Ghana's high forests: trends, scenarios and pathways for future developments

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Thesis

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General introduction

1.1 Tropical deforestation and forest degradation

Tropical deforestation is one of the most serious environmental problems in recent decades and has become a major global concern due to the importance of tropical forests in biodiversity conservation and its critical role in global climate change (Culas 2007, Kanninen et al. 2007, Nabuurs et al. 2007, Payn et al. 2015). Deforestation also affects economic activity and threatens the livelihood and cultural integrity of forest-dependent people at the local level. It reduces the supply of forest products and causes siltation, flooding and soil degradation (Culas 2007). Reducing tropical deforestation is therefore of global importance for the sustainable production of timber and non-timber forest products, the mitigation of climate change, and the conservation of biodiversity (IPCC 2007).

Notwithstanding the global acknowledgement of the importance of forests, particularly tropical forests, recent data show that forest area has continued to decline (Keenan et al., 2015) while agricultural land continues to expand in tropical areas (Gibbs et al. 2010, Payn et al. 2015). Globally, total forest area declined from 4,128 million ha in 1990 to 3,999 million ha in 2015. The forest loss is occurring almost exclusively in the tropical forest areas having particularly high ecological value; with either stable or expanding forest in other domains (FAO 2015, Keenan et al. 2015, Morales-Hidalgo et al. 2015). In Africa, total forest area declined from approximately 706 million ha in 1990 to 624 million ha in 2015 (FAO 2015).

In Ghana, however, the 2015 Global Forest Resources Assessment results showed that total forest area increased from 8.6 million ha in 1990 to 9.3 million ha in 2015, due mainly to a reclassification of more areas as forests (Affum-Baffoe 2015, FAO 2015). On the other hand, recent deforestation rate for Ghana has been estimated to be over 135,000 ha annually between 1990 to 2010 (FAO 2010a, FAO 2010b). At that rate of deforestation, it is estimated that forests outside forest reserves in Ghana are likely to be completely lost in the next 10 years, and the forest reserves will continue to be under a more acute threat of encroachment and other illegal activities if urgent and concerted action to eliminate the threats of deforestation and forest degradation is not taken (PWC 2015). As Ghana loses its forests, it threatens the security of supply of some of the most important foreign exchange earners in the country since the forests provide ecosystem services and functions that support the country's predominantly agricultural economy (PWC 2015).

The drivers of deforestation and forest degradation are complex and interconnected. Geist and Lambin (2002) distinguish between proximate, or direct, drivers and underlying, or indirect,

drivers. The proximate causes that impact directly on the forests are agricultural expansion, infrastructure, wood extraction, grazing, mining and fuelwood collection, among others. The underlying causes in general terms include demographic trends, economic decisions, technological change, and policy and cultural factors (Geist and Lambin 2002). In Latin America, commercial agriculture, including livestock, is the most important direct driver of deforestation, contributing around two-thirds of total deforestation. In Africa and sub-tropical Asia, commercial agriculture and subsistence agriculture accounted for approximately one-third of deforestation each. Both mining and infrastructure development are important drivers in Africa and Asia, more than in Latin America (Brack and Bailey 2013, Geist and Lambin 2002, Kissinger et al. 2012). Concerning forest degradation, timber and logging activities accounted for more than 70 per cent in Latin America and Asia, whereas fuelwood collection, charcoal production, forest fires and human settlements are among the main drivers for Africa (Brack and Bailey 2013, Damnyag 2012, Kissinger et al. 2012).

The underlying, or indirect, drivers constitute an interplay between demographic, economic, technological, institutional, cultural and socio-political changes (Geist and Lambin 2002). Forest sector governance and institutions including conflicting policies beyond the forest sector, and increasing demand for timber and agricultural products in a globalizing economy are among the underlying causes of deforestation and forest degradation. Other causes are illegal activity relating to weak enforcement, poverty and insecure land tenure (Brack and Bailey 2013, Kissinger et al. 2012, Prince's Rainforest Project 2009).

For Ghana, the principal drivers of deforestation and forest degradation are agricultural expansion (50%), wood harvesting (35%), population and development pressures (10%), and mining and mineral exploitation (5%) (Ghana Readiness Preparation Proposal 2010). Thus, the direct causes of deforestation and forest degradation are clearing of forests for food and cash crop farming, logging (both legal and illegal), fuelwood harvesting, infrastructure expansion, and wild fires. The underlying causes are a high international demand for timber, cocoa and minerals, poverty, corruption, the overcapacity of the forest industry, low forest fees, the low enforcement of forestry rules, population growth, urbanization and land and tree tenure issues (Appiah et al. 2009, Benhin and Barbier 2004, Hansen et al. 2009).

Over the years, the government of Ghana has become ever more concerned about the extent of deforestation and forest degradation and the future timber production prospects in the country. As a result, various measures are being pursued that are targeted at addressing deforestation and forest degradation and at increasing the forest resource base. These include

policy and legislative reforms, capacity building, awareness creation, the establishment of a law enforcement unit to address illegal logging activities, the implementation of a stricter wood procurement policy, consultation with stakeholders in resource management, forest plantation development and the restoration of degraded forest lands (Abbey 2011, Bamfo 2009, Hansen et al. 2009). The measures being pursued in forest management today will have an impact on forest resources for decades to come and so insights into the future outlook of the Ghanaian forest resource base is important. The aim of this thesis, therefore is to generate insights into possible future developments of Ghana's high forests by assessing the trends in current forest use and management and by exploring future developments.

1.2 Major issues affecting forest resources in Ghana

The forestry sector of Ghana has been recognized over the years to have played a significant role in the country's development. Currently, the forestry sector contributes 2.3 percent (USD 862.9 million) to the country's gross domestic product (GDP) (GSS 2015). The timber industry is the fourth largest foreign exchange earner after minerals, cocoa and oil exports. In addition to timber, forests provide the main source of domestic energy in the form of fuelwood and charcoal. The average annual per capita wood energy consumption estimate is 1.3 m^3, giving a total estimated wood removal of more than 30 million m^3 for fuelwood and charcoal, or about 85% of the total wood removal in Ghana (MLNR 2012). Although important as a sector, forestry in Ghana is struggling with a number of challenges: overexploitation beyond annual allowable cut (AAC), declining stocks and productivity, overcapacity of the timber industry, chainsaw milling, and illegal logging. These challenges are briefly elaborated below.

In an effort to ensure continuous supply of timber from the timber production systems in Ghana, timber harvesting is controlled by the annual allowable cut (AAC), i.e. a maximum volume of timber that is set for annual exploitation. The current AAC is 2.0 million m^3: 0.5 million m^3 from forest reserves and 1.5 million m^3 from the off-reserve areas (Bamfo 2005, Bird et al. 2006). However, current total timber harvest in Ghana is estimated at approximately 3.7 million m^3 to 6 million m^3, which is almost two to three times the AAC (Birikorang et al. 2001, Hansen et al. 2012). For many years, off-reserve timber harvests accounted for substantial share (70% to 75%) of the total timber harvests in Ghana but the greater proportion of the current harvest rather originates from the forest reserves (FPIB LMC Totals 1980-96, Hansen et al. 2012, Treue 2001). Due to the low compliance with the AAC and the many decades of

overexploitation in the timber production systems, the current AAC no longer represents a sustainable level for harvesting (Wong 1998). Moreover, fuelwood extraction which used to take place in the savanna zone is increasingly being shifted to the forest reserves in the high forest zone (HFZ), contributing to forest degradation in the HFZ.

Consequently, the forest resources in Ghana are being depleted at a fast rate. Recent forest inventory shows a decline in the stocking levels of timber within forest reserves (MRI 2002), an indication that forest productivity is declining with each subsequent harvesting. The current management regime for timber production within production forest reserves is the use of a polycyclic selection felling system using a cutting cycle of 40 years. There are regulations that define the selection of harvestable trees and the setting of the annual allowable cut (AAC). This is supposed to result in less damage to the residual forest and ensure sufficient regeneration. However, silvicultural treatments after harvest are not applied and the increment of the residual forest depends entirely on the forest's response to logging, leading to continuous decline of the forest resource base.

Ghana's timber industry is characterized by an over-capacity and inefficient mills. The industry has a processing capacity of about 5.2 million m^3, which is far in excess of the AAC (Agyeman et al. 2003). The increase in mill capacity is attributed largely to the availability of relatively cheap raw material. Worsening the situation is the fact that the industry is operating at a low recovery rate (20-40 %) due to the inefficiency of the mills. The timber industry is distressed due to unavailability of trees for felling and growing demand for timber. Consequently, a major problem facing the timber industry is the large unutilized installed capacity and low rates of recovery against a rapidly declining timber resource base.

Ghana is among the countries in West Africa having a well-developed sawmilling industry and the export of timber has been a key activity in the country. The Ghanaian timber industry is made up of 130 wood-processing units and about 200 other enterprises focusing on furniture production. There are over 41,000 small-scale carpenters registered with the Association of Small Scale Carpenters. These represent the largest group of end-users and they require about 219,000 m^3 of sawn timber annually. This represents about 72 % of the total domestic timber requirement for the entire country (Agyarko 2001). Meanwhile, the sawmill industry in Ghana is export-oriented serving the more attractive export market and does not find it economically feasible to satisfy the low-priced domestic lumber market. The high domestic demand for sawn timber of about 590,000 m^3 (Marfo 2010), and the conventional sawmill industry's inability to supply the domestic demand remains one of the principal driving forces,

not only of chainsaw milling (CSM) but also of illegality in the timber industry in general. CSM refers to the on-site conversion of logs into lumber for commercial purposes using chainsaws. CSM has been banned in Ghana since 1998 making it illegal, but remains widespread in the country despite measures put in place by government to enforce the ban (Marfo 2010). The domestic timber trade is mostly served by chainsaw operators who operate without any legal authority or license, contributing about 84 percent of the domestic lumber supply (Marfo 2010) with the remaining 16 percent being supplied by sawmills. The supply of legal timber to the domestic market is a crucial issue in the forestry sector in Ghana. The informal CSM sector is almost equal in size as the formal sector in terms of employment: CSM employs 97,000 people, formal sawmill employs 100,000 people (Adam and Dua-Gyamfi 2009, Marfo 2010). The CSM sector is also the main source of illegal overland export lumber to neighbouring countries with an estimated volume of around 260,000 m^3 (Marfo 2010, MLNR 2012).

1.3 Reforestation and tree planting in Ghana

Plantation development has for a long time been identified as one of the important strategies required to meet the increasing demand for timber resources in Ghana. Between 1970 and 1980, Ghana established 75,000 ha of plantations within degraded forest reserves using the taungya system. The taungya system in Ghana is a forestry system in which farmers are given part of degraded forest reserves to inter-plant timber trees with food crops so that farmers would help establish and maintain the timber trees. By the mid-1980s, only 57% of the total plantation had however survived with only 21% of the total area considered commercially viable. This low percentage of survival was due to the fact that under the taungya system farmers had no rights to benefits accruing from the planted trees (Milton 1994) and no decision-making role in any aspect of forest management (Birikorang et al. 2001). As a result, farmers tended to neglect the tree crops and to abuse the system. Some farmers deliberately killed planted seedlings to extend their tenure over portions of land (Agyeman et al. 2003). In the mid-1990s, the Ghanaian government embarked on a reforestation programme as part of the 1994 Forest and Wildlife Policy to address the problem of declining forest resource base arising from deforestation and forest degradation. In 1996, the Forestry Development Master Plan (FDMP 1996–2020) was launched. The aim of the FDMP was to promote private plantation development, with a target of 10,000 ha annually for 20 years. To achieve the purpose of the plantation development programme, the Forest Plantation Development Centre was set up in Akyawkrom (near

Kumasi), and a Forest Plantation Development Fund was created to encourage private investors to invest in plantation forestry in Ghana.

In 2001, the government initiated a National Forest Plantation Development Programme (NFPDP) which had a target of 20,000 ha per annum to accelerate the rate of establishment of forest plantations. Key objectives of the NFPDP comprise the following: restoring the forest cover of degraded forest lands; generating employment as a means to reducing rural poverty; addressing the future wood deficit situation and enhancing food production through the adoption of the modified taungya system (MTS). Under the MTS, farmers would in essence be owners of the timber trees and would have a 40% share in the timber benefits. In 2002, legal reforms were carried out in support of plantation development. The Timber Resources Management (Amendment) Act, 2002 (Act 617), and the Timber Resources Management (Amendment) Regulations, 2002 (LI 1721) excluded the granting of timber rights on land with private forest plantations or land with any timber grown or owned by individuals or groups of individuals. This provided incentives for small-scale farmers in off-reserve areas to engage in on-farm tree planting.

An estimated 168,910 ha of forest plantations had been established nationwide under the NFPDP by both public and private sectors, mainly in degraded forest reserves from 2002 to 2012 (FC 2013). In addition, tree plantations were developed, covering a few hectares at a time, in some farmland areas. There is however concern about the future productivity of these plantations due to the lack of appropriate – let alone 'best' – technologies and practices in their establishment and management. Ghana's reforestation schemes include the establishment of forest plantations in degraded forest reserves in addition to afforestation in the form of economic tree planting on off-reserve farmlands where there was no forest in the recent past.

1.4 Problem description

In Ghana, timber is harvested from two main management regimes in the high forest zone (HFZ) namely, the forest reserves (FRs) and areas outside forest resevres (commonly called off-reserve areas); and a limited amount (mainly teak) from forest plantations. The forest reserve is the permanent forest estate grouped into forest management units, which is the area placed under management. The off-reserve areas is made up of trees on farms (agroforestry systems), fallow and secondary forest patches, and is not under any specific management regime. Timber resources in the HFZ are over-exploited and degraded, and future production

prospects have become questionable and of concern to sustainable forest management. Currently, there is a wide gap between the national demand and supply of timber in Ghana resulting from, among others, the over-capacity of the timber industry with an annual milling capacity of 5.2 million m^3 (Treue 2001, Agyeman et al. 2003) as against the rapid decline of timber resources from the forests due to agricultural expansion, extensive logging, and population growth. The question is whether this gap can be bridged and through what means?

Agricultural expansion and extensive logging in the HFZ has raised major concerns about the current and future status of the timber resource development in the country. Until 2004, the annual allowable cut (AAC) was 1 million m^3, but the actual timber harvest far exceeded this volume. For instance, in 1999 the total timber harvest was estimated to be about 3.7 million m^3, which was almost four times the then AAC of 1 million m^3 (Birikorang et al. 2001). In 2004 the Ghana government increased the AAC to 2 million m^3 by increasing the off-reserve AAC to 1.5 million m^3. This increase was not realistic as it did not consider the sustainability of the off-reserve forest resource base. At the time of the increase, recorded off-reserve timber harvest had usually been below the previous AAC of 0.5 million m^3 for off-reserve areas.

Although agricultural expansion is the major driving force of deforestation and forest degradation in Ghana, the off-reserve area is still to be known as significant in terms of timber production. However, there is lack of detailed information on (1) how timber resources develop (or are developing) in the off-reserve area, (2) factors that motivate farmers to plant and manage on-farm trees, and (3) how farmers perceive the benefits and challenges associated with on-farm tree planting and management. Treue (2001) indicates that without creating a sustained production of timber from off-reserve areas, including farm systems, the obvious alternative, over-exploitation of the remaining resource in the forest reserves, will definitely be a risk. Since the off-reserve area is made up of combined timber production and farm systems, the effectiveness of on-farm tree planting initiatives will depend on how we understand and address the factors which encourage or discourage farmers to plant and manage trees in the agricultural landscape. To this end, it is essential to understand farmers' decision-making process with regard to on-farm tree planting and management.

Furthermore, population growth and demand for timber continue to increase. Concerns have thus been raised about the future developments of timber resource from the HFZ. These have renewed the call to look into future development scenarios of the forest resources. Stakeholders are unsure about how the accelerating pace of change in society will affect the

forests and timber supplies in the future. The rapidly changing societal and political demands will have to be met by a forest resource base that can only be changed slowly. It is critical for forest managers and policy makers to understand the key driving forces behind current forest resource development trends and to have insights into the possible courses of action they can take to improve the developments of the resources in the HFZ. Therefore analyses of future development of forest resources, particularly timber availability, are needed especially where choices that are being made today will have an impact on the forest resources for many years to come. One way of guiding these choices is to provide scenarios based on scientific data that illustrate the possible developments of the forest resources base, given certain conditions. The information so provided will enable policy makers and forest managers to make informed choices, have insight into the consequences of different policy scenarios on the developments of the resource and also allow the wider stakeholder group to participate in decision-making more effectively.

Although the forest resource base has continued to decline over the past decades, there are some promising developments with respect to rehabilitation and restoration of degraded forest reserves as well as national forest plantation development in Ghana. Globally, efforts to increase forest cover have included the establishment of forest plantations, which increased from 168 million ha in 1990 to 278 million ha in 2015 (FAO 2015, Keenan et al. 2015). Some tropical developing countries have experienced forest transitions, i.e. a shift from net deforestation to net reforestation through multiple trends including forest plantation establishment (Mather 1992, Meyfroidt and Lambin 2011, Rudel et al. 2005). In addition, a number of other factors operate at national, regional, and local scales that promote forest resources development, potentially contributing to forest transition. In Ghana, a country level analysis of forest resource development trends towards forest transition is lacking. A better understanding of trends that are related to forest transition pathways at the country level is necessary to identify which factors would drive forest transition in the future.

Information on the above issues (resource base, future scenarios, farmers' motivations, transition pathways) is crucial for developing policy and management options to help sustain timber production in Ghana. Such information is also necessary for rationally planning timber production from the forests and for supporting current and future discussions on sustainable forest management policies and strategies in Ghana.

1.5 Research objectives and questions

The main objective of this PhD research is to provide insights into the current status of the forest resource base in Ghana and into its likely and possible future developments. We assess the current resource availability situation in the timber production systems in the country, both off- and on-farm, explore the consequences of different scenarios for future timber resource development and assess whether a forest transition is likely to occur in Ghana in the next decades.

The following research questions were retrieved from the main objective:

1) What are the trends and changes associated with the growing stock in the timber production areas?
2) What driving forces account for current trends and future developments of timber resources in Ghana?
3) What different scenarios can be identified and how will these affect future developments of timber resources in the high forest zone?
4) What factors motivate farmers to engage in on-farm tree planting and management?
5) To what extent do the current trends of forest resources drive forest transition in Ghana?

Except for questions 2 and 3 which were addressed in one chapter, each of the remaining questions is addressed individually by a separate chapter in this thesis.

1.6 Methodology

This thesis uses interdisciplinary research methods, both qualitative and quantitative, for data collection and analysis to answer the five research questions and to achieve the main objective of the study. In this section, a brief outline of the description of the methods used in this thesis is presented. The details of the different data sources, data collection and data analysis methods for each research chapter (Chapters 2 to 5) are presented in methodology section of those.

The chapters in this thesis are ordered according to two themes: i) assessing the current situation with respect to resource availability - Chapters 2 and 4; and ii) exploring the future through scenarios and forest transition pathways with respect to resource development - Chapters 3 and 5 (Figure 1.1). Different data collection methods, including semi-structured interviews, bio-physical assessments, literature and document research, workshop participation and scenario planning were used.

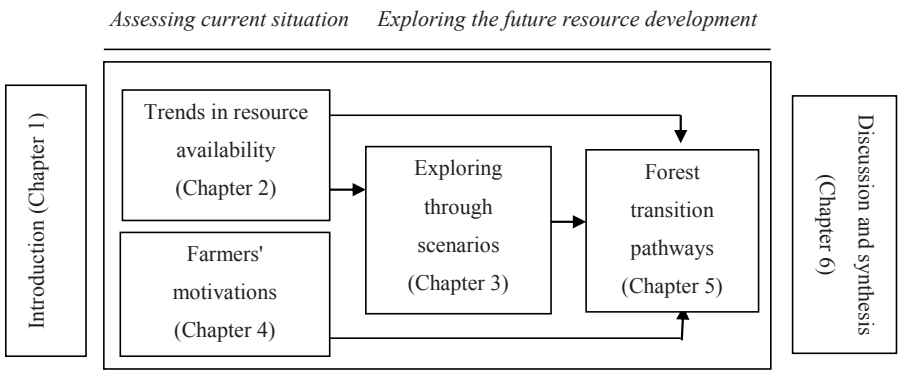

Figure 1.1: Conceptual framework used in this thesis showing linkages among the various chapters under two broad themes

Towards assessing the current situation on resource availability, three main methods of data collection were used: literature and document review, bio-physical assessment, and semi-structured interviews. Desk research using a number of published and unpublished documents from different sources was undertaken. Publications and reports on forest plantations, timber harvesting levels, area of production forest, deforestation rates, and growing stock estimates based on analyses of national forest inventory data were particularly used. The analysis was done at the macro level covering the entire high forest zone (Chapter 2). Another aspect of assessing the current situation was to determine the factors that motivate farmers to engage in on-farm tree planting and management and how that affects timber resources in the agricultural landscape. In doing so, we combined farmers' demographic data and farm inventory data in a socio-psychological model of farmers' behaviour (Duesberg et al. 2013, Gasson 1973, Meijer et al. 2015, Willock et al. 1999) to explore the factors that motivate farmers to participate in on-farm tree planting and management. The analysis was carried out at the micro level covering two on-farm tree planting schemes: the Oda-kotoamso Community Agroforestry Project (OCAP), and the Forest Resources Creation Project (FRCP) situated within the high forest zone. Data was collected from 156 smallholder farmers from five communities under OCAP and FRCP using pre-tested semi-structured questionnaires. Reference is made to the methodology section of Chapter 4 for more detailed information.

In exploring the future development of timber resources, two main approaches were followed. First, scenario planning (Scearce et al. 2004, Tapinos 2012, Wulf et al. 2010a) and

the scenario matrix tool proposed by Wulf et al. (2010b) to identify and describe the scenarios were used. The approach involves collecting data by reviewing scientific and professional literature, consulting experts and organizing stakeholders' workshop with the objective of identifying and selecting the two most important driving forces for the construction of the scenarios. The analysis was considered at the micro scale involving selected stakeholder groups. Second, we traced the trends of forest resources developments in Ghana using the five pathways of forest transition (Lambin and Meyfroidt 2010, Rudel et al. 2005). We analyzed factors that can accelerate forest transition in Ghana focusing at the macro level covering the high forest zone and part of the savanna zone. Data were collected through literature research of government policies and legislation, published and unpublished literature including project reports, and government and other agencies databases. Chapter 5 presents detailed data sources for the analysis.

1.6.1 Study area

Ghana's forest resources are found in two main zones: the savanna zone in the north, and the high forest zone (HFZ) in the South Western part of the country. This study was carried out in the high forest zone which covers approximately 8.2 million ha or about one third of the total land area of 23.9 million ha. Most of Ghana's forest are found in the HFZ. The zone is dominated by forest reserves, agricultural land and fallows; and produces timber to supply the domestic and export markets. The areas outside forest reserves is commonly referred to as "off-reserve" areas and have little remaining closed canopy forests because most of it has been converted to agriculture land-use, and is partly dominated by perennial crops like cocoa and oil-palm. The timber resources found in the off-reserve areas in the HFZ include scattered individual trees in farms and fallow lands, patches of closed-canopy forests and trees around settlements (Kotey et al. 1998).

According to Hawthorne (1993), the HFZ may be divided into nine forest types or vegetation zones (Figure 1.2), each having distinct associations of plant species corresponding to local rainfall and soil conditions. These are Wet Evergreen, Moist Evergreen, Moist Semi-deciduous South East subtype, Moist Semi-deciduous North West subtype, Dry Semi-deciduous Inner Zone, Dry Semi-deciduous Fire Zone, Upland Evergreen, Southern Marginal and Southern Outlier. In general, these forests cover a gradient from wet areas in the south west to dry sites towards the north and east. The high forest zone has a two-peak rainfall season from March to July and September to November, with dry periods in August and between December

to February. The annual rainfall varies between 1,200 to 2,200 mm along a gradient from the northeast to the southwest.

The analysis in this thesis focused mainly on the high forest zone because the zone contains the main timber production systems where the bulk of timber production, illegal logging and plantation development activities take place. In addition, most of the economic activities in Ghana such as cash crop farming, mining and forest industries are concentrated in the high forest zone.

However, trees and forests are found also in the savanna zone (Figure 1.2), and reference is made to tree planting activities as well as extraction and consumption of woodfuel from the savanna zone (SZ) and its contribution to the trends in the forests in the HFZ. The savanna zone covers about 15.7 million ha. It is characterized by an open canopy of trees and shrubs with a distinct ground layer of grasses (Hall and Swaine 1981). Woodland covers about 9.4 million ha of the savanna zone, producing mainly woodfuel and small amounts of building poles for local use. The main economic activities in that zone include production of livestock and annual crops, such as cereals, root crops and cotton. A transitional zone that consists of a mixture of dry forest and savanna vegetation occurs between the HFZ and the SZ.

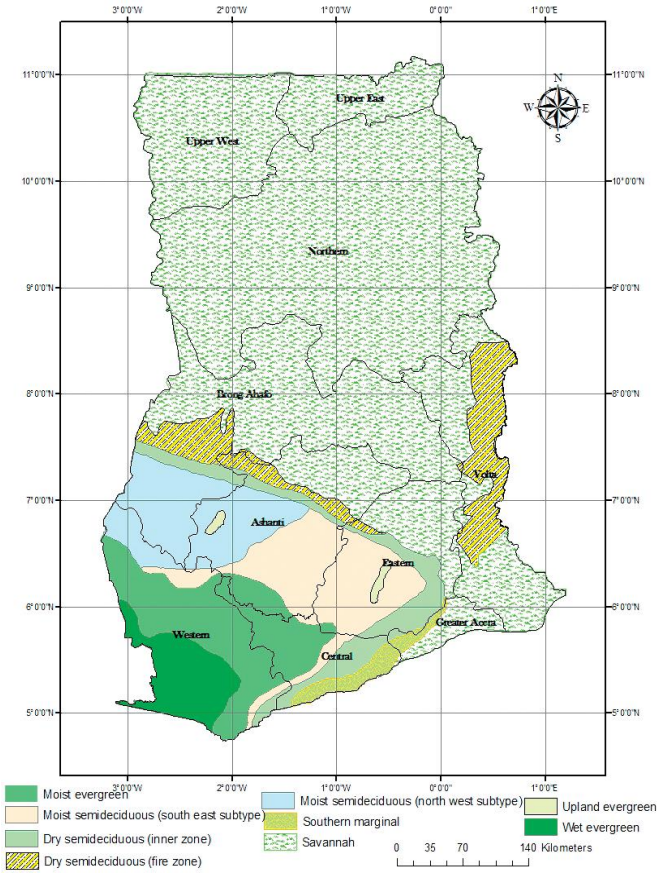

Figure 1.2: Vegetation cover of high forest and savanna zones of Ghana

1.7 Thesis outline

This thesis consists of six chapters: the introduction (Chapter 1), four research chapters (Chapters 2 to 5) and the general discussion and synthesis (Chapter 6) (Figure 1.1). In the four research chapters, we assess the current timber resource availability in timber production areas (Chapter 2), identify farmers' motivations for engaging in on-farm tree planting (Chapter 4) and explore options for future timber resource development and forest transitions in Ghana (Chapters 3 and 5).

