moved to (Name of places)?...
   ……………………………………………………………………………………
   ii. For what reason did they move to those places (please provide reason for each of the places)?
   ……………………………………………………………………………………
   ……………………………………………………………………………………
9. Major Occupation (please list all)...……………………………………………
10. Minor Occupation (please list all)………………………………………………
11. Household size (including you)…………………………………………………
12. Please fill the table below for the other members of the household

No.	Sex (M/F)	Age	Education level	Occupation (Please list all that apply)
1				
2				
3				
4				
5				
6				

PART B: FARM ECONOMIC ACTIVITY

13. How many years have you been farming? ………………………………………
14. How many days in a week do you go to farm? ……………………………………
15. How many plots do you currently farm on? ....
16. Please complete the table below for the current plots you farm on

No.	Year acquired	Acquisition method	Size (Ha/Acres)	Location	Crops grown (please list all)	
					Major	Minor
1						
2						
3						
4						

   i. Acquisition method? a) Purchased b) Inherited c) Leased/ share cropping d) gift
   ii. If leased, for how many years?..............., and how many years left?.................

iii. If leased, what is the arrangement? a) Annual payment of………. b) Abunu c) Abusa

17. Do you have any plot/ portion of your current farm land in fallow? a) Yes b) No

18. If yes, please fill the table below (if on current plot, indicate proportion under "size")

No.	Year acq	Acq. method	Size	Location (e.g. in community)	Length of fallow
1					
2					
3					

19. What farming system do you practise (Please fill all that apply)?

Farming system	Labour hired (e.g. 2)	Freq per season (e.g. 4)	Household labour #
a. Shifting cultivation			
b. Crop rotation			
c. Mixed cropping			
d. Mono cropping			

i. Why do you practise (e.g. a=shifting cultivation)?
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

20. Please fill the table below for the crops you grow.

Crop (e.g. maize)	Harvests per year (e.g. 3 times)	Output per harvest (e.g. 10 bags)	Quantity consumed (e.g. 2 bags)	Quantity sold (e.g. 8 bags)

21. Please fill the table below for the crops grown for the past five years

Year	1st 4 major crops and farm size (e.g. maize=5acres)				Farm size
2014					
2013					
2012					
2011					
2010					

22. What factors are influencing this trend?...
……………………………………………………………………………………………
……………………………………………………………………………………………

PART C: EFFECTS OF ROADS ON FARMING

23. Please fill the table below for transporting farm output from farm.

	i. Mode of transport to		ii. Route to…..		iii. Cost of transport to	
Crop	house	market	house	market	house	market

i. a) head portage (b) by bicycle (c) family car (d) hired car (e) passenger car (f) others

………………………………………………………………………………………

ii. a) farm-roadside-house (b) farm-house (c) farm-roadside-market (d) farm-home-market (e) farm-market (f) sold on the farm

iii. Example ¢1 per bag or ¢20 per trip

PART D: EFFECTS OF ROADS ON TRANSPORT COST

24. Distance from farm and house to the market (GPS will be used to verify this)

Origin	Distance (mi/km)	Travel time (hrs/mns)	Waiting time (hrs/mns)	Travel cost
Farm				
House				

25. What basis do drivers use to charge the cost for transporting your produce to home or market center? a) Fixed price to market irrespective of quantity of produce and road condition (b) Distance to destination and quantity of produce (c) Road condition, distance and quantity of produce to transport (d) others ……………
26. In which months are the roads impassable due to rains? ………………………

………………………………………………………………………………………

i. In those months, how do you transport your produce from farm to the market?

………………………………………………………………………………………

ii. In those months, how many days can it take to get your produce to the market/home?.........

iii. What quantity/ proportion of your produce destroy due to impassable road (e.g. 2 bags, 10%)?

………………………………………………………………………………………

iv. How high can the transport cost be in those months (e.g. 2x, give example say from ¢2 to ¢5)?

………………………………………………………………………………………

27. Are vehicles always available to travel to other areas outside your community? a) Yes (b) No
    a. If no, please explain ……………………………………………………………
28. Are vehicles always available to transport produce to home/ market? a) Yes (b) No
    a. If no, please explain ……………………………………………………………

PART E: NON-FARM ECONOMIC ACTIVITY

29. How many years have you been in these activities (refer to Q9 or 10)? …………
30. Why did you adopt these activities? ....
31. How many members of your household are into these and other activities?.................
    a. Please state the other activities (if applicable) ………………………………
32. How many days and hours per week do you spend on this activity? (e.g. 5 days, 7am-6pm)
    ……………………………………………………………………………………
33. If you are to weigh this/these activity(ies) on a scale of 10 with your farm work in terms of income, what scale will you give (e.g. 7= trading, 3= farming)?....................
34. How much/ proportion of your non-farm income is saved (e.g. ¢1 a day)?.................
35. How much/ proportion of your non-farm income is consumed?...............................
36. How much/ proportion of your non-farm income is invested in farm per season?........

PART F: ASSET AND EXPENDITURE

37. Please fill the table below for farm inputs expenses

Item	Cost per season. You can write additional comments here
Agricultural inputs per season:	
1. Fertilizers (Qty…………)	
2. Weedicides (Qty………..)	
3. Pesticides (Qty………….)	
4. Hired labour (cost per 1)	
5. Manure (cow dung, poultry)	
Plant seeds (pls list all and qty)	
e.g. maize, 10 packets	**¢5 per packet**
1.	
2.	
3.	
4.	
5.	
Other inputs	

38. Where do you buy/ get your farm seeds and inputs from?...
    ……………………………………………………………………………………

39. Please fill the table below for assets you have

	#/amount	Acquisition (e.g. farm income, inherited, gift, etc.)
House		
Vehicle/car/truck		
Tractor		
Plough		
Motor		
Bicycle		
Push truck/ cart		
Wheel barrow		
Cutlass		
Hoe		
Pickaxe		
Mattock		
Shovel/ spade		
Rake		
Silos/storeroom		
Chainsaw		
Watering can		
Sprayer		
Shop/ kiosk		
Savings		
Remittances		

40. Please tick "√" if the following facilities are available in this community

Facility/ Service	**tick**	**Facility/ Service**	**tick**	**Facility/ Service**	**tick**
KG		Clinic			
Primary sch.		Drug store			
JHS		Pharmacy			
SHS		Hospital			
Hand dug well		Rural Bank			
Borehole		Credit Union			
Pipe-borne		Susu collectors			
Electricity		Market center			
TBA		Police Post			

End of the survey. Thank you for your cooperation.