In chapter 2, national forest inventory data, timber harvesting data and forest plantation establishment data were used to assess the trends associated with the growing stock in the main timber production areas of Ghana. The chapter highlights recent development that has led to the current state of the forest resources in the high forest zone of Ghana. Additionally, the

chapter highlights the widening gap between national timber demand and supply which drives illegal logging in Ghana, and the limitations of current forest plantation establishment to bridge the gap.

In chapter 3, the future development of timber resource in Ghana were explored through the use of scenarios. In this chapter we first identify and describe the key driving forces that affect development of timber resources in the high forest zone of Ghana. Then, based on the two most important driving forces selected by experts and the potential interactions among these forces, we construct scenarios using a scenario planning process, to explore the future of timber resource development. Finally, options for future development of the timber resource and the associated policy implications are discussed.

In chapter 4, we describe current on-farm tree management and conservation in Ghana and identify farmers' motivational factors and barriers to engage in on-farm tree planting. For this we combine both socio-psychological and external factors to understand farmers' motivation under two on-farm tree planting schemes. The chapter discusses the policy implications for current efforts to increase timber supply from agricultural landscapes to bridge the gap between national timber demand and supply.

Chapter 5 analyzes forest resources development trends in Ghana by focusing on forest transition pathways and discusses the implications for a forest transition in the country. The chapter provides inputs to support ongoing national policy debates to halt deforestation, particularly Ghana's policy efforts on REDD+. Finally, in this chapter we discuss policy and management options that will help accelerate a forest transition in Ghana.

Chapter 6 presents a synthesis of discussions of the major findings of the research chapters within the wider frame of societal development in Ghana to assess future development of timber resources in the high forest zone. We discuss how the various driving forces affecting timber resources development can interact to promote a forest transition in Ghana. Finally, the chapter provides a reflection on the interdisciplinary research approaches used and a number of recommendations for research, management and policy.

Chapter 2

Trends in timber production systems in the high forest zone of Ghana

This chapter is published as:

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International Forestry Review 16 (3): 289-300

Abstract

Forest degradation and deforestation is high on the international forest agenda, and in countries with a strong timber industry and dwindling forest resource such as Ghana, this poses severe threats to the sustainability of the industry as well as of the resource itself. To curb this, forest plantations are being established to supplement the rapidly declining timber resource base to meet the country's demand for timber. Concerns have been raised about the future timber productions from the plantations and natural forests due to poor management and widespread illegal logging. This study assesses the trends of the growing stock in the main production systems and recent development that has led to the current state of the forest resources in the high forest zone of Ghana. Analysis of national forest inventories data and timber harvesting records in Ghana highlights the trend of the growing stock in timber production areas and the increasing gap between timber demand and supply, which drives illegal logging. Current plantation establishment efforts are not sufficient to bridge the gap between demand and supply of timber, partly due to low establishment rates and lack of appropriate management of newly established plantations. Secure tenure and rights to on-farm trees appears to be a key condition to stimulate large scale planting of forest trees by farmers and other investors. Reform in the management practices is required to align timber harvesting levels to sustainable timber production in Ghanaian forests.

Keywords: annual allowable cut, degradation, forest reserve, growing stock, over-exploitation

2.1 Introduction

Ghana has a total land area of 23.9 million hectares of which 15.7 million ha lie within the savanna zone (SZ) in the north. The remaining 8.2 million ha lie within the high forest zone (HFZ) in the south of the country. The savanna zone is characterized by an open canopy of trees and shrubs with woodland covering about 9.4 million ha (60% of the total area). This zone (SZ) produces mainly woodfuel and small amount of building poles for local use (Oduro et al. 2012, Riegelhaupt 2001). The high forest zone (HFZ) is dominated by farmlands and fallows with about 20% being occupied by forest reserves (designated forest areas, see Hawthorne and Abu-Juam 1995, Nolan and Ghartey 1992) that are used to produce wood to meet the country's demand for timber. A transitional zone that consists of a mixture of dry forest and savanna vegetation occurs in between the HFZ and the SZ.

In the high forest zone of Ghana, timber is harvested from two distinct land-use types: forest reserves (on-reserve forest areas) and areas outside forest reserves (off-reserve areas). Forest reserves are designated forest areas to be retained as high forest, and are managed for timber production and biodiversity or environmental conservation (protection). Despite the designation as forest reserves, some forested areas have been severely degraded or deforested in the past due to overexploitation. Off-reserve areas have little remaining closed canopy forests because most of it has been converted to agriculture land-use, and is partly dominated by perennial crops like cocoa and oil-palm. However, naturally regenerated trees on farms and fallows are common, and agroforestry systems have developed over large areas (Gelens et al. 2010). The timber production system of the HFZ comprises areas within forest reserves that have been designated for harvest of timber, and off-reserve areas that are suitable for timber harvesting. The current area for timber production is estimated at 1.5 million ha, with 1.1 million ha from the forest reserves (FAO 2010b). Currently, a total area of about 0.4 million ha inside the forest reserves with a tree basal area of ≤ 5 $m^2 ha^{-1}$ has been classified as severely degraded (Davies and Awudi 2001, FAO 2010a). These severely degraded areas have been designated as Conversion Areas, to be converted into commercial forest plantations for timber production. These Conversion Areas are included in the total area of the production systems.

With the objective of sustaining the productive capacity of the timber production systems, timber harvesting in Ghana is regulated by the annual allowable cut (AAC) representing a maximum that is set for annual exploitation. The current AAC is set at 2.0 million m^3, comprising 1.5 million m^3 from the off-reserve areas and 0.5 million m^3 from forest reserves

(Bamfo 2005, Bird et al. 2006). The interim yield formula (IYF) has been used at the national level to calculate the AAC (Hawthorne et al. 2012). The IYF allocates species specific yield from each felling compartment based on the results of a 100% inventory of all trees above 50 cm diameter at breast height (DBH) in the compartment. The IYF has two entries: the normal formula given as $Z = 0.2X + 0.5Y$, and the reduced formula, $Z = 0.2X + 0.25Y$; where, X is the number of trees in the 20 cm DBH size class immediately below the girth limit for the species; Y is the number of trees equal to or above the girth limit; and Z is the number of trees to be harvested. The reduced formula is applied to species designated as heavily over-exploited and to all species in the dry semi-deciduous ecological zone, where there is increased risk of fire. The normal formula applies to species in the evergreen and semi-deciduous forest zones.

The Ghana government identified commercial timber plantation development as one of the important strategies for expanding the timber resource base to meet the country's demand for timber. At the same time plantations are expected to take away pressure from the remaining natural forests in order to preserve them. Consequently, in 2001, the government initiated a national forest plantation development programme, aiming at a planting target of 20,000 ha per annum, in the degraded forest reserves or so-called Conversion Areas (FC 2007). In addition, tree plantations of exotic and indigenous species have been established, covering a few hectares at a time, in off-reserve areas scattered over the country. While these are promising developments with respect to increasing the timber resource base in the future, there are concerns about the future timber production from plantations, and in the timber production systems in general. These have arisen due to the poor management of plantations, widespread illegal logging, deviation from management prescriptions and the low quality of residual production forests. The study reported here assesses the trends of the growing stock in the main production systems and the recent development that has led to the current state of the forest resources in the HFZ of Ghana. The aim is to contribute to the international debate on forest degradation and deforestation in relation to sustainable development, and to highlight how the timber demand and supply gap drives illegal logging in Ghana. The paper highlights plantation development activities and documents the continuous degradation and decline of timber resources in Ghana that constitutes a critical concern for future timber supply and economic development in the country.

2.2 Methods

2.2.1 The study area

This study focuses on the high forest zone situated in the South Western part of the country. While trees and forests are found also in the savanna zone, the analysis in this paper is focusing primarily on the high forest zone because it contains the timber production systems where the bulk of timber harvests in Ghana take place. However, reference will be made to extraction and consumption of woodfuel from the savanna zone and its contribution to the trends in the forests in the high forest zone (HFZ). Ghana's HFZ may be divided into nine forest types or vegetation zones (Figure 2.1), each having distinct associations of plant species corresponding to local rainfall and soil conditions. These vegetation zones are Wet Evergreen, Moist Evergreen, Moist Semi-deciduous South East, Moist Semi-deciduous North West, Dry Semi-deciduous Inner Zone, Dry Semi-deciduous Fire Zone, Upland Evergreen, Southern Marginal and Southern Outlier (as described by Hawthorne 1993). These forests cover a gradient from wet areas in the south west to dry sites towards the north and east. The high forest zone has a two-peak rainfall season from March to July and September to November, with dry periods in August and between December to February. The annual rainfall varies between 1,200 to 2,200 mm along a gradient from the northeast to the southwest.

Timber resources outside forest reserves in the high forest zone vary in nature from scattered individual trees in farms and fallow lands to patches of closed-canopy forests and trees around settlements (Kotey et al. 1998). In Ghana as elsewhere in West Africa, farmers incorporate trees within cropping systems to provide fruits, firewood, poles, shade for crops, timber and to improve soil fertility and protect the environment. For example, in cocoa and coffee agroforestry systems trees are incorporated to provide shade as well as timber and firewood. Trees are also common in food crop, cola, and oil palm cropping systems. Trees on farms may broadly be divided into (i) those that are left standing because it is too laborious to remove them, (ii) those that are tolerated because they have few negative impacts on crops, and (iii) those that are actively tended or planted by farmers (IIED 1994, Treue 2001) because they expect benefits from them. Most of the country's economic activities, such as cash crop farming, mining and forest industries are concentrated in the high forest zone. The HFZ contains the main timber production systems where timber production, illegal logging and plantation development activities as analyzed in this paper take place.

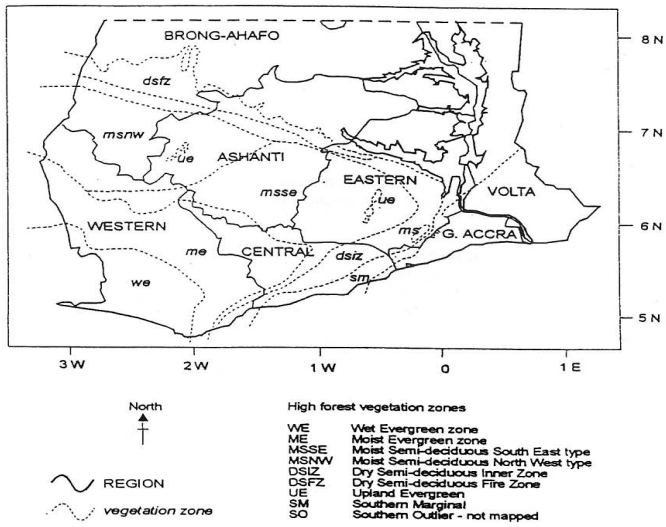

Figure 2.1. The high forest zone of southern Ghana (source: Treue 2001)

2.2.2 Sources of data

The assessment is based on existing published and unpublished information. Forest data and total growing stock estimates were based on analysis of national forest inventories by the Resource Management Support Centre (RMSC) of the Forestry Commission of Ghana (e.g. FAO 2010b, MRI 2002, RMSC 2002). Additional data were compiled from publications and reports on forest plantations, and on forest area and growing stock estimates based on analyses of national inventory data (e.g. Affum-Baffoe 2009, Davies 2003, FAO 2006, FC 2009, FAO 2010b, Silviconsult 1985, Treue 2001).

2.2.3 Estimation of growing stock volume and exploitation levels

The RMSC estimated the growing stock using local volume equations developed through detailed volume measurements of trees, and stand volume tables generated from this (MRI 2002, Wong 1989). Inventories in forest reserves were carried out in 1985–89 and again in 2001 with the objective of estimating the growing stock of timber in the production areas of the forest reserves. The inventory was conducted at a sampling intensity of 0.25% of the area using 20 m x 500 m plots in a systematic sampling design (Blackett 1989, Wong 1989). In off-reserve areas, inventories were conducted using 200 two-hectare plots with dimensions of 20 m x

1,000 m in a stratified sampling design, with the plots stratified according to the area of vegetation zones. The objective of the off-reserve inventories in 1995–96 and 2004 was to quantify the existing timber stock in off-reserve areas of the high forest zone. Finally, timber harvesting records from the Forestry Commission were used to describe the trends in timber exploitation levels between 1980 and 2009.

2.3 Results

2.3.1 Growing stock within production forest reserves

Estimates of growing stock volume of Ghana's forests and in production forest reserves in the high forest zone for the period 1980 to 2010 are presented in Table 2.1. The production forest reserve areas constitute the most important source of timber, comprising about one-third of the total growing stock of timber trees in the high forest zone. Out of the estimated total growing timber stock of 291 million m^3 for Ghana's forests, 97 million m^3 was from the production forest reserves as at 2010. A comparison of the 1989 and 2001 forest inventory results indicate that the total growing stock in the production forest reserve had declined from 191 million m^3 (or 165 m^3/ha) to 102 million m^3 (or 142 m^3/ha). The 1989 estimate of the total growing stock within production forest reserves is approximately 33 million m^3 higher compared to the estimated total growing stock for 1985.

Table 2.1. Estimates of wood volume in forests in Ghana

Year	Growing stock in forests			Growing stock in production forests reserves		
	area (1,000 ha)	per ha (m^3ha^{-1})	total (1,000 m^3)	area (1,000 ha)	per ha (m^3ha^{-1})	total (1,000 m^3)
1980	8 768	48.8	428 310	1 167	138	161,046
1985				1 183	133.7	158,188
1989				1 160	164.9	191,296
1990	7 448	56.8	422 921	1 159	162.7	188,600
1995				762.4	160.5	122,380
2000	6 094	57.7	351 741	762.4	136	103,686
2001				719.3	142	102,219
2005	5 517	58	321 409	719.3	136	97,825
2010	4 940	59	291 077	715.3	136	97,274

Sources: Davies 2003, FAO 2006, FAO 2010b, MRI 2002, Silviconsult 1985, Treue 2001

2.3.2 Growing stock within off-reserve areas

The 1995–6 off-reserve inventory carried out by the Resource Management Support Centre of the Forestry Commission provided data on the stocking of timber in the off-reserve areas. The inventory covered the entire off-reserve area in the high forest zone (approximately 5.5 million ha), with the exception of towns, villages and large scale agricultural areas. The results showed a total growing stock estimate of 268 million m^3, with 102 million m^3 made up of trees larger than the minimum felling limit (Table 2.2).

In 2004, off-reserve areas (totaling about 165,000 ha) scattered within the HFZ identified as off-reserve Timber Utilization Contract (TUC) areas were assessed for their potential timber stocking prior to bidding by timber concessionaires. The growing stock above the felling limit was estimated to be 37 million m^3; representing approximately 30% of the total volume in the area. In Ghana, the felling limit defines the point in the species diameter distribution where the average national stocking shows a sharp decline. In principle, the growing stock above the felling limit could be considered suitable and available for harvesting.

Table 2.2. Estimated off-reserve tree standing stock in Ghana

Year	Area (1,000 ha)	Per hectare (m^3ha^{-1})	Volume (1,000 m^3)	Volume ≥ felling limit (1,000 m^3)
1996	5,482	48.9	268,188	101,680
2004	165			37,225

Sources: Affum-Baffoe 2009, FAO 2010b, Silviconsult 1985, Treue 2001

2.3.3 Timber harvesting levels in the forests

The official recorded timber harvest data in the main production systems in the high forest zone shows a two peak trend in 1993 and 2006 for the period 1980 to 2009 (Figure 2.2). The official timber harvest data show that in the last decade, recorded forest reserve timber harvest has always been above the on-reserve AAC of 0.5 million m^3 except in 2009 when the harvest was equal to the AAC. Meanwhile, the total harvest from forest reserves is estimated to be 2.0 million m^3 annually, with about 1.5 million m^3 being illegal (Hansen and Treue 2008). Between 1996 and 2004 when the off-reserve AAC was increased to 1.5 million m^3, recorded off-reserve harvest had mostly been below 1.5 million m^3; and since 2005, there has been a downward trend in the recorded off-reserve timber harvest. Since 2004, total recorded timber

harvest in the production systems appears to have been below the AAC of 2.0 million m^3 but the greater proportion of the harvest rather originates from the forest reserves.

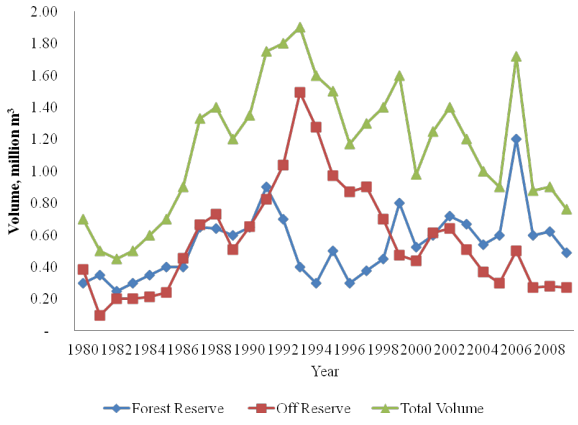

Figure 2.2. Official recorded timber harvesting levels in forest reserve and off-reserve production systems (1980-2009). Sources: Oduro et al (2012), RMSC timber harvests record sheets

2.3.4 Area of forest plantations established in the high forest zone

It is estimated that approximately 50,000 ha of plantations were established by the state in forest reserves in the high forest zone between 1963 and 1987 (Odoom 2005). By 2001, Ghana had a total area of about 76,000 ha of forest plantations (FAO 2003) using taungya and direct planting methods.

Total area of plantations established in degraded forest reserves (Conversion Areas) and in off-reserve areas between 2002 and 2008 were approximately 126,000 ha and 14,000 ha respectively (FC 2009). Indigenous species planted included *Mansonia altissima, Aningeria robusta* (A.Chev.) Aubrév. & Pellegr., *Terminalia superba*, *Terminalia ivorensis, Ceiba pentandra* (L.) Gaertn., *Heritiera utilis* (Sprague) Sprague, *Entandrophragma angolense* (Welw.) C.DC., *Pycnanthus* angolensis (Welw.) Warb., *and Triplochiton scleroxylon.* The exotics are predominantly *Tectona grandis* L., *Cedrela odorata* and *Eucalyptus camaldulensis* Dehnh.

There is a general decline in the trend of annual rate of commercial plantation establishment between 2002 and 2008 in degraded forest reserves; however, in the off-reserve

areas, the rate have been fairly stable but below 5,000 ha per year (Figure 2.3). About 70% of the commercial timber plantations in degraded forest reserves are made up of teak with the remaining 30% consisting of a mixture of indigenous and exotic species other than teak. In the off-reserve areas, teak constitutes about 95% with indigenous species making up the remaining 5% (FC 2013). The different forest types in the high forest zone cut across the seven regions in southern Ghana, namely Ashanti, Brong Ahafo, Central, Eastern, Greater Accra, Volta and Western (Figure 2.1). About 75% of the total area of plantations established is found in the Ashanti and Brong Ahafo regions.

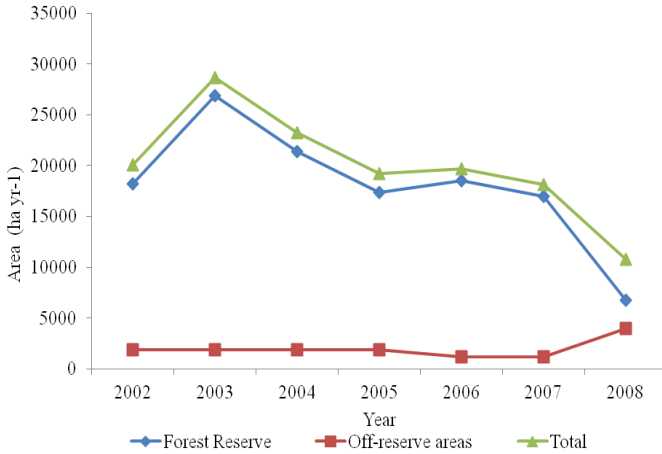

Figure 2.3. Annual rate of plantations established in degraded forest reserves and off-reserve areas between 2002 and 2008. Sources: FC 2007, 2008, 2009

Assessment of survival rates for all the commercial plantations established since 2002 had not been done. But in 2008, the RMSC carried out survival assessment in four plantation districts/areas sampling approximately 10% of the total area of plantations established in 2006 and 2007. The results indicated a survival rate of approximately 76% and 68% for trees in plantations established in 2006 and 2007 respectively (FC 2009). About 12% of the total area of commercial plantations established between 2002 and 2008 had received some tending operations, mainly beating-up, weeding, pruning and protection from fire damage (FC 2009).

2.4 Discussion

2.4.1 Reliability of the data and growing stock estimates

Data collected as part of literature search for the assessment in this paper included total growing stock estimates and forest areas for the different production systems in the high forest zone. The reliability of the growing stock estimates presented depends on the accuracy of the national inventory data upon which the growing stock estimates were made. According to Davies (2003) and Treue (2001) the 1989 inventory, which involved measurement of 1,332 one-ha temporary sample plots, yielded accurate estimates of the standing volume at the national level. Concerns over uncertainties surrounding the current growing stock estimates for the forest reserves and off-reserve areas based on analysis of the forest inventories data are thought to be minimal (Treue 2001, Wong 1989); and/or not likely to change significantly the direction of the results and the general trend of degradation and decline in the timber production systems in the high forest zone.

2.4.2 Growing stock trends in the production systems

The total growing stock within forest reserve production system has progressively declined since 1990. Between 1990 and 2010, 2.5 million ha of Ghana's forest cover was lost largely due to overexploitation (i.e. illegal logging), agricultural expansion and intensification, infrastructural development, mining activities, and forest fires (Hansen et al. 2009). The area of production forest reserves was reduced by about 40% between 1990 and 2010. The growing stock per hectare in production forest reserves and in forests in general, has declined since 1990, but has largely remained unchanged in the last 10 years. This decline is caused by the combined effect of a decrease in the area of production forest reserves and a decrease in basal area of the remaining growing stock. Comparatively, other West African countries such as Gabon, Liberia and Nigeria, all report substantial decrease in their production forest reserves, but also a gradual increase in the growing stock per hectare since 2005. In Gabon the decrease is a result of a change in the forest legislation in 2001 and a reassignment of forest functions; in Liberia the reported decline was caused by the cancellation of forest concessions after 2005 (FAO 2010a). Ghana's forest growing stock per hectare of 59 m^3 is lower than that of Cote d'Ivoire: 253 m^3, Gabon: 223 m^3, Liberia: 158 m^3 and Nigeria: 128 m^3. Both Gabon and Nigeria report of decrease in rate of loss of forests, with Gabon having 65% of total forest area

being made up of primary forests. The extent of forest area in Cote d'Ivoire has been increasing since 1990 and rate of forest loss in Liberia is less than 0.7% (FAO 2010a).

The sudden increase in the 1989 estimate of growing stock of approximately 33 million m^3 over that of 1985 can be explained in two ways. First, the 1985 growing stock estimate was based on inventory of 16 forest reserves found in the southern part of Central and Western Regions of Ghana and did not cover all the forest types or vegetation zones in the high forest zone. Growing stock estimates within the production reserves of the entire high forest zone was then generated by extrapolating the results from the 16 forest reserves to account for all forest reserves within each forest type. Mean volume per ha from other vegetation zones was used for the forest types that were not included in the inventory. Second, the area for the production forest reserves during the 1989 inventory may be argued to have been over-estimated by about 20% (see e.g. FIMP 1994, Treue 2001, Wong 1989). This may have introduced bias in the national growing stock estimates. The analysis of temporary sample plot inventory data, also taken in 1989, showed that depending on the criteria for setting aside protection areas within the forest reserves, the estimated area of production forest during the 1989 inventory was between 0.76 to 0.92 million ha (FIMP 1994, Treue 2001). That being the case, the approximately 1.2 million ha used as the area of production forest reserves during the 1989 inventory may therefore be an over-estimation of at least 0.24 million ha resulting in the increase in the growing stock estimate for 1989.

In 1996, the total standing stock for the off-reserve areas was 268 million m^3, with more than 100 million m^3 being above the felling limit. The 2004 assessment of the standing stock for the off-reserve timber production system indicated a total standing stock above the felling limit of 37 million m^3. Although the 2004 assessment focused on only off-reserve areas that qualified to be timber utilization contract areas, the reduction in the standing stock above the felling limit in the eight years between 1996 and 2004 appears extremely high. This magnitude of decline suggests that the off-reserve production system has been more affected by degradation and over-exploitation than the forest reserve production system. Kotey et al. (1998) reports that by the early 1990s, up to 80% of timber exports in the country originated from off-reserve areas and in the absence of management controls the off-reserve areas became rapidly depleted of timber stocks. The records of official timber harvests emphasize that between 60 to 80% of total recorded timber harvests originated from off-reserve areas in the period 1993 and 1997. Currently, illegal logging contributes an estimated 2.7 to 4.0

million m^3 (approximately 70%) to the total timber harvest in Ghana (Hansen and Treue 2008, Hansen et al. 2012, Marfo 2010).

Woodfuel (firewood and charcoal) extraction and consumption in Ghana has contributed significantly to the changes in growing stock trends in the forests. Woodfuel constitutes over 65% of the total energy consumption making it the most important energy form in Ghana. More than 90% of all households in Ghana use woodfuel as their primary source of energy. About 80% of the households, primarily in the rural areas, rely on firewood collected on farms and fallow lands, and about 13% of households, mainly in the urban areas, rely on charcoal (UNDP 2004, Wiafe 2005). It is estimated that every person in Ghana uses about 1.0 m^3 of woodfuel annually, with the total consumption estimated to be 25–28 million m^3 of raw wood annually (Grados and Janssen 2008, EC 2010, UNDP 2004). Charcoal is mainly produced in the transition zone between the high forest zone and the savanna zone. The off-reserve area has been the main source for the most suitable and preferred species for charcoal production. However, recently the forest reserves in the transition zone and nearby high forest zone are increasingly being exploited for charcoal production (Obiri et al. 2012). This gradual but progressive shift to the forest reserves is as a result of deforestation and depletion of the most suitable and preferred tree species in the savanna and transition zones (Obiri et al. 2012), and presents an important additional overexploitation threat to the forest resource in the HFZ. While national land use policies acknowledge the effective utilization of wood resources, little progress has been made to develop and manage forest resources especially for woodfuel production. Concerted efforts are needed to develop and manage forest resources in the off-reserve areas of the savanna and transition zones, especially for woodfuel production. One option is the need to promote smallholder forests with short rotation species to provide raw materials for woodfuel production in the off-reserve areas. These will serve as buffers that could effectively protect forest reserves in the savanna/transition zone as well as the HFZ.

2.4.3 Production and harvest levels in forests

Currently, the annual allowable cut (AAC) is 2.0 million m^3: 1.5 million m^3 from the off-reserve areas and 0.5 million m^3 from forest reserves. Up until 2004, the AAC was 1.0 million m^3 (0.5 million m^3 each for forest reserves and off-reserves). The off-reserve AAC was however increased by the Government in response to the desire to salvage timber trees before they are lost to the extensive illegal exploitation and conversion of off-reserve secondary forests

to agriculture and other land-uses such as mining. However, Hansen et al. (2012) argue that the total timber harvest is approximately 6 million m^3 a year, representing three times the AAC. Even if the conservative estimate of total timber harvest by Hansen and Treue (2008) of 3.3 to 3.7 million m^3 is taken into account, the situation is still alarming. The total timber harvest is the sum of the roundwood equivalent (RWE) of the total production by the formal sector and the RWE of the total production by the informal sector or chainsaw operators (Hansen and Treue 2008).

Additionally, Hansen and Treue (2008) conservatively estimate that the total forest reserve harvest may well approach 2.0 million m^3 annually of which at least 1.5 million m^3 is illegal. The high harvest levels are well supported by the reduction of total growing stock in production forest reserves between 1995 and 2010 (Table 2.1) and considering the fact that the actual size and share of forest reserve and off-reserve illegal harvest is unknown but thought to be high (Hansen and Treue 2008). It is clear that the degraded nature of the off-reserve areas has put much pressure on the forest reserves, hence the current annual harvest of 2.0 million m^3, which is four times the forest reserve annual allowable cut of 0.5 million m^3. This is alarming because the declining nature of the growing stock in the production forest reserves suggests that the current pressure on the forest reserves seems extremely high; making it doubtful if the forest reserves can sustainably accommodate an annual exploitation level of 2.0 million m^3 much longer. Consequently, if the current level of exploitation continues, not only will it likely lead to a serious shortage of harvestable trees and a collapse of the formal timber sector (Hansen and Treue 2008, Marfo 2010) in the next 20 years, but also to loss of biodiversity, emissions of millions of tons of carbon and loss of revenue to support economic development.

The off-reserve area, which in the past, accounted for 60–80% of the total recorded (legal) timber harvest (Affum-Baffoe 2009, Treue 2001) now account for 30–40% of the total recorded timber harvest. But the actual total off-reserve harvest is thought to be above the 1.5 million m^3 AAC (Hansen and Treue 2008), suggesting continuous degradation of the off-reserve resources. Official timber harvest records suggests a two peak trend in the 25 years between 1980 and 2006. The first peak in 1993 was as a result of increased harvest from off-reserve areas. Management strategies that were being implemented in the forest reserves resulted in a decrease of timber harvest in the reserves in 1993. Attention was turned increasingly to the off-reserves and in absence of sufficient management controls, up to 80% of recorded timber harvest originated from the off-reserve areas in 1993. In 1994,

interim measures were put in place to control harvesting in off-reserve areas resulting in the decline since then. The second peak was recorded in the years immediately following the increase in the AAC from 1.0 million m^3 to 2.0 million m^3 in 2004.

The timber industry in Ghana is currently distressed due to high installed processing capacity against a rapidly declining resource base in the country. The timber industry has an installed processing capacity of at least 5.2 million m^3 (Agyeman et al. 2003, Birikorang et al. 2001, Treue 2001) and is seriously concerned about the degradation and depletion associated with the production systems. Illegal chainsaw milling currently consumes an estimated 2.5 million m^3 (Marfo 2010) mainly to meet the demands of the local market. This is a major concern for future timber supply for the country as the current demand together with the rate of degradation is not commensurate with the rate of commercial timber plantation establishment in Ghana. It is also noteworthy that reducing the supply-demand gap requires measures at the demand side such as ensuring wood use efficiency. In Ghana, the wood industry is inefficient, thus contributing to the intense pressure on the already degraded forest resource base. The inefficiencies are fueled by undervalued timber prices and a steady supply of illegal chainsaw lumber that provides a surplus of raw material. Demand-side measures such as forest taxes or fees, export levies, log export bans, have not been effective in reducing overexploitation. Richards (1995) argues that the log export bans have caused severe distortions on the domestic market encouraging consumption of endangered species and negating the environmental objectives of the bans. Both low royalties and log export ban have encouraged over-capacity and inefficiency in processing, to add to already high wastage levels in the forest.

2.4.4 Area of forest plantations established before 2001

The history of forest plantations in Ghana has been documented by Odoom (2005). Commercial forest plantations began in the country in the 1960s within forest reserves in portions that were designated as poorly stocked (Odoom 2005). The main objectives for establishing forest plantations in Ghana were to produce raw materials for the timber industry, to reduce pressure on the natural forests, and to serve as an interface or buffer for excluding fires and other damaging effects of the encroaching savanna. As in other tropical regions, the early phase of plantation development in Ghana focused on high-value hardwood species such as *Tectona grandis* L. (teak), making up about 40,000 ha of the 76,000 ha of total

plantations established with an estimated production capacity of about 600,000 m^3 per year (ITTO 2006, 2009). Other species that were planted were *Cedrela odorata* L., *Mansonia altissima* (A.Chev.) A.Chev., *Gmelina arborea* Roxb. ex Sm., *Triplochiton scleroxylon* K.Schum., *Terminalia superba* Engl. & Diels, and *Terminalia ivorensis* A.Chev.

The success level of these plantations and the factors that affected them have been discussed by other studies (e.g. Odoom 2005, Zhang and Owiredu 2007). In most cases farmers rights to benefits from established plantations were not recognized and farmers had no incentives, other than access to land for farming, to plant and manage forest trees. Only about 15 000 ha of the established plantations were considered to be of commercial value in terms of producing timber for the industry, but could not supply the raw material needs for the timber industry in the country.

2.4.5 Area of forest plantations established between 2002 and 2008

Between 2002 and 2008, Ghana established approximately 140,000 ha of commercial timber plantations within the production systems in the high forest zone. Teak has become the most attractive species for plantations establishment in Ghana constituting over 70% of the commercial plantations established (FC 2013). In Ghana, teak yields average 8 to 10 m^3 per hectare per year on a 25-year cycle (ITTO 2006). It was expected that 20,000 ha of plantations would be established each year for 25 years and that the management of the plantations would be efficient so as to achieve a yield of about 390 m^3 ha^{-1}. This would have generated approximately 8 million m^3 of timber per year on a 25 year rotation. However, there have been barriers to forest plantation development in Ghana that have resulted in few plantations been established and that are not well managed. The barriers limiting the development of forest plantations include ambiguous land and tree tenure arrangements, lack of technical expertise, poor extension services, uncertainty about markets for timber and uncertainty about benefit sharing arrangements on off-reserve areas. Other factors are the inability to control wildfires, and poor financial incentives including lack of credit facilities that makes it unattractive for farmers and companies to invest in forest plantations in Ghana (HRC 2008, Zhang and Owiredu 2007). In addition, Government's funding of the National Forest Plantation Development Programme has been intermittent and unsustainable, resulting in poor management of established plantations (FC 2008).

The declining nature of the rate of commercial plantation establishment since 2003 and the quality of the established plantations are worrying developments since the natural production systems for timber continue to experience degradation and depletion. Only approximately 12% of the total area of commercial plantations established within this period has received tending operations. This raises concerns about the future yields from the plantations and Ghana's ability to bridge the gap between demand and supply of timber for which the plantations are being established. The concerns have been heightened since the historical records suggest that before 2001, approximately 15,000 ha of the total 76,000 ha of plantations established survived to produce trees of commercial interests to the timber industry (Odoom 2005).

Furthermore, the 14,000 ha of commercial plantations in the off-reserve areas seem low considering the total area available (approximately 5.5 million ha) and the depleted nature of the resource in this area. Taking into account that trees outside forest reserves are important source of timber and fuelwood the rate of planting would need to be intensified in the off- reserve area. In addition, analysis of timber tree recruitment, retention and planting in cropping systems indicates the potential of the off-reserve area to once again be a source for the supply of higher proportion of timber compared to the forest reserves. The key lies in the incorporation of timber trees in agricultural production systems (Acheampong and Marfo 2009, Adam et al. 2007, Anyomi et al. 2011, Gelens et al. 2010, Inkoom 1999, Treue 2001). However, incorporating timber trees into agricultural system would require a change of the tree tenure system such that farmers can own, manage and utilize timber trees on land they cultivate (Acheampong and Marfo 2011, Damnyag et al. 2012, Hansen et al. 2009). Zhang and Owiredu (2007) provides empirical evidence to the fact that secured rights to land and market factors influence positively on farmers forest plantation activities and investment.

2.5 Conclusions

The paper highlights and documents the continuous degradation and decline of timber resources in the main production systems of the high forest zone in Ghana. This should be cause for critical concern for future timber supply and economic development in the country. The current forest reserve production area has a growing stock of 97 million m^3 representing a third of the total growing stock in the forests. This area of production forest reserves has reduced by 40% in the past two decades and the growing stock has declined by 50% in the same period. Off-reserve areas contain a growing stock of 37 million m^3 above the minimum

felling limit, representing a decline of over 60% since 1996. The results also highlights that the high demand for timber and woodfuel has contributed to illegal logging and other activities causing degradation and deforestation.

On one hand, the timber industry has a processing capacity of more than 5 million m^3 but the annual allowable cut is only 2 million m^3. On the other hand, official recorded (legal) timber harvest is approximately 1 million m^3 but total timber harvest is at least between 3.3 and 3.7 million m^3 annually. This suggests that the difference between demand and the legal harvest (supply) is currently being covered by illegal logging, leading to severe degradation and deforestation. The high demand for woodfuel and the gradual shift from off-reserve areas in the savanna and transition zones to the forest reserves in the transition and high forest zones to meet this demand is likely to add to degradation and deforestation in Ghana. This has serious consequences: loss of biodiversity, future collapse of the timber industry resulting in loss of livelihoods, and loss of revenue to the state for economic development. As an example, Damnyag et al. (2011) estimate that approximately US$134 million gross revenue is lost annually through deforestation in Ghana. Moreover, the continued destruction of the forests will result in the emission of millions of tons of carbon at a time when there is concerted global effort to reduce carbon emissions.

The production systems in their current degraded state cannot sustainably meet the industry demand for timber. It suggests also that the current annual allowable cut is no longer a valid standard or guideline of a sustainable harvest level from the forests since the main production systems cannot supply the current AAC of 2 million m^3 on sustainable basis. There is no doubt about the potential of commercial timber plantations to satisfy the demand for timber in Ghana. However, current commercial plantation activities in the production systems indicate that present plantation establishment efforts are not sufficiently successful to bridge the gap between demand and supply of timber, as a result of low rate of establishment and lack of management of the established plantations. The combined effect of land and tree tenure issues including farmers rights to trees they manage on agricultural lands, acceptable benefit sharing arrangements and lack of attractive financial incentives weaken potential investors' confidence that forest plantation establishment in Ghana can be a profitable undertaking. The policy implication is that secure tenure and rights to trees in the cropping system is a key condition to stimulate large scale planting of forest trees by farmers and other investors. Farmers must feel confident that their rights to trees on agricultural lands will not be taken away

in the medium to long term. Considerable efforts are urgently needed to increase the rate of current commercial plantation establishment in both degraded forest reserves and off-reserve areas. There is also the need to promote sustainable harvests in the production systems by aligning the AAC and actual harvest to the capacity of the production areas. At the same time, there is a need to pursue alternative sources, such as importation, to bridge the gap between the demand and supply of timber in Ghana.

Chapter 3

Exploring the future of timber resources in the high forest zone of Ghana

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Abstract

Ghana's forests, particularly the timber resources, face an uncertain future, because of high deforestation rate, a rapidly declining timber resource base, rapid population growth and increasing demand for timber. This paper explores the future development of timber resource in Ghana by constructing scenarios and considering options policy-makers could take to ensure sustainable future development of the timber resource. Data was collected by reviewing the literature and consulting experts. The scenarios follow the deductive approach, exploring the potential interactions among key driving forces as selected by experts. The two most important driving forces for the future of timber resources selected by the experts were forest governance and resource demand. Four plausible scenarios were developed: legal forestry scenario with emphasis on improving the resource base to meet high demand; forest degradation, a business-as-usual scenario; forest transition, with emphasis on expanding the resource base in response to environmental concerns; and timber substitution scenario seeking to provide wood substitutes to conserve the resource base. The scenarios provide insights for policy making and strategic planning for forest resource management in Ghana. To ensure a sustainable future for timber resources, policy reform is needed, focusing on land and tree tenure, revenue capture, benefit-sharing schemes and satisfying the domestic demand for timber.

Keywords: Deforestation, forest degradation, resource demand, forest governance, future scenarios

3.1 Introduction

Forests in the tropics have been undergoing significant changes in recent years. Ghana is reported to have one of the highest deforestation rates in West Africa (FAO 2010a), and its forests, particularly the timber resources, face an uncertain future. There is deforestation, rapid forest degradation and declining timber resource base, and also rapid population growth and increasing demand for timber. While the current annual allowable cut for Ghana is set at 2 million m^3, which is probably too optimistic given actual annual increment, it is estimated that total timber harvest is approximately 6 million m^3 a year (Hansen et al. 2012). Without substantial imports, this implies overexploitation of existing resources. The resulting continuous degradation of the forest resources and the declining timber resource base pose serious threats to the ecological, economic and socio-cultural functions of Ghana's forests. In Ghana, forest degradation and declining timber resource base are important issues that feature prominently in the national forest policy debate. The debate has tended to focus more on illegal (chainsaw) logging and on how to balance timber supply between the export and domestic markets. Subsequently, policy options and strategies have been proposed for regulating the domestic timber market by reducing the illegal operations and streamlining legal supplies (Gyimah and Parren 2007, Marfo 2010, TBI 2012).

Another key issue of concern is the development of the timber resource in the high forest zone[1] (Oduro et al. 2014a). Many stakeholders are unsure about how the accelerating pace of change in society will affect timber supplies. Policies are needed to ensure the sustainable use and future development of the timber resource. Policy makers and forest managers are thus increasingly confronted with the question of how to manage the process of degradation and develop a sustainable timber resource base. Whether the current gap between demand and supply can be met in the future, and if so, how, are also questions to be answered. Identifying policies to deal with these and other questions is a major challenge because of the great uncertainty resulting from the diversity, complexity and dynamics of the resource and the systems for governing and managing it (Huntley et al. 2010, Scearce et al. 2004). Although scenario studies are increasingly being used worldwide to help decision-makers better understand, anticipate and respond to different dynamic and uncertain futures (Reed et al.

[1] Ghana's high forest zone, situated in the south western corner of the country, covers approximately 8.2 million ha. It is dominated by forest reserves, farmland and fallows and produces timber to supply the domestic and export markets.

2009), little effort has so far been devoted to developing scenarios investigating the future of timber resource development in Ghana.

This paper explores the future development of timber resource in Ghana through the use of scenarios. The objective is to explore the possible ways in which the future of timber resources might unfold and what options policy makers and forest managers could pursue to achieve sustainability (i.e. continuous supply of forests goods and services without compromising the quality of the resource base). The paper provides forest managers and policy makers in Africa, particularly West Africa and Ghana, with insights into the possible courses of action they could take to ensure the sustainable future development of the timber resource.

3.2 Methods

This paper uses scenario planning to explore the future of timber resource development in Ghana. Scenario planning is intended to be used within strategy teams to enhance strategic thinking and to address uncertainties in the external environment (Tapinos 2012). Five steps suggested in the scenario planning literature were followed: (1) defining the scope of the scenario exercise, (2) identifying key driving forces, (3) prioritising and selecting two most important driving forces or uncertainties, (4) identifying the scenarios on the basis of the two driving forces and describing them, and (5) identifying possible strategies and policy options (see e.g. Scearce et al. 2004, Tapinos 2012, Wulf et al. 2010a). The first four steps of the scenario planning process constitute the scenario development stage; the last step is the strategy development (Figure 3.1).

3.2.1 Defining scope, identifying key driving forces and selecting two for the scenarios

The scope was defined as the high forest zone. The time frame was medium term (10-15 years), so as not to introduce much uncertainty into the scenarios. Data was collected by reviewing scientific and professional literature and consulting experts with the objective of identifying driving forces that affect forest resources development and that cause changes in Ghana's forestry sector. The resulting driving forces were used to construct a causal diagram showing the linkages between the driving forces derived from the literature. The list of driving forces and the causal diagram were sent to 25 selected experts on Ghanaian (and international) forestry and

related disciplines, from different backgrounds and organisations, including the forestry sector, research and academia, and non-governmental organisations, to seek their professional judgement on the key driving forces.

At a subsequent workshop attended by the experts, the driving forces were further discussed and prioritised according to their potential impact on forest resource development in Ghana. The causal diagram was also discussed and amended according to the prioritised driving forces. Then the experts selected the two most important key driving forces for the construction of scenarios.

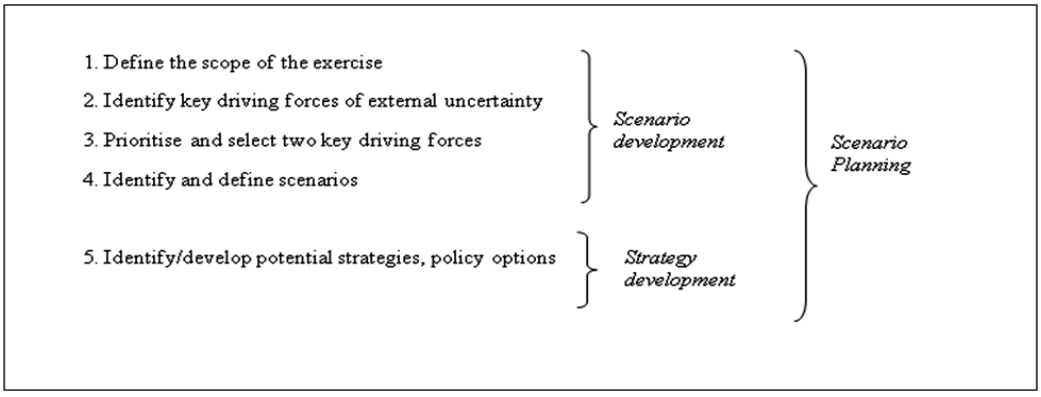

Figure 3.1. Scenario planning process followed in this paper. Source: Tapinos (2012)

3.2.2 Scenario identification and description

The scenario matrix tool proposed by Wulf et al. (2010b) was adapted and used to identify and describe the scenarios. Using this tool, the identified key driving forces were converted to a plausible set of four scenarios indicating how the forestry sector might develop in future. To construct the scenarios, the two most important driving forces were drawn on the scenario matrix (x-y axes) with two contrasting outlooks (positive and negative) at the end of each axis. One scenario was then positioned in each of the four quadrants of the scenario matrix to define the four different scenarios, i.e. one scenario for each quadrant. After the four scenarios had been identified, they were described in more detail by systematically writing storylines for each, using the causal diagram and the driving forces to determine the path towards the future for each scenario. In the final strategy development step, possible policy options and strategies that could guide sustainable development of timber resources in Ghana were identified.

3.3 Results

3.3.1 Driving forces

The driving forces affecting forests and timber resources development in Ghana are shown in Table 3.1. They are interlinked and cut across different sectors of Ghana's economy and also the broader changes nationally and internationally. The driving forces are the results of the literature review and have been grouped into 5 categories as shown in Table 3.1. The list of driving forces prioritised by the experts are shown in Table 3.2, and briefly presented in this section.

Forest governance system

Weak governance structures and ineffective policies and laws encourage forest degradation in Ghana (Hansen and Lund 2011). A major cause of forest degradation is increasing illegal commercial chainsaw milling; it has been the subject of extensive public debate and attention in the forest governance discourse in Ghana (Agyeman et al. 2004, Hansen and Treue 2008, Marfo 2010, Odoom 2005). It is estimated that illegal commercial chainsaw milling processes between 1.7 million and 4.8 million m^3 of raw wood annually (Hansen et al. 2012, Hansen and Treue 2008; Marfo 2010). The government's main strategy of banning and criminalising this milling activity has been ineffective; chainsaw lumber still reaches the market.

Important driving forces behind the illegal commercial chainsaw milling include poor law enforcement, and insufficient supply of sawmill lumber to the domestic market (Gyimah and Parren 2007, Marfo 2010, Odoom 2005). The insufficient supply of industrial sawmill lumber to the domestic market is due to low timber prices at the domestic market compared to the export market prices. The industrial sawmills have largely remained export-oriented and domestic demand has largely been met by illegal commercial chainsaw milling (Hansen and Lund 2011, Marfo 2010, Odoom 2005).

Other important forest governance issues in Ghana are the insecurity associated with land and tree tenure system, and inequitable benefit sharing arrangements. Different tree tenure arrangements operate within and outside forest reserves. Tree rights to all naturally regenerated trees are vested in the state on behalf of the people, regardless of the land on which trees occur or grow. Famers are not legally entitled to logging rights to naturally regenerated timber trees on their farms, even if they have protected such trees (Acheampong and Marfo 2011). In addition, farmers do not benefit directly from revenue accruing from the legal harvest of naturally regenerated timber on their farms. This is because the only legitimate receivers of

forest revenue on behalf of the entire communities are traditional authorities and local government authorities. However, in practice, farmers are free to determine which trees they wish to maintain on their farms while cultivating the land.

Table 3.1 Driving forces affecting forest and timber resources development in Ghana as identified from literature

I.	Social and demographic category
1	Population and urbanisation
2	Rural economy, employment and poverty
3	Disposable income among urban population
II.	Policy and institutional (governance) category
1	Tenurial and ownership arrangements
2	Revenue collection and benefit sharing arrangements
3	Law enforcement
4	Exploitation rates
5	Conditions of service at the forest management (district) level
6	Strategic planning
7	Institutional and administrative capacity
8	Timber rights allocation system
9	Political pressures/interference
10	Sectoral and extra-sectoral policies
11	Plantation development schemes
12	Role of environmental NGOs, civil society, private sector and development partners
13	Accountability and corruption
14	Illegal chainsaw milling
15	Supply of sawmill lumber to domestic market
III.	Economic, market and trade category
1	Forest fees
2	Demand for timber, cocoa and minerals
3	Domestic market timber prices
4	Sawmills market preference/export oriented sawmills
5	Industry profit and resource use efficiency
6	Timber industry processing capacity
7	Infrastructure development
8	Agricultural practices
9	New and emerging markets for forest environmental services
10	Artisanal mining
IV.	Environmental and forest management category
1	Forest management practices including management plans
2	Forest fires
3	Local communities' incentives and participation in forest/tree protection
4	Climate change, carbon and REDD+ issues
V.	Technological category
1	Introduction of new cocoa varieties
2	New rotary veneering techniques
3	New mining technology

Hansen et al. (2009) maintain that Ghana's forest taxation regime subsidises log prices, which increases the profitability of the log-processing industry and encourages the industry to increase its log-processing capacity and expand extraction. The low forest fees contribute to high profit margins and thus there are no financial incentives for the industry to improve

efficiency (Birikorang et al. 2007) but rather increase exploitation rates. In addition, the industry do not increase revenue to the local traditional authorities, resulting in lack of incentives or motivation for the communities to protect the forests. Consultation of farmers prior to timber harvesting from their farms, which is required under the law, is generally ignored, and that in most cases the compensation paid does not fully compensate for the damage to crops (Hansen et al. 2009, Marfo et al. 2006). Farmers and local communities therefore have little or no motivation at all to carry out tree/forest protection activities. As a result, the farmers engage in and/or consent to illegal commercial chainsaw milling activities, since the chainsaw operators pay farmers cash. Other farmers take preventive measures to remove (kill or burn) timber trees on their farms during cultivation, to avoid crop damage caused by legal timber operators (Amanor 1996, Ardayfio-Schandorf et al. 2007, Hansen et al. 2009, Treue 2001).

An important driving force affecting forest resources development in Ghana is the introduction of new cocoa varieties that require no shade (Hansen et al. 2009). Because farmers assumed that the new cocoa varieties require no overhead shade and are more profitable in the short term, many farmers (especially in the west of the high forest zone) remove all tree cover when introducing them (Darko-Obiri et al. 2009, Osei-Bonsu et al. 2003).

Resource demand

Rapid population growth is increasing demand for resources from the forests, and is among the important driving forces that affect the present and future development of forest resources in the tropics (DeFries and Pandey 2010). In Ghana, population and urbanisation have both increased rapidly since Ghana's independence in 1957, and Ghana is gradually becoming a predominantly urban society with increasing disposable income among the urban population. The current annual urban population growth rate is approximately 4 percent (World Bank 2011). Ghana's total population has increased from 6.7 million in 1960 to 24.2 million in 2010 and is expected to reach 31 million by 2025 (NPC 2006). The current population growth rate is about 2 percent per annum but in past decades exceeded 3 percent per annum (NDPC 2005, NPC 2006, World Bank 2011).

The rising disposable income among the Ghanaian urban populace have resulted in increasing timber demand for furniture and construction. In addition, the increasing population increases demand for energy (firewood, charcoal), and land for farming, resulting in deforestation. High poverty levels in rural areas also allow the populace to support illegal chainsaw milling operations to support their livelihood.

Table 3.2 List of prioritised driving forces that affect forest resource development in Ghana

I.	Forest governance system
1	Poor law enforcement
2	Sawmills are export oriented
3	Domestic market timber prices are lower
4	Low supply of sawmill lumber to domestic market
5	Insecure land and tree tenure
6	Inequitable benefit sharing arrangements
7	Poor incentives for local communities to engage in forest/tree protection
8	Low forest fees
9	High industry profit and resource use inefficiency
10	Over-exploitation of resources
11	Increased sawmill processing capacity
12	Exclusion of trees from the introduction of new cocoa variety
13	Increasing illegal chainsaw milling to supply domestic market
II.	Resource demand
1	Population growth and urbanisation
2	Increasing disposable income among urban dwellers
3	High poverty levels among rural populace
4	Increasing demand for timber and energy

3.3.2 Causal diagram and future scenarios

The causal diagram discussed and amended during the workshop identifies the linkages between the key driving forces that cause changes in the forest resources (Figure 3.2). The two important driving forces identified during this exercise and upon which the scenarios were built were noted not to be single driving forces but severally interlinked in clusters. These are: (1) the governance system in the forestry sector, and (2) resource demand of the Ghanaian populace (Figure 3.2). Based on these and additional trends and driving forces, four plausible scenarios emerged on how the forest resource might develop in the next 10-15 years. These are: (1) legal forestry scenario, (2) forest degradation scenario, (3) forest transition scenario, and (4) timber substitution scenario (Figure 3.3).

Legal forestry scenario

An effective governance system is in place and there is high demand on the forestry resource. Although deemed unlikely in the very short term (e.g. within 5 years), given the long history of corruption, poor law enforcement and non-compliance in the forestry sector, this scenario assumes that it would be possible to halt and possibly reverse the existing timber resource degradation in the high forest zone. In this scenario, government embarks on tenure reforms to grant secure land and tree use rights to communities and farmers, to gain their support in

managing forest resources. In addition, private sector investments in commercial timber plantations in areas outside forest reserves increase. Fiscal policies are reformed to ensure that appropriate fees and taxes are paid for resources used, and that local communities, landowners and individual farmers benefit from timber revenue. With secured tenure and benefiting from tree revenue, farmers would have incentives to plant trees on farmland, and manage naturally regenerated trees, resulting in improved natural regeneration and expansion of timber resource base in areas outside forest reserves. In addition, streamlined institutional and administrative structures ensure transparency, accountability and good cooperation between relevant government agencies and civil society for effective law enforcement and compliance.

The Ghanaian population continues to grow at the current rate of two percent, and rising disposable income among the urban dwellers results in high demand for the resources. Timber prices on the domestic market are increased to match the export market prices. The strong governance structures ensure progressive elimination of illegal chainsaw lumber and that resources are used efficiently. Timber harvesting rate is reduced from the approximately 6 million m^3 a year to the current annual allowable cut (AAC) of 2 million m^3. The AAC is further progressively aligned with a newly determined AAC that is within the sustainable capacity of the production forests (e.g. the 0.8 million m^3 annually suggested by Mayers et al. 2008). To meet domestic demand, Ghana would temporarily import lumber or suspend all exports until there is adequate natural regeneration and growth of the production forests and commercial timber plantations reach maturity.

Forest degradation scenario

A weak forest governance system is in place coupled with high demand for timber resource. In this scenario, land and tree tenure are largely insecure and farmers have no commercial use rights to naturally regenerated timber on their farms. Farmers do not get a share of revenue in the benefit-sharing arrangements. Communities and farmers therefore do not effectively participate in forest management and protection; neither do they have incentives to plant trees and maintain naturally regenerated trees. Fiscal policies remains unchanged with low forest fees and taxes. Law enforcement is poor, and there is corruption and biases in the central forest management system. Weak cooperation between relevant government agencies and civil society for effective law enforcement and compliance. The formal timber industry with its high processing capacity continues to be export-oriented even though the domestic market is entirely dependent on internal timber resources.

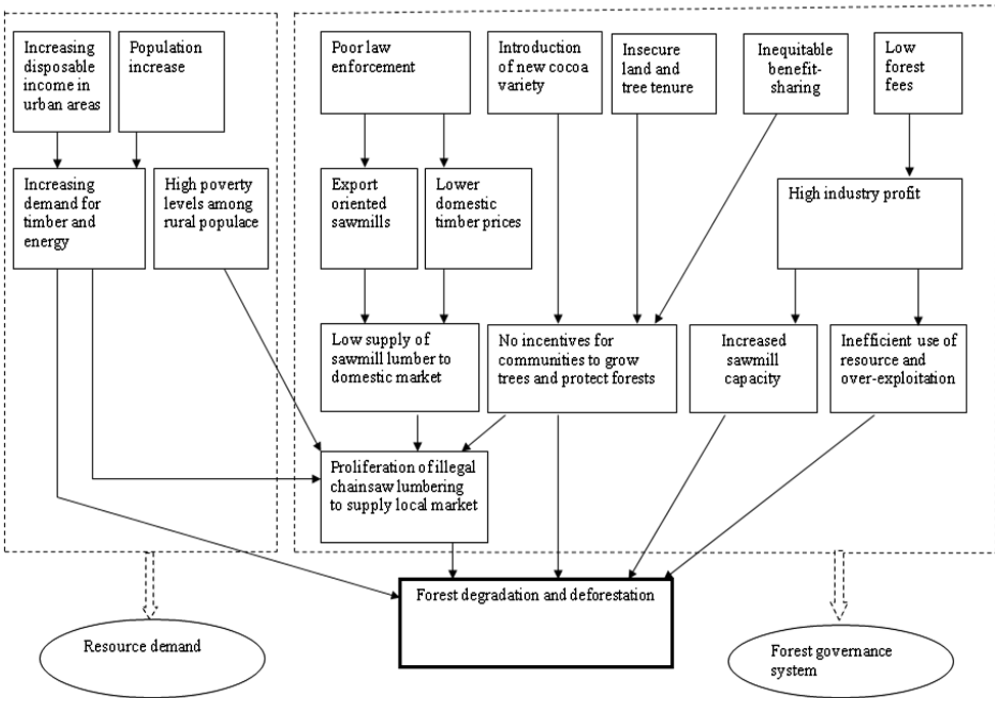

Figure 3.2 Simplified linkages between the two key drivers of forest resource change in Ghana

Population continues to grow at current rate of two percent. Demand for timber remains high. High poverty levels and weak governance system allows the high demand for wood products to be met by illegal chainsaw milling operations which produce lumber at affordable prices at the domestic market. With both the formal sawmills and illegal chainsaw operators harvesting timber to supply the export and domestic markets under weak governance structures, the AAC will continue to be exceeded, leading to forest degradation. Recognising the need to increase the resource base, the government/Forestry Commission invests more in establishing commercial timber plantations by engaging the services of farmers and professional institutions such as the Forestry Research Institute of Ghana. Benefit-sharing agreements are made between the Forestry Commission and farmers participating in the Forestry Commission's plantation development programmes.

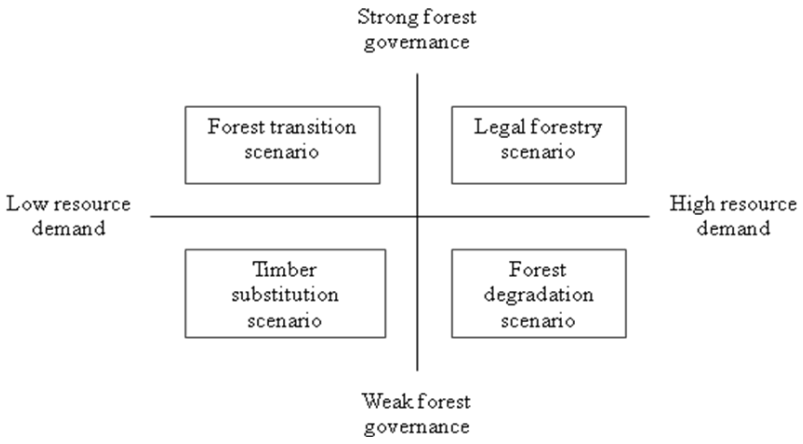

Figure 3.3 Future forest resource development scenarios in Ghana

Forest transition scenario

Tenure reforms are pursued to give secure tree use rights to local communities and farmers for their support in managing forest resources. Appropriate forest fees and taxes are paid. Benefit-sharing arrangements include provisions for individual farmers. As a result, farmers are well motivated to manage on-farm trees, improve natural regeneration and restore the timber resource base in the off-reserve areas. Demand for timber resources is low due to social-economic development in Ghana that make people become less dependent on timber. But environmental considerations (e.g. payment for environmental services or REDD+) motivate the government and civil society to engage in tree planting and improve forest management and protection, thereby encouraging natural regeneration.

The population growth rate is still two percent. There is growth in Ghana's economy, particularly in the service and industrial sectors, creating jobs in rural and urban areas. The low demand together with improved governance system reduces the support for illegal chainsaw milling activities. Institutional and administrative structures are improved to ensure transparency and accountability. Domestic market prices of timber match the export market prices. Volume of lumber on the domestic market decreases, due to availability of substitutes (e.g. plastic, steel and concrete) on the local market. Timber industry remains export-oriented but the industry's processing capacity is reduced and harvesting rate is aligned with a sustainable AAC.

Timber substitution scenario

Under this scenario, there exist corruption, lax law enforcement and non-compliance in the forestry sector. There are no ownership and tenure reforms to grant local communities and farmers secure rights. Farmers do not have ownership rights to naturally regenerated timber trees on their farms. But the low demand for the resource prevents farmers from destroying most timber trees from their farms since damage to their agricultural crops is minimal due to reduced on-farm harvesting rates. There is however low motivation or incentive for farmers and local communities to either plant trees or participate in forest management or forest protection. There is no fiscal reform and forest fees and taxes are low; benefit-sharing arrangements do not favour individual farmers. The allocation of timber rights is centralised and the timber industry receives most of the rights. The formal timber industry continues to be export-oriented, and the weak governance system still allows for some illegal chainsaw activities, mostly from on-reserves for export. Total timber harvest is above the sustainable capacity of the production forests. Domestic market prices of timber are low to medium but local demand mostly shifts to wood substitutes.

Population growth is two percent; growth in the economy allows for more job creation in the service and industrial sectors, attracting labour from the timber sector, particularly from the illegal timber activities. This trend is boosted by the declining demand on the resource, resulting from increasing availability of substitutes.

3.4 Discussion

3.4.1 Scenario methodology as a tool for exploring future developments

Scenario methodology is useful when strategic decisions must be taken within the context of specific societal, economic or environmental conditions and when developments in these domains cannot be forecasted over a lengthy period (Behlau et al. 2010). Even though it is impossible to predict the future precisely, scenario methodology can be used to develop plausible and justifiable visions of the future by clarifying the nature and impact of the most uncertain and important driving forces (Behlau et al. 2010, Peterson et al. 2003, Sarpong and Maclean 2011). One advantage of scenario analysis is that it can be used to consider the impact of future exogenous factors and changes in a sector such as forestry. This is because qualitative information usually provided by expert assessments is used for envisioning future developments of the sector (Bunn and Salo 1993, Zanoli et al. 2012) as was the case in this study. For example, the four scenarios developed to explore the future of timber resources in

the Ghanaian high forest were based on expert judgment/assessment that the most important clusters of driving forces are forest governance and resource demand. Future development of the timber resources seems to be highly dependent on these. The narratives created for each of the four scenarios are plausible images of the future which should be used by policy makers and forest managers to envision the future of timber resources so as to help them prepare their mind set for possible alternatives situations (Tapinos 2012, Zanoli et al. 2012). Summary of key characteristics of the different scenarios is presented in Table 3.3.

3.4.2 Measures for improving forest governance system

The scenario narratives suggest that strengthening forest governance is crucial for the sustainable future development of Ghanaian timber resources to meet the increasing demand. They show that secure land use rights, local communities' and farmers' direct benefits from timber revenues, appropriate forest fees, and enhanced law enforcement will be critical in the future development of the high forest zone timber resources.

Reforming on-farm tree tenure rights and benefit-sharing arrangements

Tenure reforms recognizing ownership or management and commercial use rights for communities and farmers are important considerations for building and protecting on-farm timber resources under the legal forestry and forest transition scenarios. Leach and Fairhead (2000) indicate that farmers who are landowners and have tenure rights in the Wenchi District of the Brong Ahafo Region of Ghana preserve and encourage a variety of forest tree species in their fields. Where population growth has forced fallows to be shortened, the farmers with secure land tenure rights engaged in fallow enrichment and integrated fast-growing trees into their cropping system. But Leach and Fairhead (2000) found that tenant farmers in the same community who had insecure tenure rights lacked incentives to plant and protect trees on their farmland. Damnyag et al. (2012) argue that the tenure system in Ghana aggravates deforestation because under informal rules governing land holdings, such as sharecropping and lease-holding, farmers with short-rotation farming systems are reluctant to undertake long-term investments such as tree planting. There is therefore the need for Ghana to consider reforming tenure of trees on farms under the legal forestry and forest transition scenarios. This is consistent with VPA/FLEGT and REDD+ objectives. In Ghana, the Government is committed in tackling deforestation and forest degradation, especially as part of Ghana's REDD+ strategy to deal with

climate change. This is also the emphasis of Ghana's new Forest and Wildlife Policy (2012), and other on-going processes, such as the VPA/FLEGT. For example, issues relating to strengthening of rights of access to resources forms part of the legislative reform agenda set out under Ghana's VPA/FLEGT. Ghana's REDD+ strategies will also clarify tree tenure and rights regimes, especially in off-reserve areas (MLNR 2012). Hansen et al. (2009) suggest reforms that grants the farmer rights to trees they manage on-farm, including the rights to sell them, as standing timber or wood products.

There may be challenges associated with the tenure reforms under the legal forestry scenario arising out of the high demand for timber. Having been granted ownership rights to on-farm trees, farmers may take advantage of the opportunity to sell more trees on their farms, which will increase the rate of harvesting and depletion of the on-farm timber resource. Since forest reserves and farmlands have different tenure arrangements, there is also the potential threat of (illegally) harvesting timber from forest reserves and marketing it as on-farm timber resource. However, improvement in law enforcement under the legal forestry scenario can address these challenges. Moreover, farmers' rights to on-farm trees and the opportunity to directly benefit from on-farm timber revenue sharing should eventually encourage farmers to plant and manage more trees on their farmlands. The ownership of planted on-farm trees under the current legislation may also present another challenge. The current legislation acknowledges that a person who plants a tree has legal rights over that planted tree. Meanwhile, a significant number of farmers in Ghana are, in full or partly, farming on leased land or as sharecroppers (Amanor 1996). What this means is that the actual legal rights to the planted tree (and to managed naturally regenerated trees as suggested under the reform) might not necessarily translate to secure rights for the tenant farmer. Hansen et al. (2009) suggests that bilateral agreements can be reached with the landowners to address this potential challenge.

Under the legal forestry scenario, on-farm timber should be subjected to tax and appropriate fees to improve revenue capture. Concerning benefit-sharing, Damnyag et al. (2012) suggest instituting a benefit-sharing scheme that recognises and rewards the contribution of tenant farmers, to encourage them to use sustainable forest management practices. In doing so, the government should use past understood lessons from the implementation of the Rent Stabilization Act (109) in Ghana where non-consultations between tenants and landowners resulted in disputes (Benneh 1988, Damnyag et al. 2012). The government should therefore undertake benefit-sharing reforms in consultation with the individual farmers, local communities and landowners. The government should also collaborate with non-governmental

organisations to support capacity-building activities in local communities and ensure effective community participation in forest protection and management. Under REDD+, each project will have to have a benefit sharing structure that is legal and that stakeholders consider to be fair and transparent. Failure to design a system that is equitable and transparent increases the likelihood of REDD+ project failure under the legal forestry scenario.

Improve industry resource use efficiency and investments in plantation development

There is the need to reduce the high capacity in the timber industry and to improve industry resource use efficiency. The low recovery rates within the timber industry contribute to the intense pressure on the already degraded resource base. In the legal forestry scenario, the industry requires significant re-tooling to increase their milling efficiency, which will in turn increase the volume of wood available for consumption. The challenge here is the significant financial investment needed to replace inefficient and outdated machinery and build the human resource capacity needed to operate new machines. Ghana's development partners and the government and private sector should support the industry's own investment efforts in re-tooling and improving efficiency.

There is also the need to align industry-installed capacity to the sustainable capacity of the production forests especially in the forest transition scenario where the demand is low. Both the current annual allowable cut (AAC) of 2 million m^3 and the current total harvest of 6 million m^3 a year are unsustainable and a new AAC is needed. Hawthorne et al. (2012) recommend calculating the new AAC on regional/district basis, taking into account the variability of the resources in each region/district. The Forestry Commission should collaborate with research institutions to conduct studies to determine the new AAC.

Table 3.3 Summary of key characteristics of the different scenarios

Characteristics	Scenarios			
	Legal forestry	Forest degradation	Forest transition	Timber substitution
Ownership and tenure	Secure tenure, ownership and commercial use rights to communities and farmers	Insecure tenure; farmers have no commercial use rights to naturally regenerated timber on farms	Secure tenure, ownership and commercial use rights to communities and farmers	Insecure tenure; farmers have no commercial use rights to naturally regenerated timber on farms
Benefit sharing	Important; farmers receive a share of revenue	Important; farmers do not receive a share of revenue	Moderate importance;	Less important; farmers do not

			farmers receive a share of revenue	receive a share of revenue
Investment in forest development (e.g. plantation development)	High by both government and private sector	Low, mostly by government	Medium to high, mostly due to environmental reasons	Low
Forest fees and taxes	High	Low	Medium to high	Low
Law enforcement	High	Low	High	Low
Demographic	Population growth at 2%	Population growth at 2%	Population growth at 2%	Population growth at 2%
Forest products demand	High	High	Low	Low, shifts to substitutes
Product prices	High	Low	Medium to high due to low demand	Low to medium
Industry market focus	Domestic and export	Export and domestic	Export	Export
Timber supply to domestic market	Through sawmills and temporary importation or suspension of exports till plantations reach maturity.	Mainly through illegal activities	Through sawmills	Through illegal channels
Institutional and administrative structures	Streamlined to ensure high transparency, accountability and good cooperation between government and civil society	Mostly unchanged. High corruption and biases in the forest management system. Weak cooperation between government and civil society to ensure law enforcement	Improvement in transparency and accountability. Good cooperation between key stakeholders to tackle environmental issues	Remains largely unchanged. Government and civil society cooperate to address environmental concerns but undermined by weak governance system
Resource use efficiency	Increased	Low	Medium to high	Poor
Ecological effects or consequences	Harvesting rates reduced to sustainable AAC of production forests; improved regeneration and on-farm trees	High harvesting rates; poor regeneration. Farmers continue to kill on-farm timber trees or consent to poor harvesting activities of illegal chainsaw operators	Reduction in harvesting rates to sustainable AAC; moderate generation on farms and rehabilitation and restoration due to environmental concerns e.g. REDD+	Low to medium harvesting rates that are higher than sustainable AAC. Farmers do not destroy on-farm trees but have no incentives to actively engage in tree protection and management

In the legal forestry scenario, future development of the timber resources depends greatly on investments in commercial timber plantations and tree planting on farms, to meet the growing demand for timber. Within degraded forest reserves and areas outside reserves there should be substantial and well-coordinated plantation development programmes by both the Forestry Commission and the private sector (including timber companies), with clearly established ownership rights. Additionally, assistance from development partners in the forest sector should include a component that specifically targets the development of the timber resource base. Research institutions and the government should develop appropriate management strategies for managing the established plantations. In the forest degradation scenario, the resource base is expanded through plantations and some incentives for tree planting. However, the challenges under this scenario would include poor financial incentives including lack of credit facilities that makes it unattractive for farmers and companies to invest in forest plantations in Ghana. In addition, the Government's funding of plantation development funding would usually be intermittent and unsustainable, and will result in poor management of any established plantations.

3.4.3 Meeting domestic resource demand

Supply of lumber to the domestic market is considered a key issue for the development of timber resources in the legal forestry and forest degradation scenarios, particularly due to the high demand on the resources. Recently, Hansen et al. (2012) suggested an annual timber harvest of approximately 6 million m^3 of which 80 percent is harvested by illegal chainsaw operators for predominantly domestic consumption. This is triple the annual allowable cut (AAC) of 2 million m^3 and more than seven times the suggested sustainable AAC of 0.8 million m^3 (Mayers et al. 2008). This suggests that current demand (both domestic and export) far exceeds the sustainable capacity of the forests, and has important implications for the development of timber resources in the high forest. To ensure sustainable management of forest resources, any policy option must address domestic timber needs. Ghana's VPA/FLEGT process underscores the need for considerable improvement of timber tracking, information management and application of best practice in forest governance and law enforcement. The most pronounced feature of the situation with illegal logging is the supply of timber from the chainsaw milling sector.

Furthermore, potential REDD+ strategies in Ghana include measures to address unsustainable timber harvesting by supporting sustainable supply of timber to meet export, regional exports, and domestic timber demand (MLNR 2012).

In the legal forestry scenario, the progressive elimination of illegal chainsaw milling through a strengthened governance system will have two policy implications. First, arrangements must be made to meet demand, particularly domestic demand, for timber. To address this, the policy option may include measures to allow formal industry (sawmills) and artisanal millers (re-organized and registered chainsaw operators) to be allocated timber harvesting rights to supply the domestic market with timber. This requires legislative reform to legalise artisanal timber production in Ghana, with a more stringent timber monitoring system in place. Without a rigorous timber monitoring system, legalising artisanal milling would result in much greater pressure on the already degraded timber resource, likely leading to the total collapse of the entire formal timber industry. Concerning access to timber rights, Hansen et al. (2009) suggest pursuing a legislation that allows for small and short-duration timber rights in forest reserves. Artisanal millers could be allowed to harvest timber species that are not commercially interesting for formal concession holders. The potential positive effect of this option on deforestation and degradation is largely associated with the creation of fair competition for timber rights and enhanced law enforcement (Hansen et al. 2009), although it temporarily may increase the pressure on already degraded forest resources. Ultimately, timber supplies to meet demand may have to come from established forest plantations and the natural production forests.

Second, alternative livelihoods will have to be found for the large labour force that have depended on illegal chainsaw milling for their livelihood. Without a clear picture of how those whose jobs would be lost can be relocated, any attempt to enforce a policy option to eliminate or restrict commercial chainsaw milling will be fiercely contested. Under a strengthened governance system, strict law enforcement is necessary but measures aimed at strict law enforcement alone are rarely successful in circumstances where the illegal activity remains economically attractive. Besides, Hansen et al. (2009) argues that the ban on chainsaw lumbering is not enforceable and results in double pressure on the resource. Wiersum (2010) recommends that strict law enforcement should be complemented by a soft law enforcement approach that provides incentives for developing alternative labour and income earning opportunities for local people involved in illegal harvesting and manufacturing, and for rural communities that are involved in illegal timber harvesting. This requires the identification of

viable alternative livelihood activities, and the process for identifying the livelihood activities should involve all actors in the sector. In the forest transition scenario, the government could take advantage of the recent increases in the sectoral growth rates of the services (9.8%) and industry (6.9%) sectors of the economy (GSS 2012a), to relocate most of the labour force to new livelihood activities in the services and industry sectors.

With approximately 80 percent of total timber production being consumed domestically, another option to meet this high domestic timber demand is to restrict timber exports. Under improved governance system, the domestic market could potentially consume all the legal timber should the total harvest be reduced to the sustainable capacity of the current production forests. The focus of timber production would therefore be on supplying the domestic market alone in the short to medium term. This requires strengthening of law enforcement to eliminate illegal chainsaw activities in order not to collapse the timber industry whose focus will be to supply to domestic market. Timber price on the domestic market would have to be high to serve as incentives to the timber industry for selling on the domestic market. Also important is the need to control the high population growth in Ghana so as to reduce the pressure on the forest resources. The Ministry of Health should embark on health development education programmes to encourage family planning, with the aim of controlling population growth. The government could set up health facility posts/centres in the rural areas to offer free education and family planning care for rural people.

In the forest transition and timber substitution scenarios, the future development of timber resources is enhanced by the shift from great demand on wood products to great demand for wood substitutes. This shift will likely make it possible for the government to strictly enforce laws and regulations and administer stricter penalties to defaulters under the forest transition scenario. To improve overall law enforcement in the forest sector and reduce political intrusion in the management of the resource, mechanisms that enable forest sector institutions to be accountable to stakeholders and the general public must be rigorously pursued. The Forestry Commission should bring cases to court and ensure that those committing forest crimes are punished. Civil society participation is needed to ensure that any reported forest crime is properly addressed and every case prosecuted (Agyeman et al. 2007, Beeko et al. 2006). As a long-term option, the Ghanaian populace should be educated about the need to comply with the law and on the effects of illegal activities. An option might be to incorporate such education into the curriculum of primary and junior high schools.

The shift from demand for timber to demand on timber substitutes requires research (for example, on alternative building materials). The Ministries of Works and Housing and of Environment, Science, Technology and Innovation should be mainly responsible for developing the alternatives. The Building and Road Research Institute of the Council for Scientific and Industrial Research should lead the development of local construction materials as substitutes for wood.

3.5 Conclusions

Forest resources in the tropics currently face significant social, economic, political and environmental change, and policy makers and forest managers need to better understand what the future may hold, in order to maintain continuous supply of goods and services without compromising the quality of the resource base from the forests. This paper has focused on developing and describing alternative scenarios to explore future developments of timber resources in the high forest zone of Ghana. The scenarios can be used by policy makers, forest managers and other stakeholders to evaluate future practice and policy options in order to prepare for different future timber resources developments in the Ghanaian high forest zone. Although the paper has focused on this high forest, the lessons from this region and the policy options developed from the scenarios have the potential to inform management decisions in forests throughout the tropics, particularly in West Africa.

The scenarios demonstrate that strengthening forest governance and addressing issues relating to high resource demand are crucial elements for safeguarding the sustainable future development of Ghanaian timber resources. Prerequisites for strengthening the forest governance system to support sustained development of the resources in the high forest zone are secure land tenure and tree use rights, fiscal reforms that ensure better revenue capture, policy reforms that support equity in benefit sharing and measures to ensure law enforcement. The legal forestry and forest transition scenarios require government to reform policy and local communities and farmers to be involved in tree planting and forest protection, while non-governmental organisations and development partners contribute to building the capacity of the Forestry Commission and communities to participate in forest management. To ensure sustainability, there must be a new AAC, including the capacity of the production forests, but separating between the remaining forest resources in the forest reserves and the new plantations, either within or outside the reserves. The Forestry Commission and private sector should invest

in commercial timber plantations in degraded forest reserves and areas outside reserves, to build the timber resource base.

The future of timber resources is strongly affected by the high domestic demand for timber. The existing timber resource base cannot meet current domestic and export market demands in a sustainable way. Policy options to address the domestic demand for timber include promotion of alternative building materials as wood substitutes in the timber substitution scenario, temporary importation of timber and/or temporary restrictions on exports in the legal forestry scenario, population growth control through family planning education, and the provision of alternative livelihoods for much of the large workforce currently dependent on the forest resource for their livelihood. Critical for the sustainable future development of timber resources in Ghana are the involvement of all actors and stakeholders, particularly the domestic lumber actors/chainsaw operators and formal timber companies in the identification of viable alternative livelihood options, plus government commitment to supporting the implementation of policy options. Policy options and measures outlined under the various scenarios aiming at improving the forest governance system and meeting the timber demand are consistent with the current forest policy trends in Ghana, especially VPA/FLEGT and REDD+ process.

Chapter 4

Farmers' motivations to plant and manage on-farm trees in Ghana

Submitted as:

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Abstract

Deforestation and continuing degradation of existing forest resources, especially in the agricultural landscapes, are serious threats to the sustainability of the timber industry in Ghana. Planting trees on farms has been identified as having great potential to increase timber supply from agricultural landscapes to bridge the gap between timber demand and supply. This study examined farmers' motivations and behaviours to engage in on-farm tree planting and management in Ghana by combining internal and external factors in a socio-psychological model. Data were collected from 156 smallholder farmers from five communities in Asankragwa and Sefwi Wiawso forest districts in Ghana using pre-tested semi-structured questionnaires. Additional farm inventory data were collected from 33 farmers under two on-farm tree planting schemes. Farmers viewed on-farm tree planting as economically beneficial. On-farm tree planting was perceived as providing income, access to personal wood for furniture, and access to loan facilities. Incentives in the form of provision of grants, farming inputs, seedlings, capacity training, and access to markets for agricultural produce are factors that motivate on-farm tree planting in Ghana. The average standing volume of on-farm trees in the study area is 51.9 $m^3 ha^{-1}$ which is higher than the national average for the off-reserve areas in the semi-deciduous forests to which much of the study sites belong. Many farmers considered high financial costs and low knowledge of proper techniques in managing planted trees in agricultural production systems as barriers to the development of tree stock on farms. On-farm tree planting programmes are more likely to succeed if the programmes incorporate policies that acknowledge and address motivational factors and barriers which underlie farmers' reasons for engaging in on-farm tree planting.

Keywords: Farmer motivation, decision-making, socio-psychological model, agroforestry, conservation.

4.1 Introduction

In Ghana, productive agricultural landscapes usually include forest trees for both economic and ecological reasons. The forests and trees in the agricultural landscapes of Ghana are of high importance for poverty reduction, economic development and maintenance of biodiversity. Their importance is expected to increase in the future due to the effects of climate change. In the 1990s, up to 80% of timber harvests in Ghana originated from areas outside forest reserves, mainly secondary forests and trees in the agricultural landscape (Kotey et al. 1998, Oduro et al. 2014a). In recent years, however, there has been a steady decline in timber harvest from off-reserve areas, which has mainly been attributed to agricultural expansion, and harvesting of timber and firewood from the off-reserve area in the past, leading to a decline in availability (Hansen et al. 2009, Oduro et al. 2014a). Others have also argued that the decline in forest trees in the agricultural landscape is a reflection of farmers' response to policies that do not provide incentives to farmers for managing tree resources on farms (Acheampong and Marfo 2009, Amannor 1996, Damnyag et al. 2012, Hansen et al. 2009). For example, rights to all naturally regenerated trees are vested in the state on behalf of the people, regardless of the land on which the trees grow, and even if farmers have protected such trees on their own farms (Acheampong and Marfo 2011). Yet, in practice, farmers are at liberty to determine the fate of all trees on their farms while cultivating the land.

In a country where the existing forest cover is unable to sustainably meet the growing demand for timber (Hansen et al. 2012, Oduro et al. 2014a), it is important to include timber trees in the agricultural production systems to estimate potential timber supply and to meet the demands for timber. Indeed, efforts to encourage farmers to plant trees on farmlands are ongoing in Ghana. Timber companies and non-governmental organizations (NGOs) have developed reforestation schemes through which they have been supporting farmers to engage in on-farm tree planting. For example, the Oda-Kotoamso Agroforestry Project (OCAP) and the Forestry Resources Creation Project (FRCP) are specific reforestation schemes that encouraged farmers to plant trees on farms and in degraded agricultural landscapes.

In addition, recent policy reforms in Ghana have sought to boost tree planting by granting ownership rights to those planting trees. In 2002, for example, the 1997 Timber Resources Management Act (Act 547) was amended to the Timber Resources Management Amendment Act (Act 617), that grants ownership rights to individuals who plant timber trees. Oduro et al. (2015) reported that by the end of 2003, more than 30,000 farmers have been

engaged in small-holder tree planting on farmlands, and an estimated 10,000 ha of farmlands were planted with timber trees. The need to encourage more integration of trees into the agricultural landscape to maintain and increase timber supply is urgent, given that the rate of forest plantation development has been lower than anticipated (Oduro et al. 2014a).

The approach to promote on-farm tree planting needs to be based on an understanding of farmers' tree management in the context of household livelihood strategies, and an understanding of farmers' value of trees and the constraints they face in developing on-farm tree resources (Arnold and Dewees 1998, Zubair and Garforth 2006). Thus, it is essential to understand the factors that motivate farmers to plant and manage on-farm trees. In the literature, socio-psychological factors, such as perceptions and attitudes, have been studied to explain adoption behaviour of farmers in relation to on-farm tree planting (Duesberg et al. 2013, Duesberg et al. 2014, Fischer and Vasseur 2002, Meijer et al. 2015, Mekoya et al. 2008). For instance, Zubair and Garforth (2006) studied the perceptions and attitudes of farmers in Pakistan and showed that the farmers' willingness to grow trees on their farms was a function of their attitudes towards the advantages and disadvantages of growing trees. These studies show that socio-psychological factors can explain the adoption and extent of on-farm tree planting activities (Meijer et al. 2015). Thus, the success of on-farm tree planting activities will to a large extent be determined by the understanding of the factors that motivate or discourage farmers to engage in on-farm tree planting. In Ghana, studies identified socioeconomic factors influencing rural farmers' on-farm conservation decisions of remnant forest tree species in agricultural landscape (Danquah et al. 2013), but there is no known research that has explored farmers' motivation for on-farm tree planting. In this study, we combine both internal and external factors to understand farmers' motivations and behaviours under current on-farm tree planting schemes. By applying a socio-psychological model this study provides insights that are helpful in the formulation of policies to encourage on-farm tree planting and management.

The objectives of this paper are to describe on-farm tree management and conservation in Ghana, to identify farmers' motivational factors and barriers to engage in on-farm tree planting assessing two schemes (OCAP and FRCP), and to determine the volume of trees resulting from on-farm tree planting and management. The results are useful to the current on-farm tree planting efforts in designing programmes that would encourage on-farm tree planting to bridge the timber demand and supply gap in Ghana.

4.2 On-farm tree management and conservation in the high forest zone of Ghana

On-farm trees in the high forest zone of Ghana are usually in the form of scattered individual trees on farmlands, fallow lands and trees around settlements (Kotey et al. 1998). In Ghana as elsewhere in West Africa, farmers manage on-farm trees to provide fruits, firewood, poles, shade for crops, timber, improve soil fertility and protect the environment. For example, in cocoa and coffee agroforestry systems in Ghana, trees are incorporated to provide shade, timber and firewood. In addition, cocoa cultivation needs substantial proportions of shade trees in a diverse structure and is viewed as a sustainable land-use practice that complements biodiversity conservation efforts (Asare et al. 2014, Rice and Greenberg 2000, Schroth et al. 2004). Furthermore, cocoa agroforests have been used as a buffer zone around protected areas like the Kakum National Park in the Central Region of Ghana to reduce forest encroachment (Asare 2005, Asare et al. 2014). On-farm trees are also common in food crop, cola, and oil palm cropping systems in the high forest zone.

On-farm trees in Ghana may broadly be categorized into (i) those that are left standing because it is too laborious to remove, (ii) those that are tolerated because farmers perceive that the trees have few negative impacts on crops, and (iii) those that are actively tended or planted by farmers (IIED 1994, Treue 2001), because farmers expect to benefit from them. The traditional agroforestry practice whereby farmers deliberately leave timber tree species on their farms to provide specific environmental, economic and cultural services is an on-farm conservation practice that protects timber species in the agricultural landscape (Anyonge and Roshetko 2003, Robiglio et al. 2011). Robiglio et al. (2011) reports that effectively, traditional smallholder agroforestry systems in Ghana contain more timber trees than the remaining secondary forest patches in areas outside forest reserves. This is because of farmers' active on-farm decisions and measures that protect forest trees on farmlands for environmental and economic use (Anyonge and Roshetko 2003, Danquah et al. 2013, Degrande et al. 2006, Dumenu 2010, Robiglio et al. 2011). Such decisions and measures enhance on-farm tree conservation efforts.

Unlike forest reserves, on-farm trees are not under any specific silvicultural management. Decisions and management strategies of farmers and landowners concerning land-use usually determine the development of on-farm trees. This is because on-farm trees are usually under the control and management of individual farmers and traditional authorities who

cultivate or own the land on which the trees occur. The type of species and the density of on-farm trees often depend on the farmers' decisions and the type of crops being cultivated. However, harvesting of on-farm trees is regulated through the use of a national Annual Allowable Cut (AAC) standard for specific species. Similar to trees in forest reserves, on-farm trees must exceed a certain minimum felling diameter for it to be harvested. Prior to harvesting, a pre-felling inspection of trees is conducted by the Forestry Commission (FC) and the timber firm interested in carrying out the harvesting operations. Harvesting only takes place after the timber firm receives a felling permit from the FC and a consent from the person who holds the farming right on the land where the trees to be harvested are located. The timber firm is also required to pay compensation for any damage to agricultural crops caused by the harvesting operations (FC 1998).

Recently, policy reforms that have granted right of ownership to individuals who plant trees have encouraged on-farm tree planting. However, farmers and landowners do not have commercial or logging rights to naturally regenerated trees they manage and protect on their farms (Acheampong and Marfo 2011, Kotey et al. 1998). Rights to all naturally regenerated trees are vested in the state on behalf of the people, regardless of the land on which trees occur or grow. In addition, farmers do not benefit directly from revenue accruing from the legal harvest of naturally regenerated timber on their farms (Acheampong and Marfo 2011, Oduro et al. 2014b). Therefore, the incentive has been for farmers to destroy naturally regenerated timber trees since timber firms that obtain legal permits to harvest on-farm trees rarely pay sufficient compensation for damage to cocoa or other crops (Amanor 1996, Hansen et al. 2009). It has also been much more attractive for farmers to sell on-farm timber trees to (illegal) chainsaw operators, who pay the farmers about one third of the value of the tree in cash or in-kind (Amanor 1996).

Another factor that has affected on-farm trees is the introduction of new hybrid cocoa varieties. Farmers (especially in the western part of the high forest zone) assumed that the new cocoa varieties require no overhead shade, and are more profitable in the short term. Therefore, farmers – particularly migrant farmers – remove all tree cover when introducing the new cocoa on their farms (Darko-Obiri et al. 2009, Osei-Bonsu et al. 2003, Ruf 2011).

4.3 Farmer motivation and decision-making theory

We use a socio-psychological model of farmers' motivations, decision making and behaviours (Figure 4.1), adapted from the works of Duesberg et al. (2013), Gasson (1973), Meijer et al. (2015) and Willock et al (1999), to explore internal and external factors that motivate farmers' decision to participate in on-farm tree planting in Ghana. As the literature shows, such socio-psychological models have been rather successful in demonstrating and explaining farmers' attitudes and behaviours regarding nature conservation in agricultural landscapes, and in stipulating the relationship between motivation for and implementation of conservation practices on farms (Duesberg et al. 2013, Gasson 1973, Home et al. 2014, Willock et al. 1999, Zubair and Garforth 2006).

The model used in this study includes both internal and external factors and their interactions in decision-making on participation in on-farm tree planting (Figure 4.1). Decision-making regarding on-farm tree planting is influenced by persons' internal factors (e.g. cognitive abilities, knowledge, perceptions, attitude, awareness) and is, in our case, usually based on gaining information and knowledge about the existence of tree planting schemes and the associated benefits and costs. However, the information and knowledge farmers tend to gather on such tree planting schemes is assumed to be dependent on perceptions and attitudes of these farmers, thus economic factors like costs and benefits are 'filtered' through psychological ones (Meijer et al. 2015). Farmers motivations to engage in on-farm tree planting are moreover affected by external factors, such as land tenure, access to new land, and national policies. In addition, the role of extension and communication are crucial in the development of knowledge, perceptions and attitudes about on-farm tree planting (Meijer et al. 2015).

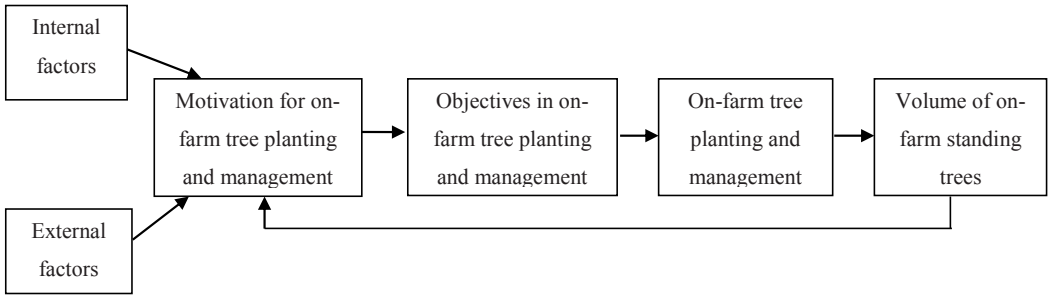

Figure 4.1: Factors motivating farmers decisions on on-farm tree planting and management.
(Adapted from Duesberg et al. 2013, Gasson 1973, Meijer et al. 2015, Willock et al. 1999)

According to existing models, farmers' decision making about on-farm tree planting is motivated by their objectives (Duesberg et al. 2013, Duesberg et al. 2014, Gasson 1973, Siebert et al. 2006, Willock et al. 1999, Zubair and Garforth 2006). The outcome variable in these models is the farmer's tree planting and management activities. However, we included in our model the *volume* of on-farm standing trees as an additional outcome variable, to indicate the interests of farmers in timber and non-timber forest products as final outputs in productive agricultural landscapes (Figure 4.1). We further included a feedback between the outcome variable and farmers' motivation, because we expect that if perceived benefits from on-farm trees are met, farmers' will become more internally motivated to plant and manage on-farm trees in the future, whereas the opposite might also be true (disappointing benefits and lower motivation).

4.4 Methods

4.4.1 Study area

Two on-farm tree planting schemes – the Oda-kotoamso Community Agroforestry Project (OCAP) and the Forest Resources Creation Project (FRCP) – were selected for this study. These two schemes were identified because they mimic the overall picture of farmer participation in on-farm tree planting schemes, rather similar to other sites in the country. Moreover, both schemes – although located in the same Western region of Ghana - are dispersed in different forest zones, one wet evergreen in Amenfi West district, the other semi-deciduous in Sefwi Wiawso municipal, so that we account for possible vegetation and social differences. With regards to ethnicity, Wassa is the dominant ethnic group in the OCAP area. However, there are other minor ethnic groups such as Nzema, Sefwi, Asante and Akyem. In the FRCP area, Sefwi Akan form the majority. The minority groups are Nzemas, Mole-Dagbani, Krobos and Ewes (GSS 2014a, GSS 2014b).

OCAP is located in the Asankragwa forest district (Figure 4.2) and the area falls within the wet evergreen forest zone with two rainy seasons: a major season (March to July), and a minor season (September to November). There are dry periods in August and from the beginning of December until the end of February. The mean annual rainfall ranges from 1,750 mm to 2,000 mm (Hall and Swaine 1981). OCAP was initiated by Samartex Timber and Plywood Company in 1997 and has a total size of about 290 ha. Under OCAP, about 20 indigenous and 3 exotic species have been planted mainly on farmlands either as mixed or

single species stands and individual trees on farms. Samartex Timber and Plywood Company provides technical and financial support for OCAP and more than 80 farmers, in and around Oda-Kotoamso village, are involved in the initiative.

The Forest Resources Creation Project (FRCP) is located in the Sefwi Wiawso forest district (Figure 4.2). The area falls within the moist semi-deciduous forest zone, with similar rainfall pattern as in the OCAP site. FRCP was initiated in 2000 by Ricerca e Cooperazione (RC), an Italian NGO that promoted on-farm tree planting in (degraded) cocoa, oil palm and food crop farms. RC organized out-grower farmers in several communities and provided seedlings, technical advice, training and equipment to support on-farm tree planting. Over 1,500 ha of farmlands, belonging to more than 1,000 farmers, have been planted with mainly indigenous tree species in about 60 communities under the scheme.

Both OCAP and FRCP are different in terms of area planted and number of farmers and communities involved. This is because OCAP scheme was developed with Oda-Kotoamso community as the main area for its implementation, hence Oda-Kotoamso and Oda-Breman (a nearby village) mainly participated in the scheme. The intention of the scheme developers was to progressively transfer the success and lessons learnt to other communities within the concession area of Samartex Timber and Plywood Company. In contrast, FRCP, from the initial stages targeted several communities for its implementation, covering about 60 communities using the same scheme approach in each community by the end of its implementation. This means that the same approach was used in each community, thus the studied communities under FRCP constituted a representative sample of all the FRCP communities as was also the case under OCAP. Therefore, the difference in both schemes does not distort the findings and comparisons of this study.

4.4.2 Data collection and analysis

Demographic data from farmers as well as farm inventory data were collected between August 2008 and December 2010. Data was collected from 156 smallholder farmers from five communities (Table 4.1) under OCAP and FRCP using pre-tested semi-structured questionnaires. These communities were recommended for selection by the project managers of OCAP and FRCP based on their active involvement in the projects. For FRCP, the three communities where the scheme implementation started were selected as representatives of all the communities under the scheme. In each community, respondents were randomly selected

from the group of farmers who were identified by the project or farmer leaders in the community.

Table 4.1: Characteristics and overview of the study areas for the household survey

Planting scheme	Community	No. of respondents	Forest district	Region of Ghana	Forest zone
OCAP	Oda-Kotoamso	62	Asankragwa	Western	Wet evergreen to moist evergreen
	Oda-Breman	9			
FRCP	Sefwi-Abrabra	43	Sefwi Wiawso	Western	Moist semi-deciduous
	Sefwi Bopa	31			
	Sefwi-Ahwiaa	11			

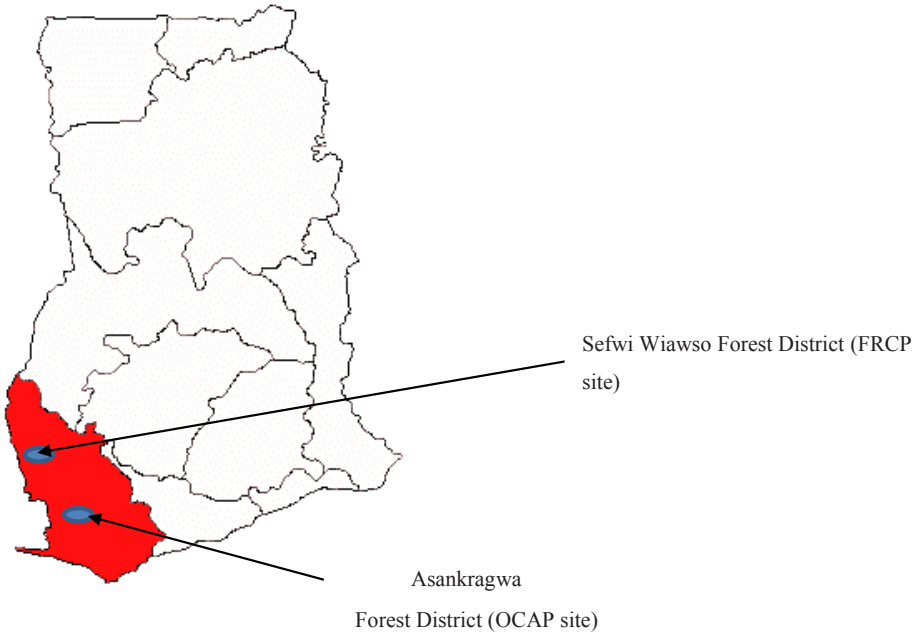

Figure 4.2: Map of Ghana showing study districts

Questions that the respondents were asked focused on their motivations, the factors that enable or constrain their decision to participate in the project, their objectives for participating and their behaviour towards on-farm tree planting and management. Additional topics covered

farmers' customary tree management practices and information about the on-farm tree planting schemes, such as inputs or incentives provided by the schemes. The respondents were also asked questions about background variables, such as household size, size of farm, and characteristics of cropping systems. In each instance, the owner or actual farmer (male or female) who is involved in the tree planting activity was interviewed. The IBM SPSS Statistic 22 was used for data analysis.

Concerning the tree inventory, data on on-farm trees (both planted and naturally regenerated) were collected through farm surveys. 33 farmers under OCAP (15) and FRCP (18) were randomly selected for data collection. Five different cropping systems were being practiced on the selected farms. The cropping systems were 1) trees only, 2) trees with cocoa (*Theobroma cacao*), 3) trees with cola (*Cola nitida*), 4) trees with food crops, and 5) trees with oil palm (*Elaeis guineensis*). All five systems show intercropping of trees with food crops in the initial years of establishment. Each farm was subdivided into plots depending on the size of the farm. Within each plot, all trees with a diameter at breast height (dbh; 1.3 m above ground) greater than or equal to 5 cm were measured, using diameter tapes, and their species identified. Total height of the trees was also measured.

The volume of individual trees was estimated using the following formula: $V=(\pi(dbh)^2Hx0.5)/40000$; where *V* is volume of tree bole (m^3), *dbh* is diameter at breast height (cm), and *H* is total height of tree (m). A form factor of 0.5 was applied to each tree in order to account for the taper effect of diameter and height measurements on the tree volume (Newbould 1967; Opuni-Frimpong et al. 2013). The volume per hectare was determined by dividing total standing volume with the area of the respective farm or plot size.

4.5 Results

4.5.1 Respondents characteristics

Table 4.2 summarizes attributes of the respondents for the two tree planting schemes: the Oda-Kotoamso Community Agroforestry Project (OCAP) and the Forest Resources Creation Project (FRCP). Chi-square tests were used to determine whether there were significant differences between OCAP and FRCP respondents with respect to origin/ethnicity, age, gender and education. Concerning origin/ethnicity, 18.3% of OCAP respondents were migrant farmers compared to 36.5% of FRCP respondents. This difference was statistically significant (*P = 0.012*). This indicates that migrant farmers show a lower interest in OCAP than in FRCP. A

slight difference in the age categories of the respondents of the two schemes also exists, statistically significant as well (*P = 0.04*). However there are no statistically significant differences in gender (*P = 0.059*) and education level (*P = 0.596*) of the respondents between the two schemes. In addition to farming being the major occupation for the respondents, 32.4% of OCAP and 37.6% of FRCP farmers reported having secondary occupations.

Table 4.2: Overview of characteristics of respondents of Oda-Kotoamso Community Agroforestry Project (OCAP) and Forestry Resources Creation Project (FRCP)

Characteristic		OCAP (N=71) (%)	FRCP (N=85) (%)
Gender	Male	73.2	58.8
	Female	26.8	41.2
Education	Tertiary	5.6	7.1
	Basic/pre-secondary	57.7	55.3
	Secondary	4.2	5.9
	No education	32.5	31.7
Major Occupation	Farming	94.4	89.4
	Others	5.6	10.6
Age	<35 years	11.3	10.6
	35-44 years	31.0	30.6
	≥45 years	57.7	58.8
Origin	Migrant	18.3	36.5
	Native	81.7	63.5
Marital status	Married	80.3	76.5
	Single	1.4	9.4
	Others (divorced/widowed)	18.3	14.1
Average household size	Mean	8	8
(persons)	Minimum	1	1
	maximum	32	20
Farm size (ha)	Mean	5.1	4.5
	Minimum	0.2	0.13
	Maximum	40.0	44.0
Farm size under OCAP and	Mean	1.2	1.6
FRCP	Minimum	0.1	0.1
(ha)	Maximum	8.0	12.0

4.5.2 Motivations for on-farm tree planting and management

On average, the willingness of farmers in the schemes to plant trees is relatively high. 44.3% of the respondent farmers in OCAP and 66.7% in FRCP are willing to invest in on-farm tree planting and management on their own. However, motivation in FRCP seems to be higher than in OCAP. This is because 65% of OCAP farmers indicated that they had lost interest in on-farm tree planting over time, compared to 22% of FRCP farmers, the reasons of which will be dealt with later. To understand farmers' motivations for on-farm tree planting and management, respondents were asked to identify what motivated them. The responses are presented in Table 4.3. Under OCAP, the opportunity existed for farmers to be granted access to new land for their tree planting activities, although under tenant conditions. These farmers were therefore required to enter into benefit-sharing agreements with landowners on the planted trees. Such an arrangement was not found under FRCP, hence FRCP farmers only used their own land in order to engage in on-farm tree planting.

Table 4.3: Factors motivating farmers' intention to plant on-farm trees

Motivation	OCAP (N=71) (%)*	FRCP (N=85) (%)*
Internal factors		
Future income from timber sale	45.1	32.9
Knowledge of environmental issues	16.9	21.2
Investment or property for (grand) children	14.1	20.0
Ownership of timber for personal use	5.6	17.6
External factors		
Access to land for farming	39.4	1.2
Education by initiative team	33.8	60.0
Access to grants/scholarships and inputs for farming	8.5	3.5
Access to market for agricultural produce	4.2	3.5
Influence of peers/friends	2.8	2.4
Access to alternative income/livelihood sources	1.4	8.2

* Percentages are based on multiple responses

Most of the interviewed farmers were motivated by the educational campaign carried out by the two schemes, the financial benefits to be derived from timber sale at maturity, knowledge

of environmental issues and the desire to preserve timber trees on their farms as future investment for their family. Conditions associated with the schemes such as access to farming inputs and opportunities to diversify income sources through alternative livelihood activities are additional motivational factors for some farmers to plant and manage on-farm trees (Table 4.3).

4.5.3 Farmers' objectives for on-farm tree planting and management

Majority of the respondent farmers in both schemes (74% OCAP and 92% FRCP) planted trees on their farms because of financial benefits (Figure 4.3). For OCAP farmers, access to loan facilities, access to farming inputs promised under the scheme and having access to land for farming are additional objectives for on-farm tree planting and management. For FRCP, the objectives of the respondents included using the planted trees as investment for family members in the future (during maturity). Other objectives are access to farming inputs, access to loan facilities and access to alternative livelihood activities provided by the scheme.

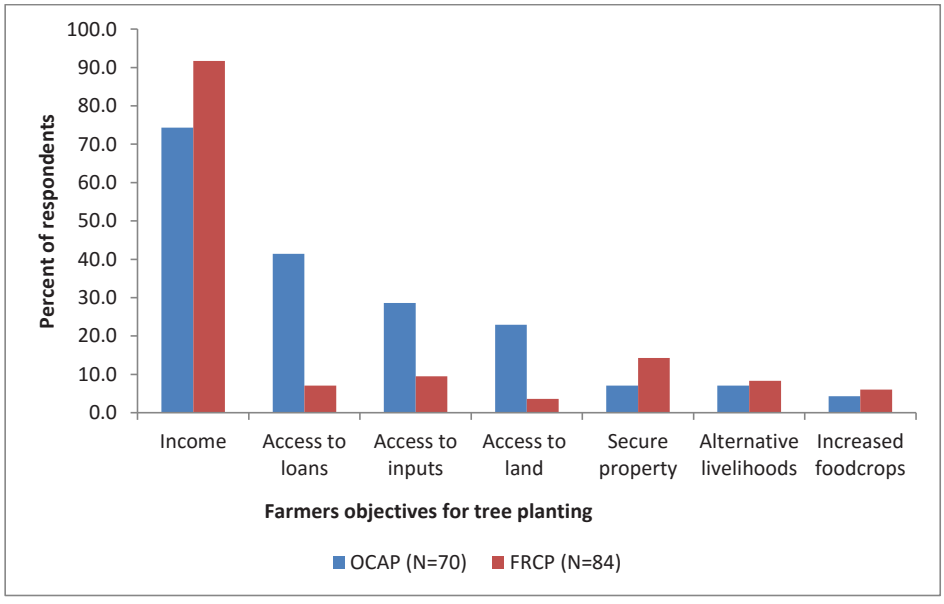

Figure 4.3: Farmers objectives for on-farm tree planting activities

4.5.4 Barriers/constraints to on-farm tree planting by farmers

In order to understand barriers or constraints to tree development on farms, farmers were asked to identify factors that hinder on-farm tree planting and management. Key constraints identified by the farmers were the high financial costs involved in managing the planted trees, insufficient supply of seedlings for beating up (i.e. replacing trees that died shortly after planting) and low knowledge about managing planted trees, e.g. thinning operations (Table 4.4).

In addition, a small group of respondent farmers indicated that insect pests and diseases are affecting the development of their on-farm trees and that they lack the knowledge to address the problem. Another small group of farmers had concerns about the low productivity of their agricultural crops due to poor crop-tree species interaction on their farms. (Table 4.4)

Table 4.4: Factors that hinder on-farm tree planting and management by farmers

Constraining factors	OCAP (N=48) (%)*	FRCP (N=28) (%)*
Internal factors		
Lack of technical knowledge to manage planted trees	18.8	57.1
Lack of knowledge on proper crop-tree matching resulting in low crop productivity	3.4	3.6
External factors		
High financial cost of managing planted trees	91.7	57.1
Lack of sufficient seedlings for replacing dead trees	25.0	7.1
Pest and disease attacks	6.0	3.2

* Percentages are based on multiple response

4.5.5 Volume of on-farm trees

The average standing volume of on-farm trees in the study areas is 51.9 m^3 per ha (45.4 m^3 ha^{-1} for OCAP and 61.2 m^3 ha^{-1} for FRCP). The mean number of on-farm trees in the study area is estimated at 297 trees per ha (Table 4.5). Cropping systems where trees are combined with food crops had the highest mean volume of trees per hectare of approximately 78 m^3 (Figure 4.4). The trees in food cropping systems accounted for 29.5% of the volume of trees in the study areas, with the trees with cocoa cropping system accounting for the least, namely 15.6%. This

is due to the fact that the average number of trees on cocoa farms (68 ha^{-1}) in the study areas was far lower than that of trees in food cropping farm (533 trees ha^{-1}).

Table 4.5: Mean volume (m^3), dbh (cm) and number of trees per hectare for Oda-Kotoamso Community Agroforestry Project (OCAP) and Forest Resources Creation Project (FRCP)

Initiative	Volume per ha		Diameter (dbh)		Number of trees per ha	
	Mean (N)	SD	Mean (n)	SD	Mean (N)	SD
OCAP	45.4 (69)	49.1	16.6 (1370)	9.6	262 (69)	159.1
FRCP	61.2 (48)	42.4	17.9 (2681)	13.6	348 (48)	327.8
Total	51.9 (117)		17.5 (4051)		297 (117)	

* N is number of plots; n is number of trees

4.5.6 Standing volume and farmers' motivations

We now try to link standing volume on farmland to farmers' motivations, although we have to use proxies, since the data to potentially correlate these variables were not collected in all plots of this study. Yet an average of 51.9 m^3 standing tree volume per ha is roughly twice as much as the national average for the off-reserve areas in the semi-deciduous forest zone, to which much of the study sites belong (Appiah 2013). Such seems to indicate that the schemes have generally triggered higher levels of motivation among farmers to plant and manage on-farm trees than in comparable regions in the rest of the country without such schemes. Moreover, the differences in standing volume between OCAP and FRCP can also be linked to farmers' motivations. Firstly, our results show that 65% and 22% of OCAP and FRCP farmers respectively had lost interests in the schemes over time. In addition, 44.3% of this group of OCAP farmers mentioned that they were willing to engage in on-farm tree planting *again* compared to 66.7% of FRCP farmers. Hence, it is likely that participating farmers in OCAP generally showed lower levels of motivation than in FRCP. Secondly, 39.4% of OCAP farmers mentioned that they were motivated to participate in the scheme by the opportunity to have access to land for *farming* rather than for tree planting. All these motivational factors are likely to explain why OCAP had lower number of trees and standing volume per hectare compared to FRCP (Table 4.5). Hence, motivation and standing volume seems positively correlated (although we need to be careful here, given that we only present indirect evidence in the above).

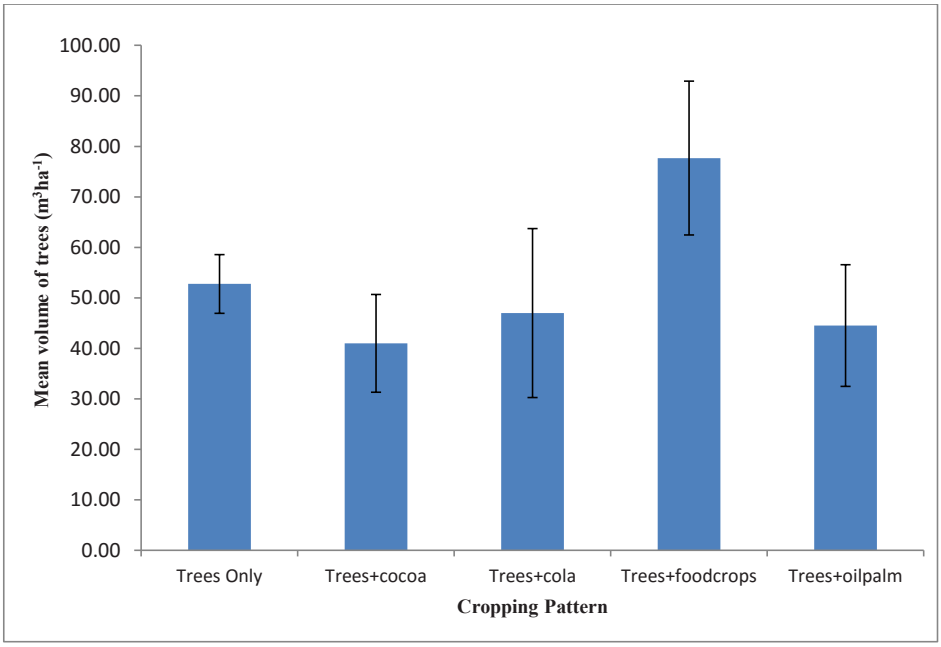

Figure 4.4: Mean standing volume of trees in different cropping system across Oda-Kotoamso Community Agroforestry Project (OCAP) and Forest Resources Creation Project (FRCP). Bars represent standard error of the mean.

4.6 Discussion

4.6.1 Farmers' motivational factors for engaging in on-farm tree planting and management

This study sought to better understand farmers' motivational factors for on-farm tree planting and management. The analysis focuses on important factors that have the potential to encourage activities that increase forest cover in the agricultural landscape of the high forest zone of Ghana. The results of the study suggest that farmers' were motivated to engage in on-farm tree planting and management by the financial benefits, communication and educational campaigns by project teams, knowledge about current environmental issues, access to land, ownership of timber for family use, and access to inputs for farming.

The results indicate that farmers recognize the financial benefits of on-farm tree planting and see it as a worthwhile investment, not only for their personal use but also for that of their

families. With the understanding that farmers have ownership rights to trees they have planted, both OCAP and FRCP farmers were motivated by the opportunity to derive income from the sale of the planted trees. Also, the farmers were motivated by the goal of providing income and services to their families as reflected in the opportunity to use the planted trees as investment that will provide future income and access to wood for their families. Similarly, Zubair and Garforth (2006) found that the willingness of farmers in Pakistan to grow trees on their farms was a function of their attitudes towards the benefits of growing trees. Other studies have also concluded that farmers are motivated to plant trees on farms by economic benefits and by actively pursuing personal and family well-being (Greiner and Gregg 2011, Ndayambaje et al. 2012). Farmers' objectives for engaging in on-farm tree planting is also motivated by becoming owners of the planted trees which may serve as source of livelihoods and inheritance for their children (Insaidoo et al. 2014). Thus the farmers' objectives of gaining economic benefits and providing for the future of their families provide the key motivations that drive farmers' decision making on on-farm tree planting and management.

Yet the economic part does not provide the full picture. For example, farmers' knowledge about current environmental issues also motivated them to engage in on-farm tree planting and management. Many of the interviewed farmers possess adequate knowledge of the environmental benefits of trees on their farm. Such knowledge influenced the farmers' perception and objectives about OCAP and FRCP on-farm tree planting. Our results corroborates with Danquah et al. (2013) who observed that farmers' perception of contemporary issues related to climate change and environmental management explain their decision to maintain remnant forest tree species in agricultural landscapes. Thus, positive perception about environmental issues enhances rural farmers' acceptance of conservation activities (Ansong and Roskaft 2011, Danquah et al. 2013) and on-farm tree planting schemes. Additionally, 39.4% and 60% of OCAP and FRCP farmers respectively said they were motivated by the environmental campaigns carried out by the project teams. Given the farmers' response to these educational interventions, the results show that educating local communities about environmental issues of climate change has the potential to address some of the challenges associated with deforestation and forest degradation, and to increase timber tree stock in agricultural landscapes.

Secure access to land is a major factor for engaging in on-farm tree planting in Africa, including Ghana. Farmers with secure rights to land are more likely to plant trees on farmlands than farmers without (Fortman 1985, Owubah et al. 2001, Oduro et al. 2014b). In our study, we

found that many OCAP farmers were motivated by the opportunity to have access to new (although tenant) land under the initiative for farming. However, it is very likely that uncertainties about future access to the benefits from planted trees have caused migrant farmers to have a lower preference for OCAP than for FRCP, because they do not have full future control of the land on which they farm and/or plant trees. A study that looked at the factors determining on-farm tree planting in rural areas of Rwanda found that gender of the head of the household was a significant predictor variable (Ndayambaje et al. 2012). Men and women have also been shown to have different levels of participation in decision-making and implementation of tree planting and tree management schemes, which in turn affects tree planting behaviour (Meijer et al. 2015b). Several other studies looking at agroforestry adoption have demonstrated that gender is an important factor affecting the uptake of agroforestry practices (Adesina et al. 2000, Phiri et al. 2004, Wambugu et al. 2011). However, in our study, we found no significant difference in gender between OCAP and FRCP farmers.

Our results show that only a small percentage of farmers were motivated by the influence of their peers to engage in on-farm tree planting (Table 4.3). This result is contrary to the general view of several studies that show that tree planting activities of trusted peers are an important source of influence on farmer decision-making regarding on-farm tree planting (Ruseva et al. 2014, Ruseva et al. 2015, Sagor and Becker 2014). For example, Zubair and Garforth (2006) show that the decision to engage in on-farm tree planting is associated with farmers' perceptions of the opinions and suggestions of their peers and the motivation to comply with their approval and disapproval. Thus, Ruseva et al. (2014) and Sagor and Becker (2014) show that information from trusted peers is often more important than advice from experts. However, we found the opposite.

Our findings suggest that incentives in the form of provision of grants, farming inputs, seedlings, capacity training, and access to markets for agricultural produce are factors that motivate on-farm tree planting in Ghana. These findings are also supported by other studies in Ghana. For example, Appiah et al. (2015) reviewed research findings on reforestation projects in Ghana and showed that provision of incentives motivated local people to participate in the project activities. In addition, incentives resulted in the improvement of the livelihood of local communities by diversification of tree products and agricultural crops such as black pepper (*Piper nigrum*), cola (*Cola nitida*), and by training farmers in alternative livelihood programmes (Appiah et al. 2015). The results have policy implications for current efforts to increase timber supply from agricultural landscapes to bridge the gap between timber demand

and supply. Our results show that policy tools (e.g. technical assistance, supply of free seedlings and other farming inputs) motivate farmers to engage in on-farm tree planting. The implication is that policy approaches that blend characteristics of incentives and capacity building can significantly increase reforestation activities (Ruseva et al. 2015), especially on farmlands.

4.6.2 Barriers/constraints to on-farm tree planting by farmers

Farmers identified high financial costs of managing the planted trees, lack of seedlings for replacing tree seedlings that have died shortly after planting, and their low level of knowledge about managing planted trees, especially about thinning operations, as the main barriers to on-farm tree planting and management in the study area. Majority of OCAP and FRCP farmers explained that planting and management of the planted trees require additional labour that implies additional costs to their regular farming activities. The farmers further explained that after the seedling distribution by the project teams were stopped, farmers who wanted additional seedlings to expand or to upgrade their planted area had to raise or buy the seedlings themselves. These barriers are seen as external factors that can hinder farmers' tree planting behaviour. In Malawi, Meijer et al. (2015) found that farmers explained that tree planting and caring for trees is labour intensive, and because of the many other responsibilities around the farm and the house, it was found that tree planting was not always prioritized.

About 19% and 57% of OCAP and FRCP farmers respectively mentioned that their lack of knowledge on proper techniques in managing the planted trees on farms constitute a barrier to the development of planted trees on their farms. The farmers explained that they lack the proper technique to do pruning and thinning operations and that they end up damaging the trees in their attempt to carry out these operations. Pest and disease attacks and the negative impact of some species on agricultural crops productivity were also mentioned by the farmers as barriers to on-farm tree planting. This observation has been noted in similar studies in Pakistan where farmers recognized that trees on farms can cause hindrance in performing agricultural operations, shade annual crops (thereby reducing yields) and harbour insects, pests and diseases that ultimately damage crops (Zubair and Garforth 2006).

4.6.3 On-farm tree volume

The average standing volume of on-farm trees in the study area is 51.9 m^3 per ha (45.4 m^3 ha^{-1} for OCAP and 61.2 m^3 ha^{-1} for FRCP). As already noted in the above, this volume is almost double the national means for the off-reserve areas in the semi-deciduous forest to which much of the study sites belong (Appiah 2013). Hence, it is likely that farmers' motivation and objectives enhance standing volume of on-farm trees in the study area. Trees with food crops had the highest mean volume of trees per hectare, while trees with cocoa cropping systems accounted for the least . However, this observation is contrary to what Gelens et al. (2010) noted, that cocoa farms in the moist semi-deciduous forest type have higher number of trees than food crop farms. However, several studies in Ghana have shown that there is a substantial stock of trees in *both* food crops and cocoa cropping systems (Inkoom 1999, Treue 2001, Adam et al. 2007, Acheampong and Marfo 2009, Gelens et al. 2010). This implies that a substantial proportion of Ghana's timber demands could be met from cocoa and food crop farms alike, at least if the resources in these production systems are managed well. FAO (2009) also reports that trees outside forests, especially on farms and in other wooded land, are becoming increasingly important in terms of productive and protective functions.

4.6.4 Limitations

The study exhibits some limitations, though. First, our theoretical model slightly changed while doing field research. Hence, theoretical model, data collection and data analysis did not fully converge right from the onset of the study. Nevertheless we tried to make model, data and analysis as consistent as possible during the research process. Second, we did not follow an experimental design, so only participants in OCAP and FRCP schemes were involved in this study. Third, we were also not able to measure the standing volume of on-farm trees of all respondents. This made the retrieving of correlation among farmers' motivations and standing volume rather difficult, but we used proxies to analyze the linkage between farmers' motivation and the volume of trees on their farms. Fourth, the risk of participation bias exists. The study focused on farmers who had already engaged in on-farm tree planting so the risk of respondent farmers having the tendency to impress the research team by exaggerating their positive views towards on-farm tree planting does indeed exist.

4.7 Conclusions

The study sought to identify farmers' motivation for engaging in on-farm tree planting and management through the use of a socio-psychological model. It identified both internal and external factors to the farmer that could potentially increase timber supply from agricultural landscapes in Ghana. Trees on farms are increasingly being recognised as having great potential to provide alternative income options for farmers and local communities. The strengthening of sustainable agricultural systems with the inclusion of timber trees is therefore seen as a way of developing long-term diversified production systems (food and timber) for local as well as export markets.

Farmers in the studied communities recognize the benefits of on-farm tree planting and see it as a worthwhile investment and therefore have planted trees on their own land or land given under the tree planting scheme. Overall, their motivation to plant and manage trees is relatively high, although differences among schemes and groups of farmers exist. But on-farm tree planting is constrained by high financial costs, lack of sufficient seedlings and low levels of knowledge on proper techniques in managing planted trees in agricultural production systems. Hence, the barriers identified by the farmers include both internal and external factors.

Our results demonstrate that farmers' motivations and objectives towards on-farm tree planting are likely to lead to more planted trees on farms. The average standing volume of on-farm trees in the study areas is substantially higher than in comparable regions in the rest of the country. Incentives in the form of provision of grants, farming inputs, seedlings, capacity building, and access to markets for agricultural produce are factors that motivate on-farm tree planting and management in Ghana. However, the main anticipated benefit from on-farm tree planting for most Ghanaian farmers is to secure income. This suggests that providing farmers with more incentives could further increase trees stock on farms because of the anticipated financial benefits to be derived from it in the (near) future. This observation definitely has policy implications for current efforts in Ghana to increase timber supply from agricultural landscapes in order to bridge the gap between timber demand and supply. Our results particularly indicate that technical assistance, supply of free seedlings and other farming inputs motivate farmers to engage in on-farm tree planting and management. Thus farmers would plant and manage on-farm trees if the financial benefits are more attractive.

Chapter 5

Tracing forest resource development in Ghana through forest transition pathways

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Abstract

Tropical deforestation is a serious environmental and economic problem that has become a global issue due to climate change and biodiversity loss. Reducing tropical deforestation is seen as national and international priority, given its impacts on carbon emissions, biodiversity and rural livelihoods. Some developing countries have achieved a forest transition: a shift from net deforestation to net reforestation, whereby a few generic pathways have been identified. Such pathways usually depend on the social, economic, ecological and political contexts of a country. A better understanding of trends related to the pathways at the country level is necessary to identify which factors drive forest transition. This paper analyzes forest resources development trends in Ghana by focusing on forest transition pathways and discussing the implications for a forest transition in the country. The analysis indicates that there is currently no strong force toward a forest transition through any of the generic pathways. Existing trends are either too small-scale or too ineffective. To accelerate a forest transition in Ghana, policy and management options should target measures that reduce current degradation of closed natural forests, increase the area and productivity of commercial forest plantations, promote sustainable forest management, and support and encourage forest conservation and integration of trees into farming systems.

Keywords: Ghana, Deforestation, Forest plantation, Reforestation

5.1 Introduction

Tropical deforestation is a serious environmental and economic problem that has become an issue of global concern due to climate change and loss of biodiversity. Deforestation affects economic activity and threatens the livelihood and cultural integrity of forest-dependent people at the local level (Culas 2007). With an annual deforestation rate of 0.5%, Africa has the second highest deforestation rate in the world (FAO 2010a). A recent estimate of Ghana's deforestation rate is 135,395 ha annually, resulting in a dramatic decrease in the forest cover from approximately 7.5 million ha in 1990 to 4.9 million ha in 2010 (FAO 2010b), and an annual loss of about US$134 million gross revenue (Damnyag et al. 2011, FAO 2010a).

The rapid loss in forest cover appears to have consequences for the climate system in Ghana. The country is already experiencing an increase in extreme weather conditions, with more frequent incidences and longer periods of drought, flooding, and lowering of water levels, particularly in the Volta River, which provides about 80% of the national electricity supply (Cameron 2011, MoFA 2007, World Bank 2010). Major concerns in Ghana arising from loss of forest cover and climate change include severe impacts on land use, biodiversity and soil fertility loss and land degradation (Bamfo 2008, Cameron 2011, Damnyag 2012). Reducing tropical deforestation is thus a national and international priority, given its impacts on carbon emissions, biodiversity and livelihoods (Culas 2007, Meyfroidt et al. 2010).

While deforestation continues to be a major concern globally, some tropical developing countries have experienced forest transitions: a shift from net deforestation to net reforestation (FAO 2010c, Mather 1992, Meyfroidt and Lambin 2011, Rudel et al. 2005). Forest transitions result from multiple trends: natural forest regeneration, forest plantation establishment and adoption of agroforestry systems that are combined in various ways through time and space (Meyfroidt and Lambin 2011). In the literature, a forest transition is at times presented as a quasi-deterministic process that implies that the long-term development of forest-cover change in a country is expected to follow a trajectory of decline and regrowth (Figure 5.1), which can only be delayed or accelerated by policies (Barbier et al. 2010, Meyfroidt and Lambin 2011). So far, considerable attention has been directed toward the analysis of forest transitions, documenting the restoration of degraded forests and the emergence of sustainable forest

exploitation practices, while assessing forces that drive these transitions (McCay and Rudel 2012).

5.2 Forest transition theory (FTT) and its pathways

Forest transition (FT), defined as a shift from a shrinking to an expanding forest area in a country or region, provides a framework for understanding scenarios in which a country or region shifts from a decreasing forest cover to an increasing forest cover over time (Farley 2007, 2010, Mather 1992, Mather and Needle 1998, Meyfroidt and Lambin 2011). Initially, deforestation is rapid and the forest area declines as a consequence of factors related to population growth, agricultural expansion and demand for timber and wood fuel. But once the country or region becomes more socio- economically developed, modernized and industrialized, forests become more valuable and political demand for forest conservation stimulates forest protection, regeneration, and plantation establishment. At the same time, the pressure for more agricultural lands may become less as a result of increased efficiency of agricultural productivity. Consequently, the forest area may enter the so-called recovery phase (Figure 5.1).

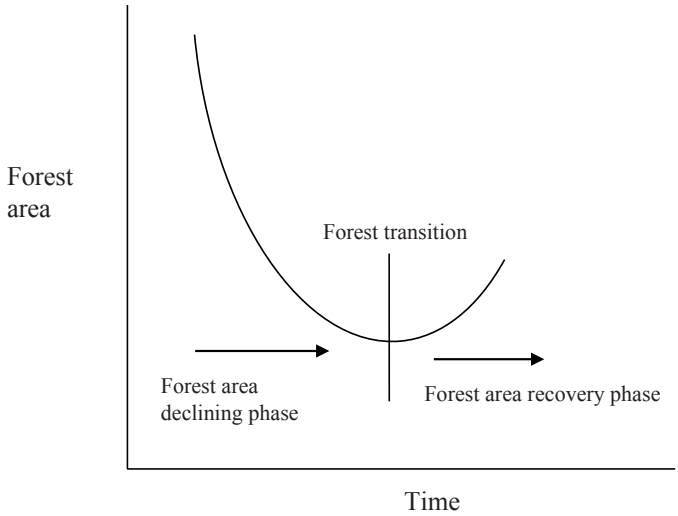

Figure 5.1: Phases of the forest transition
(Source: Barbier et al. 2010)

The exact mechanisms that operate in forest transitions vary across locations (Perz 2007). Five pathways of forest transition have been suggested (Lambin and Meyfroidt 2010, Rudel et al. 2005): the economic development; forest scarcity; globalization; state forest policy; and smallholder, tree-based land use intensification pathways. In the economic development pathway, it is hypothesized that economic development creates enough non-farm jobs to cause farmers to abandon their land, thereby inducing forest regeneration, and conversion of marginal lands into forests. Industrialization and the growth of the service economy drive labor force from agriculture in rural areas to other economic sectors in urban areas. Agricultural intensification and productivity increase food production on most suitable areas resulting in depopulation and agricultural decline in the least suitable areas. Thus, labor scarcity rather than forest products scarcity drives conversion to forests (Klooster 2003, Kull et al. 2007, Meyfroidt and Lambin 2011, Rudel et al. 2005). The economic development pathway has been commonly observed in developed countries, but some examples are also found among developing countries, such as Vietnam and Mexico (Farley 2007, Lambin and Meyfroidt 2010, Meyfroidt and Lambin 2011, Turner II 2010).

In the forest scarcity pathway, an increase in forest area occurs in response to the adverse impacts of deforestation and/or a decline in the flow of services provided to society by forest ecosystem. The scarcity of forest products increases their value and prompts governments and land owners to plant trees or establish afforestation programmes. Governments are also induced to implement policies to restrict forest exploitation, create protected areas, promote more sustainable management practices and fuel wood substitution, and invest in forestry research and reforestation programmes (Lambin and Meyfroidt 2010, Meyfroidt and Lambin 2011, Rudel et al. 2005).

Rudel (2002) conceptualized globalization as the internationalization of markets. Thus, the globalization pathway occurs as national economies become increasingly integrated into and influenced by international markets and ideologies. The globalization pathway can manifest itself in a variety of ways: through the export of forest products from rural areas or through the implementation of international environmental agreements related to forestry practices. Globalization could also be manifested through rural poor seeking employment outside their region or country and sending back remittances to marginal rural areas, which can relieve pressure from the land. International environmental non-governmental organizations (NGOs)

may also globalize forest management practices (Farley 2010, Hecht et al. 2006, Lambin and Meyfroidt 2010).

In the state forest policy pathway, also referred to as "government-led path" by Bae et al. (2012), national forest policies, motivated by factors outside and within the forestry sector, play a central role in promoting forest transition. While the policies may be in part triggered by elements of the forest scarcity pathway, the state forest policy pathway differs by its underlying motivations, which are often factors outside the forestry sector, such as willingness to modernize the economy, integrate marginal social groups, promote tourism or foreign investment by greening the image of the country, assert control over lands through creation of natural reserves or managed state forests (Lambin and Meyfroidt 2010).

Table 5.1: Summary characteristics of forest transition pathways

FT pathway	Characteristics/explanations
Economic development	- service sector growth and creation of enough non-farm jobs in urban areas - agricultural intensification on most productive land - marginal land abandonment - labour scarcity drives reforestation
Forest scarcity	- existing or anticipated scarcity raises value of forest products resulting in investments in tree planting, forest management and restriction on exploitation
Globalization	- national economy integrated into global markets for commodities, labour, capital, and tourism - local manifestation of international conservation and forest management ideologies - sending of remittances to marginal rural areas to relieve pressure on land
State forest policy	- national forest policies influenced often by factors outside forest sector, e.g. willingness to modernize economy, greening image of country; integration of marginal groups; tree planting not motivated by scarcity of forest products
Smallholder, tree-based land use intensification	- involves expansion of woodlots, agroforestry systems and secondary succession; rural communities restore degraded lands and their ecosystem services - decreasing vulnerability to economic and environmental shocks, and to generate livelihoods through economic and ecological diversification - forests have different composition and structure from primary forests - associated with fragmented landscapes

Source: Lambin and Meyfroidt 2010, Rudel et al. 2005

Increase in forest cover through the smallholder, tree-based land use intensification pathway is associated with the expansion of wood lots and agroforestry systems and secondary succession on abandoned fallows that are sometimes enriched with timber species, usually at the forest margins. This pathway is not associated with a decline in rural population or in agriculture. The motivation of smallholders may be to decrease their vulnerability to economic and ecological shocks and guarantee their livelihood through ecological and economic diversification. This pathway is considered to be more likely to include indigenous species (although different in composition and structure than primary forests), to have conservation value, to make substantive contributions to the provision of ecosystem services, and is associated with fragmented landscapes (Lambin and Meyfroidt 2010).

Given that the country context can strongly influence which factors are most important in driving forest transitions (Farley 2010, Klooster 2003), a better understanding of trends relating to the pathways at the country level is needed. The pathway that ultimately drives forest transition (Table 5.1) has important implications for the design and implementation of policies that aim at halting deforestation and ensuring forest recovery. In Ghana, trends suggest processes of rehabilitation and restoration of degraded lands, which seem consistent with certain forest transition pathways. Therefore, this paper analyses these trends and discusses the implications for development of forest resources in the country. The insights gained can be valuable for informed policy decision-making. The paper should also provide inputs to support ongoing national policy debates to halt deforestation, particularly Ghana's policy efforts on REDD+ (Reducing Emissions from Deforestation and forest Degradation, enhancing forest carbon stocks, sustainable forest management and conservation of forests).

5.3 Methodology

Data were collected through desk/literature research of government policies and legislation, published and unpublished literature including project reports, and government and other agencies databases (Table 5.2). Additional sources of data were correspondence with key actors in local communities, project implementation agencies and workshop participation. We compiled data about deforestation rates, forest area and cover change and growing stock levels between 1990 and 2010 from the Food and Agriculture Organization of the United Nations (FAO) Global Forest Resources Assessment reports of 2000, 2005 and 2010. The growing stock data were derived from analysis of forest inventory data from 2501 1-ha plots systematically

distributed across Ghana. Additional information was obtained from the 2013 mapping study of Ghana that used wall-to-wall land use and land use change mapping for 1990, 2000 and 2010.

Data on area of plantations established, management regimes and challenges were obtained from the annual reports of the National Forest Plantation Development Programme. We also drew on literature and analysis of legislation for plantation establishment targets and the intended motivations or purposes for the different forest plantation programmes. These were obtained from government policy and programmes documents related to forest plantation development at the Ministry of Lands and Natural Resources, the Forestry Commission (FC) and the Forestry Research Institute of Ghana (FORIG), where much documentation and expertise on plantation establishment in Ghana are located.

Further data collection included reviewing several reports published by non-governmental organizations (NGOs) that have worked with local communities in tree planting initiatives in Ghana. In addition, five open discussions were held with individual farmers who have planted trees on farms, representatives of NGOs involved in tree planting and forest/plantation managers, to better understand the history, background and development of the tree planting initiatives. Data were also collected at a workshop in Kumasi, Ghana on "Forest plantation development in Ghana: strategies, challenges and way forward" in June 2010. This was part of a series of workshops being jointly organised by FC and FORIG and included participants from government and NGOs, research and academia, private investors in forest plantations in Ghana and members of local communities.

We compiled data on trends relating to population, employment, remittances, and GDP from the Ghana Statistical Services and the World Bank databases. Changes in the area of agricultural lands from 1990 to 2010 were obtained from the Ministry of Food and Agriculture database. These were all supplemented with additional information from literature. Data on wood products exports from Ghana between 1999 and 2010 were extracted from annual reports on export of wood products that are published by the Timber Industry Development Division (TIDD) of the Forestry Commission of Ghana.

The data from the different data sources were first summarized and categorized using the characteristics of the five FT pathways. Since FT has not yet taken place in Ghana, the FT pathways were used as guidelines for the categorization, but an open approach was also adopted to determine if a different pathway was emerging. Second, we examined all the data to determine the extent to which they reflect the characteristics of the different FT pathways.

Table 5.2: Data sources and variables/measures

Variable/Measure	Sources
Government policies/programmes on plantations	- Reports and documents from Ministry of Lands and Natural Resources, Forestry Commission, Forestry Research Institute of Ghana - Workshop participation
Extent of forest plantations, 2002-2008	- Annual reports of National Forest Plantation Development Programme, Forestry Commission.
Forest area and cover change, 1990-2010	- FAO's Global Forest Resources Assessments reports
Growing stock, 1990-2010	- FAO's Global Forest Resources Assessments (main and country reports)
Population, 1980-2010	- Ghana Statistical Services database
Wood products exports, 1999-2010	- Reports of Timber Industry Development Division, Forestry Commission
Employment and remittances	- Ghana Statistical Services, other published literature (e.g. GSS, 2008)
GDP per capita and sectors contributions to GDP	- Ghana Statistical Services database - Word Bank website
Tree planting, smallholder plantations, trees on farms/agroforests, community reforestations	- Project documents and newsletters, plantation annual reports, published literature (e.g. Appiah 2001, Blay et al. 2008), workshop participation - SADA development strategy (2010-2030)
Area of agricultural land area, 1990-2010	- Ministry of Food and Agriculture database - Other reports and documents (e.g. Braimoh 2009, MOFA 2010)
Other government policies (restrictions of forest exploitations, woodfuel substitution, etc)	- Forestry Commission, Energy Commission, published literature - Other documents (e.g. Biscoff et al. 2012, UNDP 2004)

5.4 Results

5.4.1 Trends in economic development pathway

Trends in Ghana that relates to the economic development pathway are increase in gross domestic product (GDP) per capita, increase in urban population and increase in service sector's contribution to GDP. Ghana's GDP per capita increased from US$398 in 1990 to US$1,319 in 2010. The percentage of urban population has increased from about 36% in 1990 to over 50% in 2010 (Table 5.3). Currently the service sector contributes about 50% of GDP, with the agricultural sector contributing 28% (Table 5.4). Employment is mainly agricultural-based, with the agricultural sector employing approximately 56% of the working population. The

industry and service sectors employ 15% and 29%, respectively. Oil production at the country's offshore Jubilee field started in December 2010 and it is expected to boost economic growth, especially in the industry and service sectors.

Table 5.3: Trends in total and urban population (1980-2010)

Year	Total population (1,000)	Urban population (1,000)	% urban population (of total population)
1980	10,922.7	7,514.8	31.2
1990	14,793.4	9,408.6	36.4
2000	19,165.5	10,732.7	44.0
2005	21,639.8	11,296.0	47.8
2010	24,658.8	11,830.0	51.5

Source: GSS 2012b

Agricultural land is mostly not abandoned in rural areas and labour is not scarce. The area under agriculture has increased since 1990 from 55% to 69% of Ghana's land area in 2010. Labour, to carry out farming activities is an important input in agricultural production in rural Ghana. Unemployment is more prevalent in urban areas than rural areas. Almost the entire rural labour force is engaged in agricultural activities. Very few of the rural population find themselves in non-farm activities.

Hence, in Ghana, the economic development pathway is not fulfilled: rural employment is still mainly agricultural, land is not abandoned, labour is not scarce and agricultural land use continues to expand.

Table 5.4: Trends in GDP per capita and percentage distribution of GDP by sector (2000-2010)

Sector	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
GDP per capita (US$)	260	270	306	370	420	495	920	1085	1226	1090	1319
Agriculture (%)	39.6	39.6	39.5	39.8	40.2	39.5	30.4	29.1	31.0	31.6	27.8
Industry (%)	27.8	27.4	27.5	27.4	27.2	27.6	20.8	20.7	20.4	18.9	21.8
Services (%)	32.6	33.0	33.0	32.8	32.6	32.9	48.8	50.2	48.6	49.5	50.4

GSS 2010, 2012a, World Bank 2012.

5.4.2 Trends relating to forest scarcity pathway

Ghana's high forest cover has decreased from about 7.5 million ha in 1990 to about 4.9 million in 2010, with a deforestation rate of approximately 2% per year (FAO 2010b). The annual change of forests in Ghana between 1990-2000 and 2000-2010 is about -135,000 ha and -

115,000 ha respectively. In addition, growing stock has been declining, from an estimated 423 million m^3 in 1990 to 291 million m^3 in 2010. In 2001, the government initiated a national forest plantation development programme (NFPDP) in response to the rapid decline of forest resources and anticipated scarcity of forest products. The objectives of the plantation programme included restoration of forest cover in degraded forest reserves; and sustainable development of timber resource base to satisfy future demand for industrial timber. The NFPDP had a planting target of 20,000 ha per annum. The NFPDP has been implemented under different schemes including the Modified Taungya system (MTS), large scale private commercial plantations development, and the government expanded plantation programme. Between 2002 and 2010, about 149,260 ha of plantations had been established under the government initiated NFPDP. These plantations are however poorly maintained and about 15% of them is estimated to have been destroyed through fires.

Under the MTS, the government (Forestry Commission) allows farmers to combine tree planting and maintenance with the cultivation of food crops in degraded forest reserves until tree canopy closure. The farmers maintain 100% share of the food crops and a 40% share from the timber returns. The government has a 40% share while landowners and communities have a 15% and 5% share, respectively. About 54% of the total area of plantations established under the NFPDP between 2002-2010 has been through the MTS (about 80,700 ha). Under the large scale private commercial plantations scheme, the government releases degraded forest reserve lands to private entities with reforestation plans to establish large scale commercial plantations. The private investor earns 90% of the total proceeds from the plantation while the landowner, government and community earn 6%, 2% and 2% respectively. More than 23,360 ha of forest plantations have been established through this scheme. In 2010, the government of Ghana launched an expanded plantation programme under the NFPDP, to include degraded areas outside forest reserves with a focus on commercial timber plantation. A total of 14,186 ha of plantations were established by the end of 2010. The expanded programme has an annual target of planting 10,000 ha as well as maintaining existing plantations over a five-year period (FC 2013, FSD-FC 2013).

The continuous decline of forest resources caused the government to introduce policies to restrict forest exploitation and to promote sustainable forest management practices. In 1995, the government introduced “Interim Control Measures” to control the exploitation and transport of trees in areas outside forest reserves. In 1996, an export levy (10-15%) was imposed on the free on board (fob) price of air-dried lumber of specific species. In early 2001 an additional levy of

1-10% fob value was imposed on all exports of primary and secondary wood products (i.e. lumber, curls, veneers and panel boards). These measures were intended to slow down the depletion rate of species in high demand, and were also expected to reduce the exploitation rate of the other species. In addition, the government instituted a restriction on the exploitation of heavily exploited timber species through the use of reduced yield formula in calculating the annual allowable cut. In 1997, the Timber Resources Management Act (Act 547) and its accompanying Timber Resources Management Regulations, 1998 (L.I. 1649), were enacted to prohibit chainsaw lumbering to control the rate of timber exploitation. More recently in 2014, there has been a ban on the felling, harvesting and exportation of rosewood (*Pterocarpus erinaceus*) in the country.

In 1990, the government of Ghana launched the national liquefied petroleum gas (LPG) programme under which Tema Oil Refinery was to be modernized for the implementation of intensive LPG campaign. This programme was to encourage inter-fuel substitution in the national energy economy, away from charcoal and other wood fuels to reduce the rate of forest destruction and to protect the environment. In line with the programme, the price of LPG was to be subsidized relative to petrol and diesel. The proportion of households in Ghana using LPG fuels increased from 4% in 1998 to about 10% in 2006.

In conclusion, in Ghana we can find trends that relate to the forest scarcity pathway. Reforestation activities are undertaken in response to the rapid decline and scarcity of forest resources, especially timber. The government has also enacted policies to restrict forest exploitation, to ban the exportation of certain timber species, to promote sustainable management practices and to promote fuel wood substitution.

5.4.3 Trends relating to globalization pathway

Trends that relate to the globalization pathway can be categorized into: international trade and agreements; international support for reforestation projects; and remittances. The growing emphasis in Ghana on forest law enforcement and governance (e.g. EU FLEGT initiative and the associated Voluntary Partnership Agreement) highlights the country's commitment to sustainable management of forests. Recent trends in Ghana's wood products export indicate the international nature of trade in wood products from Ghana (Figure 5.2). Also, a number of timber companies, NGOs, and other institutions have received international support to engage in tree plantations, as well as reforestation and rehabilitation programmes across the country (Table 5.5).

More recently, the global climate policy is creating new markets for carbon credits that can be produced through plantation establishment. As a result of this the company FORM Ghana Ltd has been undertaking projects that seek to establish over 14,000 ha of plantation for timber and non-timber forest products (FSD-FC, 2013). The plantation is intended to be certified according to the Forest Stewardship Council standard for sustainable forest management and carbon credits.

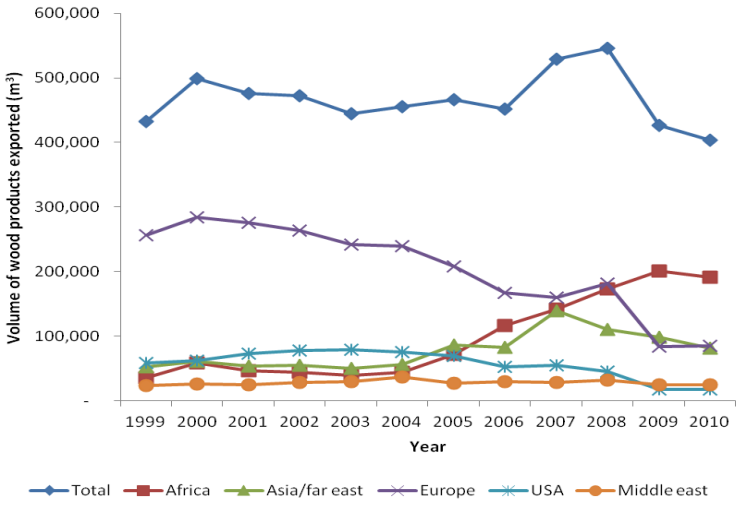

Figure 5.2: Total volume and major markets of wood products export (1999 to 2010)
(Source: Wood product export reports at Timber Industry Development Division, Forestry Commission, Ghana)

Remittances constitute less than 10% of total household income in Ghana. Remittances constitute 11% and 6% of urban and rural income, respectively. Therefore, in Ghana trends relating to the globalization pathway can be seen in export of wood products, commitments to international agreements and international support for reforestation activities.

Table 5.5: Examples of international support for reforestation activities in Ghana

International organization	Activity	Type of support	Outputs	Location
International Tropical Timber Organization (ITTO)	Projects on community rehabilitation and management of degraded forest sites	Funding, technical assistance	Over 250 ha of degraded forest areas rehabilitated	High forest zone (HFZ): 3 regions in southern Ghana.
ITTO	Rehabilitation of degraded forest lands	Funding, technical assistance	1,350 ha of degraded lands rehabilitated in the Volta region of Ghana	HFZ
Ricerca e Cooperazione (Italian NGO)	Tree planting on farmlands under an European Union funded 'forest resources creation project' with local communities	Technical advice, training, seedlings, equipment, other farming inputs	Formation of tree-grower associations in communities, over 1,000 farmers in 60 communities plant trees on farms, over 1,500 ha of farms planted with trees	HFZ
International Institute for Tropical Agriculture	Sustainable tree crop programme	Training of farmers on timber tree planting and management in cocoa farms	More than 33,000 ha of cocoa farms planted with timber trees	HFZ

5.4.4 Trends relating to state forest policy pathway

The 2012 Ghana Forest and Wildlife Policy promotes tree planting and forest management to increase awareness and understanding of the role of trees, forest and wildlife and the importance of conservation. The policy also supports tree planting for environmental improvement including peri-urban green-belts, riparian buffer zones, shade trees in public parks, and erosion control on hilly slopes. The Government has established the Savanna Accelerated Development Authority (SADA) to coordinate a long term comprehensive development strategy (2010-2030) for the northern savanna ecological zone. The SADA initiative is part of government's strategies to bridge the increasing development gap between the northern savanna and the rest of the country. Through SADA, the government launched a 5-year afforestation project aimed at encouraging tree planting to green the SADA zone. The project sought to plant and maintain an initial five million seedlings of assorted trees in 2012-2013. Using the vision of a **"**Forested & Green North by 2030**"**, the strategy stimulates economic growth and sustainable

development. This is done by ensuring that small-holder families and poor farmers develop a long-term stake in agriculture by inter-cropping with economic tree species.

Hence, the state forest policy trends in Ghana include policies on urban greening as well as integration and development of marginal savanna regions of the country.

5.4.5 Trends relating to smallholder, tree-based land use intensification pathway

In Ghana, local communities involvement in tree planting on farms (agroforestry system) have been part of the process of addressing concerns over soil erosion, and poor soil fertility. By the end of 2003, more than 30,000 people were engaged in smallholder tree planting on farmlands, and an estimated 10,000 ha of farmlands were planted with trees. By 2010, there were more than 37,500 ha of cocoa farms planted with trees in over 108 farming communities, reflecting farmers' efforts to increase trees across the cocoa landscape to enhance economic gains, improve agronomic productivity and contribute to biodiversity conservation. Thus, the trends relating to this pathway in Ghana involve tree establishment in the agricultural landscape either alone or in combination with crops.

5.5 Discussion

5.5.1 Contribution of trends in Ghana to forest transition theory and its pathways

A summary of key trends and existing/emerging conditions in Ghana relating to various FT pathways is presented in Table 5.6. The results show that Ghana lost about 33.7% of its closed forest cover (about 2.5 million ha) between 1990 and 2010. The average annual reforestation rate (i.e. increase in forest cover through plantations) between 2000 and 2010 constitute only about 13% of the annual change of forest cover over the same period, estimated at about 115,000 ha. While the country is not undergoing an overall FT, the trends indicate the existence/emergence of conditions that begin to mimic some pathways, as hypothesized by Rudel et al. (2005) and Lambin and Meyfroidt (2010). For example, the smallholder, tree-based land use intensification pathway is associated with tree establishment in agroforestry systems. These tree-based land use systems

usually include indigenous species but they do not have the same composition and structure as primary forests and are associated with fragmented landscapes (Lambin and Meyfroidt 2010). In Ghana, more than 100 local communities in cocoa growing areas of the high forest zone have actively planted indigenous trees in over 37,500 ha of cocoa farms. In addition, the almost 150,000 ha of forest plantations established has mainly been in response to the scarcity of forest products, especially timber. These numbers show that the smallholder tree-based land use intensification system and forest scarcity have the potential to become relevant pathways of forest transition in Ghana.

However, according to the FT definition, pathways toward forest transition will only work when they pass a certain threshold such that there is a shift from net deforestation to net reforestation, usually resulting from multiple trends. In Ghana, the trends that contribute to the development of forests are either too small-scale or too ineffective yet to initiate a full scale forest transition. Currently, there is no strong force toward a FT in the country. Ghana's situation may show consistency with the conclusion that FTs are contingent upon the local socioeconomic, ecological and political contexts of a country (Bae et al. 2012, Meyfroidt and Lambin 2011); and that a few generic pathways of FT can be identified (Meyfroidt and Lambin 2011).

Additionally, Ghana's situation illustrates the difficulty associated with categorizing trends into one of the generic FT pathways. For instance, the government implements specific policies under national plantation programmes that respond to both scarcity of forest resources and tree planting for urban greening. Hence, it is difficult to link forest cover trends under national plantation programmes to just one specific FT pathway since the trends tend to overlap among different FT pathways such as state forest policy and forest scarcity. Yet the notion of different FT pathways suggests that trends that lead to FT may be expected to be linked to one of the different pathways proposed by Lambin and Meyfroidt (2010).

Furthermore, the economic development pathway predicts labor scarcity, land abandonment and creation of enough non-farm jobs, but the results in Ghana shows that the government is rather using plantation programmes as an opportunity to achieve economic development. The National Forest Plantation Development Programme (NFPDP) is designed to reduce rural poverty and promote economic development by offering job opportunities to local communities and to increase food production through the use of agroforestry technology. The case in Ghana is similar to the example of the

Ecuadorian Andes where afforestation was used to promote economic development rather than as a consequence of it (Farley 2007). This questions some of the underlying assumptions of the different FT pathways with respect to the economic development pathway. The results suggest that the different pathways leading to FT merit more attention, and clearly supports the hypothesis of Mather (2007), when he analyzed the FT in China, India and Vietnam, that there are other undefined pathways of FT.

Table 5.6: Summary of key trends and existing conditions in Ghana relating to FT pathways

FT pathway	Trends	Spatial level observed
Economic development	- GDP per capita has increased - Increase in service sector contribution of 50% to GDP compared to 28% by agricultural sector - Percentage urban population has increased - High unemployment in urban areas - Employment still mainly agricultural based (56%) - Rural land is not abandoned and labour is not scarce	Country
Forest scarcity	- Rapid decline of forest area - Government initiates and invests in forest plantation development in response to scarcity of forest resources - Government institutes yield formula, export levy and other restrictions to control timber exploitation; launches wood fuel substitution programme	Country HFZ, SZ Country
Globalization	- Increasing international organizations involvement in reforestation projects - Commitments to international trade agreements - Economy integrated into global markets for products - Emerging carbon credits market opportunities - Low remittances	HFZ, SZ Country HFZ/SZ Country
State forest policy	- Government policies promote urban greening - Government agency established to integrate and develop marginal savanna regions of country - Government promotes tree planting as economic development activity in rural areas	Country SZ HFZ/SZ HFZ/SZ
Smallholder, tree-based land use intensification	- Increasing community involvement in smallholder on-farm tree planting - Land retention through use of trees to improve soil fertility - Increased use of indigenous tree species in tree plantations or woodlots	HFZ/SZ HFZ/SZ HFZ

HFZ-high forest zone; SZ- savanna zone

5.5.2 Trends affecting forest resource development and implications for FT in Ghana

In Ghana, the economic development pathway is currently not a strong force toward FT as employment is still mainly agricultural and agricultural land is mostly not abandoned. Labor is not scarce because labor to carry out farming activities such as land preparation, planting, tending and harvesting, is crucial in agricultural production in rural areas of the country. In comparison, FT in Vietnam resulted from both an increase in natural forested area in the less profitable mountainous regions through land abandonment, and in the more profitable lowland areas through timber plantations. While a perception of ecological degradation contributed to initiate FT in Vietnam, Lambin and Meyfroidt (2010) found that policies that contributed to the FT were embedded in broader socio-economic dynamics; and that active reforestation in the high potential regions was driven by economic development and industrial market demand. In Vietnam, the expansion of timber plantations in the high potential regions accounted for about half of the reforestation in the country. These were mainly driven by policy reforms including allocation of forestlands to households, economic development forces and industrial market demand for timber (Clement and Amezaga 2009, Lambin and Meyfroidt 2010), causing policy makers to prioritize economic development in reforestation programmes with strong government commitment (Lambin and Meyfroidt 2010).

In learning from the Vietnamese example, Ghana can take advantage of the National Forest Plantation Development Programme to accelerate FT in both degraded forest lands and in agricultural lands through appropriate mix of policy reforms, incentive schemes, capital investments and strong government commitment. Forest plantation programmes should focus on meeting industrial demand for timber as well as offering opportunities for poverty reduction, job creation, and economic development for rural communities being promoted by government policies. Such scheme has also been used successfully in the Ecuadorian Andes where afforestation was promoted for economic development and to avoid the projected timber scarcity (Farley 2007). This suggests that the current linkage between FT and economic development under the forest transition theory (FTT) needs further research and clarification. Policies and incentives packages (e.g. land acquisition) for forest plantations development have been part of government strategies

to promote economic development instead of being an outcome of it as hypothesized by FTT. Accordingly, Farley (2007) suggests that the economic development path can be used to describe forest transition, but it can be conceived of as a "reverse economic development path" that seeks rather than responds to economic development.

Moreover, with Ghana's status as an emerging oil economy it is expected that non-farm employment and national income will increase. This offers more prospects for the economic development pathway to influence forest recovery but remains to be seen how this would proceed in the country. While some countries with high per capita GDP have not yet achieved FT (Pfaff and Walker 2010), others (e.g. South Korea) demonstrate that even with low economic development, FT can be achieved. The turnaround point of FT in South Korea occurred in 1963 at a time that the GDP per capita was US$100 (Bae et al. 2012).

In Ghana, trends relating to the forest scarcity pathway are mainly seen in the establishment of forest plantations in response to scarcity of forest products, to increase the resource base, and to restore degraded lands. The policies directly promote plantation establishment by providing financial support (e.g. through the forest plantation development fund), technical support, access to land, benefit-sharing schemes and other incentives to local communities and private investors to engage in plantation establishment. This approach is similar to the one used in the Aglomerados Cotopoxi, S.A. (ACOSA) plantation in Ecuador, which was a response to government policies that directly promoted plantation establishment by providing financial support and technical assistance to rural landowners who would plant and maintain trees (Farley, 2010). The ACOSA plantation is a prominent example of private sector involvement in plantation forestry, with a focus on production of timber and other wood products in Ecuador (Farley 2010). In Ghana, by the end of 2010, commercial private plantation developers had established about 23,260 ha of the over 80,000 ha of degraded forest lands allocated to them. This suggests that Ghana would need to encourage more private sector involvement in the establishment and maintenance of forest plantations.

In addition, the substitution of firewood with fossil fuels was a factor for continuous increase in forest resources in South Korea (Bae et al. 2012). In Ghana, the government's policy to encourage substitution of wood fuel (charcoal and firewood) with liquefied petroleum gas (LPG) has not been very effective in reducing forest loss. Though the proportion of households using LPG has increased in response to government's policy,

consumption by vehicles has been the main contributing factor to the increase in LPG consumption. This is because from 2002 onwards, importation of bi-fuelled vehicles (i.e. vehicles that switch between LPG and gasoline at will) has become common in the country (Biscoff et al. 2012).

Concerning the globalization pathway, labor out-migration and global conservation ideologies were among the factors that contributed to FT in Costa Rica. In 2004, Costa Rica received more than US$329 million in workers' remittances, contributing to the progressive abandonment of pastures and marginal farming areas. In addition, foreign environmental NGOs and bilateral aid donors funded and implemented conservation projects together with their Costa Rican counterparts (Hect et al. 2006, Kull et al. 2007, World Bank 2005). In contrast with Costa Rica, most Ghanaian farmers are not abandoning their farmlands as a result of alternative livelihood or non-farm employment opportunities. Remittances accounts for only 6% of rural income in Ghana, with the rural economy mostly dependent on agriculture. Agricultural land continues to expand and such expansion is actually considered to be a leading driver of deforestation in Ghana. The increase in urban population has also not resulted in rural depopulation that might lead to land abandonment, hence forest regeneration and conversion of marginal lands into forests for FT may not take place as expected under a transition scenario.

Like Costa Rica however, there are foreign environmental NGOs and bilateral aid donors that provide funding to support conservation and reforestation activities in Ghana. Also, the emergence of new markets for carbon credits represents new sources of funding and income for the country, thus potentially contributing to the globalization pathway. Payments for ecosystem services might definitely become a driver of forest resource development and of FT in the country. So far, the majority of the globalization trends are found in the high forest zone, while other trends relating to the increasing open forests are mostly observed in the savanna zone. Potential FT in Ghana is likely to begin in one zone or area of the country and spread to other regions in agreement with the suggestion by Klooster (2003).

In South Korea, the key driver of FT was the government-led reforestation policy that established a comprehensive and strict reforestation plan in 1973. The central government took the lead in the reforestation efforts by developing an effective institutional framework that included changes in policy, rules, and enforcement to prevent further forest degradation, to build fuelwood forests and to plant trees on degraded lands. The South Korean government

campaigned to raise public awareness, repeating that "cutting a tree is a menace and planting a tree is an act of patriotism," in the president's public addresses and in other education and publicity campaigns (Bae et al. 2012). The government mobilized the consistent administrative structure by coordinating the activities of the central government, provincial, and municipal governments as well as individual villages to implement the forestation plans. Local forestry associations and county forestry cooperatives, which were organized in every village, provided the direct and indirect extension services to support the government's forestation policy by offering technical training for rural communities (Bae et al. 2012).

Like South Korea, the government of Ghana (through the Ministry of Lands and Natural Resources and the Forestry Commission) takes the lead in reforestation efforts in the country. Ghana has policies that focus on reforestation of degraded land areas; and through the Savanna Accelerated Development Authority, Ghana launched a 5-year afforestation project that aimed at encouraging tree planting in non-stocked savanna areas. But in contrast to South Korea, government-led reforestation efforts in Ghana have not been successful in achieving FT due to poor management of established plantations, administrative lapses as well as weak cooperation between institutions. Furthermore, Ghana has only recently (in 2013) developed a draft national plantation strategy 2015-2040 for the country that seeks to develop a sustainable forest resource base that will satisfy future demand for industrial timber and enhance environmental quality.

The smallholder tree-based land use intensification pathway is associated with tree cover through agroforestry systems, wind breaks, and woodlots by local communities, usually using native tree species, for conservation or to restore and/or improve the production of ecosystem services (Lambin and Meyfroidt 2010). Farley (2010) reports the use of this pathway to achieve FT in Zuleta, Ecuador. In Zuleta, the provision of ecosystem services played a dominant role in driving plantation establishment. Land retention was an explicit objective of the plantations to prevent encroachment from neighbouring communities as well as to prevent certain uses by community members that are seen as degrading the land (Farley 2010). In Ghana, local communities are involved in tree planting in agroforestry systems. For instance, more than 100 farming communities in the cocoa growing areas of the country actively integrate trees into their cocoa farms to improve cocoa productivity. The challenge is that at the national level, the scale of conscientious on-farm tree planting is marginal or mostly at project level.

5.5.3 Policy and management options for accelerating forest transition in Ghana

In this section we discuss policy and management options that will help accelerate a FT in Ghana. According to PASCO CORPORATION (2013), the trend of an increase of forest land area is stemming from the expansion of open forests, while Ghana's closed forest area is decreasing. This implies that actual deforestation rate may have slowed down but forest degradation is ongoing due to the widening gap between demand and supply of timber in Ghana. Policies to achieve forest transition would, therefore, have to aim at reducing current degradation of closed natural forests as well as include measures to increase the area of and production from forest plantations. Increasing timber supply without decreasing forest area requires investments in the productivity of plantations, as well as in the adoption of sustainable forest management practices in natural forests. The forest transition in India, for example, was a result of increases in tree plantations even though the area of natural forest is still decreasing (FAO 2010a, Meyfroidt and Lambin 2011).

Achieving forest transition, especially through the smallholder tree-based land use intensification pathway requires conservation of indigenous trees through agroforestry systems. One of the major weaknesses of the forest management framework in Ghana has been the lack of an appropriate mechanism to provide incentives for the conservation of indigenous trees in agroforestry farming systems, hence to accelerate a forest transition in Ghana, there is a need for policy reforms and incentive schemes that will encourage and support integration and conservation of native trees in agricultural production systems. Sneath (1998) argues that changes in land ownership regimes and effective governance are a major driver of land use transition in rangelands. Tenure reforms recognizing ownership and use rights for communities and farmers are important considerations for tree conservation and integration into farmlands that have the potential to lead to transition. Farmers must be confident that the rights to trees on their agricultural lands will not be taken away from them, and that there is an acceptable benefit sharing arrangements in place for the trees. In Europe, forest transitions involved privatization of forestland while several cases in Asia were associated with the devolution of land management decisions to villages or communities, even though the state sometimes retained formal ownership of the land (Lambin and Meyfroidt 2010).

For accelerating FT in Ghana, there is the need to intensify the establishment and management of forest plantations: the current rate of forest plantations establishment will have

to be increased in both degraded forest reserves and areas outside forest reserves. In this regard, a clear national reforestation strategy with private sector and local communities' partnership and with strong government commitment to its implementation is necessary. Tree planting campaigns, especially in the savanna zone of Ghana are also more likely to accelerate a forest transition in Ghana due to the availability of large tracts of land for tree planting. In addition, management of the established plantations and appropriate natural forest management practices that reduces the current degradation will need to be pursued. Forest plantations are certainly important in accelerating FT and its role and characterization in the FTT may need to be re-examined since forest cover trends under plantations tend to cut across different FT pathways.

5.6 Conclusions

Rudel et al. (2005) and Lambin and Meyfroidt (2010) proposed five generic pathways of forest transition. In Ghana, trends that partly relate to the five pathways exist. Similar processes are at work in Ghana as in FT countries such as Costa Rica, Ecuador, South Korea and Vietnam, yet with important differences in scale, effectiveness and characteristics of each FT pathway. At this moment forest resource development trends in Ghana, such as reforestation or plantation programmes and local farmers' tree planting initiatives, are usually too small-scale and ineffective. Thus, there is currently no strong force driving an overall forest transition in the country through any of the generic pathways.

The current widening gap between demand and supply of wood, continuous degradation of closed natural forests and the low rate of forest plantation establishment makes a forest transition in Ghana difficult to achieve. However, the analysis of the forest resources development trends demonstrates the potential of rehabilitation and reforestation activities, even under different contexts, for a forest transition in Ghana. Additionally, the emergence of new markets for carbon credits represents new sources of funding and income for the country, and might definitely become a driver of forest resource development and of FT in the country. Policy and management options should target measures that address poverty reduction, reduce current degradation of closed natural forests and increase the area and productivity of commercial forest plantations. Implementation of sustainable forest management practices, intensification of forest plantation establishment, and supporting and encouraging conservation and integration of trees into farming systems will accelerate a forest transition in Ghana.

Chapter 6

General discussion and synthesis

6.1 Introduction

Over the years, policy makers, forest managers, researchers and other key stakeholders have become increasingly aware of the impacts of deforestation and forest degradation on the environment and on livelihoods of people. In Ghana, the government has become concerned about the continuous decline of the resource base and the extent of deforestation and forest degradation. Future developments of forest resources have understandably been questioned due to ongoing deforestation and forest degradation. The main objective of this PhD research was to provide insights into the current status of the forest resource base in Ghana and into its likely and possible future developments. Five research questions were retrieved from the main objective and the main findings are highlighted below.

What are the trends and changes associated with the growing stock in the timber production areas?

Analysis of national forest inventories data indicate that the growing stock in both on- and off-reserve production areas have seriously been declining since 1990. Similarly, between 1990 and 2015, the growing stock volume decreased in Western and Central Africa sub-region as well. But Ghana's average forest growing stock of 40m^3 per ha in 2015 is much lower than the 195 m^3 per ha for the Western and Central Africa sub-region (FAO 2015, Köhl et al. 2015). Timber harvesting records also indicate that in recent decades total timber harvests have mostly been substantially higher than the annual allowable cut. These trends have resulted in an increasing gap between national timber demand and supply, which drives illegal logging. Other trends affecting the growing stock include increasing clearing of forest lands for subsistence farming and the harvesting of fuelwood. In general, current plantation establishment efforts are not sufficient to bridge the gap between demand and supply of timber, partly due to low establishment rates and lack of appropriate management of newly established plantations.

What driving forces account for current trends and future developments of timber resources in Ghana?

The forest governance system and resource demand are the two key driving forces that affect the current trends and future developments of forest resources in the high forest zone of Ghana. Key elements of the governance system that drive the shrinking resource base include insecure

land and tree tenure system, inequitable benefit sharing arrangements, insufficient supply of sawmill lumber to the domestic market due to low timber prices at the domestic market, poor law enforcement and introduction of new cocoa variety into the agricultural landscape of the high forest zone. Under resource demand, rapid population growth, urbanization, increasing disposable income, poverty and increasing demand for timber and energy are the key driving forces affecting the development of forest resources. Other authors agree with the aforementioned driving forces (Angelsen and Kaimowitz 1999, Culas 2007, Kissinger et al. 2012); and others identify additional driving forces as infrastructure extension, agriculture and extraction of wood and woodfuel (Fisher 2010).

What different scenarios can be identified and how will these affect future developments of timber resources in the high forest zone?

Four scenarios were developed: (1) legal forestry scenario with emphasis on improving the resource base to meet high demand; (2) forest degradation, which implies a business-as-usual scenario; (3) forest transition, with emphasis on expanding the resource base in response to environmental concerns; and (4) timber substitution scenario seeking to provide wood substitutes to conserve the resource base. The scenarios provide insights for policy making and strategic planning for forest resource management in Ghana. To ensure a sustainable future for timber resources, policy reform is needed, focusing on land and tree tenure, revenue capture, benefit-sharing arrangements and satisfying the domestic demand for timber. The scenarios can be used by policy makers, forest managers and other stakeholders to evaluate future practice and policy options in order to prepare for different future timber resources developments in the Ghanaian high forest zone.

What factors motivate farmers to engage in on-farm tree planting and management?

Farmers' were motivated to engage in on-farm tree planting and management by the following incentives: financial benefits, educational campaigns by project teams, knowledge about current environmental issues, ownership of timber for family use and access to land, grants, farming inputs, seedlings, capacity building, and market for agricultural produce. Our results corroborates that of Greiner and Gregg (2011), Ndayambaje et al. (2012) and Zubair and Garforth (2006) who found that farmers in Australia, Rwanda and Pakistan were motivated by similar factors. Many farmers considered high financial costs and low knowledge of proper

techniques in managing planted trees in agricultural production system as barriers to the development of tree stock on farms.

To what extent do the current trends of forest resources drive forest transition pathways in Ghana?

Forest transition pathways were used to assess the extent to which forest resources developments trends drive forest recovery in Ghana. We found no strong force toward a forest transition through any of the five generic pathways (economic development; forest scarcity; globalization; state forest policy; and smallholder, tree-based land use intensification). This is because the existing trends are either too small-scale or too ineffective. In order to accelerate a forest transition in Ghana, policy and management options should target measures that reduce current degradation of natural forests, increase the area and productivity of commercial forest plantations, promote sustainable forest management, and support and encourage forest conservation and integration of trees into farming systems.

6.2 Forest resource development situation in Ghana

6.2.1 Key driving forces

In Chapter 3, the forest governance system and resource demand were identified as the two key driving forces affecting current trends and future developments of forest resources (see Table 3.2). Each key driving force consists of different key elements that drive the current trends and future developments of forest resources. The key elements of the governance system and resource demand and how they drive the shrinking resource base are highlighted further in this section.

As the findings of this thesis suggest in Chapters 2, 3 and 5, tree tenure, like benefit sharing, is a key element of the governance system affecting forest resources development in Ghana. Farmers do not have rights to naturally occurring trees that they manage or protect on their farms. Several authors have shown that such insecure tenure does not encourage tree planting and management (Agrawal et al. 2014, Damnyag 2012, Davis et al. 2009). Others argue that farmers experience direct losses in the form of crop damages as a result of timber extraction, and the fact that they are not officially rewarded for their nurture of timber trees constitute key causes of deforestation and forest degradation (Hansen et al. 2009). Secure tenure

and rights to trees in the agricultural landscape is therefore a key requirement for the future development of forest resources. Farmers must feel assured that their rights to trees on agricultural lands will not be taken away in the medium to long term for them to support the development and protection of on-farm timber resources (Chapter 3).

Another key element of the governance system is the unfair benefit sharing arrangement (Chapters 2 and 3). In Ghana, the law allows key stakeholders to receive a share of timber and forest revenues, and the procedure by which the revenues are shared is known as the benefit-sharing arrangement. The existing benefit sharing arrangement allows for some of the forest fees to be paid to traditional authorities and local governments. The Administrator of Stool Lands receives 10% of stool land revenue (stumpage fees and concession rents). The remaining share is to be divided between the District Assemblies: 55%, Traditional Councils: 20% and Stools: 25% (Ghana's Constitution 1992). In this arrangement, farmers and local forest fringe communities are not directly included in the benefit sharing and they get few direct benefits from the constitutional beneficiaries. Thus the existing benefit sharing arrangement on trees as contained in Ghana's 1992 Constitution, stipulates an arrangement under which key stakeholders such as farmers do not benefit directly from revenue accruing from the legal harvest of naturally regenerated timber on their farms. Such benefit sharing arrangement is unfair and does not provide farmers and forest fringe communities with direct incentives to engage in forest/tree management and conservation (Chapter 3). In combination with poor law enforcement, the benefit sharing arrangement provides perverse incentives for farmers and communities to engage in illegal activities (such as commercial chainsaw lumbering), kill or burn valuable timber trees, and thus contributing to deforestation and forest degradation (Hansen et al. 2009).

Insufficient supply of sawmill lumber to the domestic market due to low timber prices at the domestic market and poor law enforcement drive illegal commercial chainsaw milling which is a major cause of forest degradation in Ghana. The Ghana government's main strategy to address the situation was to ban and criminalize commercial chainsaw milling activity in 1998. However, in 1999 just about a year after the ban was introduced, about 1.7 million m^3 of wood was illegally harvested by commercial chainsaw operators. Currently, chainsaw milling is the main supplier of lumber to the domestic market, supplying about 84% of the domestic market lumbar demand (Birikorang et al. 2001, Marfo 2010). The enforcement of the strategy has been ineffective and chainsaw lumber continues to be on sale in the market. This is because the conventional sawmills have not been able to supply the domestic timber demand by legal

means. Furthermore, chainsaw milling provides easy access to timber in rural areas, and chainsaw milling provides economic opportunities for unemployed young people to be employed (Acheampong and Marfo 2011, Marfo 2010).

In addition, low forest fees and the existing forest taxation regime results in subsidized log prices. This increases the profitability of the timber-processing industry, encouraging the industry to increase its timber-processing capacity and expand timber extraction. Moreover, the low forest fees (or subsidized log prices) provide no financial incentives for the industry to improve efficiency but rather to increase exploitation rates. Low forest fees also result in low revenue flowing to local traditional authorities and communities, which reduce their incentive to protect, manage and conserve timber trees, both on- and off-reserves. A number of other studies have also demonstrated that low forest fees is a key issue in forest management in Ghana (Birikorang et al. 2001, Treue 2001, Hansen et al. 2009); thus, low forest fees contributes to deforestation and forest degradation. Accordingly, the results of this thesis agree with the conclusion findings of Hansen and Treue (2008) that the high incidence of illegal logging is the result of policy failures, notably the failure to establish positive economic incentives for farmers and local communities to tend and conserve timber trees and forests, and the banning of the commercial chainsaw milling.

Another important element affecting forest resources developments has been the rapid transition from traditional shaded cocoa cultivation under primary or secondary forests, to progressively open cocoa cultivation driven mainly by higher short-term profit and increasing competition for land. Indeed agricultural expansion, especially cocoa, has been a major driving force of land use change in Ghana, and the cocoa frontier has expanded much at the expense of forests mainly outside forest reserves. However, this expansion is expected to reduce due to ongoing efforts to integrate trees into the cocoa agroforest systems in the high forest zone of Ghana.

Concerning resource demand, population growth and urbanization, increasing disposable income, poverty and increasing demand for timber and energy are the key driving forces affecting the development of forest resources (Chapter 3). Rapid population growth, urbanization and increasing disposable income among the urban populace have increased the demand for timber and woodfuel for energy above the sustainable capacity of the forests. Hansen et al. (2012) suggested that annual timber harvest in Ghana is approximately 6 million m^3 of which 80 percent is harvested by illegal chainsaw operators mainly for domestic consumption. However, the annual allowable cut (AAC) is 2 million m^3, and some authors have

even argued that the current condition of the forests could only support a sustainable AAC of 0.8 million m^3 (Mayers et al. 2008). Furthermore, high income inequality among the populace drives the poor into unsustainable practices due to lack of alternatives. Thus, high poverty levels in rural areas also allow the populace to support illegal chainsaw milling operations to support their livelihoods. This highlights the huge pressure on the already dwindling forest resources resulting from increasing demand.

On woodfuel, it is estimated that every person in Ghana uses about 1.0 m^3 of woodfuel annually, with the total annual consumption estimated to be 25–28 million m^3 (Chapter 2). These figures have also been increasing since 1990. Globally, the total amount of wood harvested and used as woodfuel has also increased over the period 1990–2015 in lower-middle income countries, where population growth has been greatest (FAO 2015, Köhl et al. 2015, Wilson et al. 2010). In Ghana, the transition and savanna zones in the northern part of the country provide the bulk of wood resources for woodfuel. However, the woodfuel resources in these areas are rapidly depleting due to unsustainable practices in the production and marketing of the woodfuel products, leading to a gradual pressure on the high forest zone for woodfuel resources. Thus, the populace's heavy dependence on woodfuel for rural and urban energy and the timber demand-supply gap (Chapter 2) have important implications for the development of forest resources in Ghana.

6.2.2 Scenarios of resource development/availability

Legal forestry scenario: This is a scenario with emphasis on improving the resource base to meet the high national demand for timber. In this scenario, a complete package of reforms in the forestry sector is pursued to achieve a better forest governance system. Broader fiscal, regulatory and tenure improvements as well as efforts to ensure equitable distribution of benefits to communities and farmers are made to support sustainable forest management. The improvements in the governance system result in increased private sector investments in commercial timber plantations in forest reserves and areas outside forest reserves. Farmers receive incentives to plant trees on farmlands, and manage naturally regenerated trees, resulting in improved natural regeneration and expansion of timber resource base in areas outside forest reserves. Institutional and administrative structures and technical systems are also streamlined to ensure transparency, accountability and good cooperation between relevant government agencies and civil society for effective law enforcement and compliance.

In this scenario, the Ghanaian population continues to grow at the current rate of two percent, and rising disposable income among the urban dwellers results in high demand for the resources. Fiscal reforms increase timber prices on the domestic market and the governance system ensures progressive elimination of illegally produced timber from the international and domestic market. A new annual allowable cut (AAC) is determined based on the sustainable capacity of the production forests including established forest plantations.

The question that arises from this scenario is: will the current resource base be able to sustainably supply the domestic and export markets demand for timber? The current status of the resource base (Chapter 2) shows that there would be the need to explore opportunities to diversify sources of wood supply to meet the markets needs to reduce the current pressure on the forests. This implies that there would be a need for Ghana to import timber in order to ensure continuous supply of legal timber to meet the high national demand. Alternatively, Ghana would have to suspend all exports until there is adequate natural regeneration and growth of the production forests and commercial timber plantations reach maturity. Incentives to encourage forest plantations on degraded lands, and to promote on-farm tree planting are needed (Chapters 3 and 4).

Forest degradation scenario: This is a business-as-usual scenario in which there is high resource demand and a weak forest governance system, which typically characterizes the situation today in Ghana. There is lack of effective tenure and farmers have no commercial use rights to naturally regenerated timber on their farms, including inadequate compensation for logging damage to farms. Rural communities and farmers do not get a share of revenue in the benefit-sharing arrangements. State control of forestry continues and communities and farmers therefore do not effectively participate in forest management and protection; neither do they have incentives to plant trees and maintain naturally regenerated trees. Forest fees remain low, the timber processing industry with low mill efficiency process more wood than the sustainable capacity of the production forests and the industry continue to be export-oriented. Forest plantation development continues at a low establishment rate with low productivity. This implies that the contribution of forest plantations to the supply of timber to the domestic and export markets is low, if not negligible.

Demand for timber remains high, which is usually met by illegal chainsaw milling operations which produce lumber at affordable prices at the domestic market, but contributes to forest degradation. The consequence of this scenario is a continuous degradation of the forest

resource base due to widespread overexploitation. This is consistent with the consequence of the business-as-usual scenario developed by Lemenih et al. (2010) for Ethiopia. In that scenario, Lemenih et al. (2010) argued that the outcome of the scenario is a forestry sector in crisis, whereby the existing remnant forest stands and woodlands will continue to be over exploited and thus decline in quality as well as in spatial coverage.

Forest transition scenario: The emphasis of this scenario is on expanding the forest resource base mainly in response to environmental concerns. Thus, environmental considerations (e.g. payment for ecosystem services) drive interests in tree planting and improve forest management and protection. The approach under this scenario could be likened to the CommuniTree project in Nicaragua that focuses on planting trees as the vehicle to generate carbon offsets (Porras et al. 2015). Under CommuniTree project, farmers establish mixed native species forest plantations on their farms in exchange for cash payments from carbon and potential future sales of timber when the trees reach maturity. The project agrees that better agricultural practices can help protect, enhance or reverse degradation patterns in the provision of ecosystem services (MEA 2005, Porras et al. 2015). Similarly, tree planting under the forest transition scenario would contribute to forest resources developments by addressing the key driving forces of deforestation and forest degradation in Ghana (Chapters 4 and 5). Under this scenario, tenure and benefit sharing reforms are pursued to give secure tree use rights to local communities and farmers for their support in managing forest resources. Demand for timber resources is however low due to social-economic development in Ghana that make people become less dependent on timber. The timber industry would remain export-oriented but the industry's processing capacity would be reduced and the existing harvesting rate aligned with a sustainable AAC.

Timber substitution scenario: This scenario seeks to provide wood substitutes in order to conserve the forest resource base. The governance system is weak but there is low demand for the resources, meaning that damage to agricultural crops is minimal due to low on-farm harvesting rates, giving rise to more natural regeneration on farmlands. Local demand shifts to wood substitutes such as plastics and steel. The shift to timber substitutes would likely encourage more regeneration in both on- and off-reserve areas. That is, increases in the availability of substitute for timber from other sources, would lower the pressure on the already dwindled resource base, and encourage natural regeneration that could contribute towards forest transition in Ghana.

6.3 Farmers' motivations and barriers to on-farm tree planting and management

The success of on-farm tree planting and management is influenced by a range of factors (Chapter 4). The key ones are financial benefits, knowledge about current environmental issues, secure investments for future of families and ownership of timber for family use. Other key factors include access to land for farming, educational campaigns by project teams, and access to inputs for farming and market for agricultural produce These factors inform policy makers and forest managers how to re-design and implement on-farm tree planting schemes in order to increase the success of their schemes.

Many Ghanaian farmers are motivated by the potential income they will receive from the sale of planted trees at maturity. This is because recent policy reforms in Ghana grant right of ownership to individuals who plant trees. To many of the farmers, on-farm tree planting is seen as an investment opportunity that will provide future income and meet their household requirements for timber. Similar evidence is provided by Greiner and Gregg (2011) for Australia, Ndayambaje et al. (2012) for Rwanda, and Zubair and Garforth (2006) for Pakistan. Farmers who have planted trees on their farms anticipated that the economic benefits in terms of future income would likely outweigh any possible adverse impacts of their on-farm trees. Thus, gaining economic benefits and providing income security for the future of their families provide the key motivations that drive farmers' decision making to engage in on-farm tree planting and management.

Besides economic benefits, farmers' engagement in on-farm tree planting and management were motivated by their knowledge about current environmental issues and by the environmental campaigns carried out by project teams from on-farm tree planting schemes (Chapter 4). Over the years Ghanaian farmers have acquired adequate knowledge of the benefits of trees on their farmlands. Such knowledge turned out to be essential for positive decision making about on-farm tree planting and management activities. It influences farmers' perception and acceptance of on-farm tree planting and conservation activities (Ansong and Roskaft 2011). Similarly, Meijer et al. (2015b) conclude that in sub-Saharan Africa, smallholder farmers' knowledge and perceptions influence their decision making to take up new agricultural and agroforestry technologies. In addition, the Ghanaian farmers also responded positively to the educational campaigns to sensitize them about on-farm tree planting. This shows that the

role of communication, extension and training is crucial for the development of forest resources in the off-reserve areas by motivating farmers to engage in on-farm tree planting and management.

Access to land for farming is another motivational factor in engaging in on-farm tree planting in Ghana. Some farmers under the Oda-Kotoamso Community Agroforestry Project (OCAP) were motivated by the prospect of gaining tenancy access to new land under the scheme for farming. Although such farmers were also motivated by the economic benefits of on-farm tree planting, one of their main interests was also to secure short-term food security by increasing crop yields from their new lands acquired under the scheme. This is consistent with Meijer et al. (2015) who found that the main priority for most Malawian farmers who plant trees on their farms is to secure short-term food security by increasing crop yields, providing fruits and nuts to complement diets, and increasing incomes. Comparatively, in both Ghana and Malawi, the main problem is that future benefits of tree planting are uncertain for tenant farmers (Meijer et al. 2015, Chapter 4); consequently most of these farmers are concerned with gaining access to new land to increase food production in the short term rather than on-farm tree planting.

In Ghana, provision of incentives (e.g. supply of free seedlings, farming inputs) as well as technical assistance and access to markets for agricultural produce motivate farmers to engage in on-farm tree planting and management (Appiah et al. 2015, Chapter 4). Similarly, Patel et al. (1995) analyzed household's tree growing and planting decisions in East Africa and found that farmers are responsive to tree-planting incentives. Accordingly, providing farmers with training, access to good quality planting material and equipment for farming activities motivate farmers to plant trees on their farms. On the other hand, some farmers tend to lose their motivation when the incentive packages associated with on-farm tree planting schemes stop. For example, in this thesis it was shown that 55% and 33% of farmers under OCAP and Forest Resources Creation Project (FRCP) schemes respectively mentioned that they would not engage in on-farm tree planting if no incentive packages were provided (Chapter 4).

Consequently, in this thesis, efforts were made to link standing volume of trees on farmlands to farmers' motivations with the aim of assessing whether higher levels of motivation will correlate with higher standing volume of trees on farmlands. Because the field inventory data to correlate the variables were not collected in all the interviewed farmers' plots, proxies were used to assess the potential correlation between motivation and volume of on-farm trees. In the analysis, farmers' interests in the schemes over time and willingness to engage in on-

farm tree planting without incentive packages were used as proxies to show levels of farmers' motivations. The results show that OCAP farmers possibly exhibit lower motivations (65% lost interest over time, 44.3% willing to plant trees again) compared to FRCP farmers' higher motivations (22% lost interest over time, 66.7 willing to plant trees again). The average standing volume of on-farm trees in the study areas is 51.9 m^3 per ha: 45.4 m^3 ha^{-1} for OCAP and 61.2 m^3 ha^{-1} for FRCP (Chapter 4). The results seem to indicate three messages: (1) the differences in standing volume between OCAP and FRCP may likely be linked to farmers' motivations, thus, using the proxies, motivation and standing volume seems positively correlated; (2) the schemes may likely have triggered higher levels of motivation among farmers to plant and manage on-farm trees because the average standing tree volume per ha of 51.9 m^3 is about double the national average for the off-reserve areas in the semi-deciduous forest zone (Appiah 2013).

As indicated above, Ghanaian farmers are relatively well motivated to engage in on-farm tree planting. However, there are some barriers to on-farm tree planting and management that the farmers face. The main barriers are high financial costs involved in managing the planted trees, low levels of knowledge on proper techniques in managing planted trees in agricultural production systems, attacks by pests and diseases and the lack of knowledge to address such attacks. Another barrier has been that farmers do not have commercial use rights to naturally regenerated trees on their farms and sufficient compensation is not paid for damage to cash/food crops during harvesting by firms with legal permits (Chapter 3). For all these reasons, farmers tend to destroy potential timber trees on their farms to avoid any damage to their crops during harvesting of such farms. These barriers should be examined to provide insights into how farmers' could be facilitated to overcome the barriers in order to promote on-farm tree planting.

6.4 Assessment of transition from deforestation to reforestation in Ghana

The global annual rate of forest loss has decreased since 2010 to 3.3 million ha, representing half the rate in the 1990s (FAO 2015). In the tropics, the rate of deforestation is also reported to be decreasing since 2000 (FAO 2010a, Keenan et al. 2015, Sloan and Sayer 2015). Mosaic forests in agricultural landscapes are increasing and the extent of planted forests in the tropics has also almost doubled since 1990, increasingly providing goods and services that were

previously derived from natural forests (Payn et al. 2015, Sloan and Sayer 2015). Notwithstanding this progress, tropical deforestation continues to be a major global concern and remains one of the main processes of land change, with multiple implications for global environmental change and livelihoods (Lambin and Geist 2006, Meyfroidt and Lambin 2011). This thesis showed that deforestation and forest decline is a major concern in Ghana. Ghana lost about 34% (approximately 2.5 million ha) of its closed forest cover between 1990-2010, similar to trends of forest area loss reported by Keenan et al. (2015) in lower middle income and low income countries for the period 1990 to 2010. The average annual change of forest in Ghana during the 2000-2010 period was -115,000 ha (FAO 2010a). Part of that was a total of about 150,000 ha of plantations established under the government initiated national forest plantation development programme (Chapter 5). This implies that the current annual reforestation compensates for only about 13% of annual forest loss.

Some tropical developing countries, such as Costa Rica, India and Vietnam have experienced forest transitions (FTs): a shift from net deforestation to net reforestation (Mather 1992, Meyfroidt and Lambin 2011, Rudel et al. 2005). FTs result from multiple trends but the exact mechanisms that operate in FTs vary across locations and the country context can strongly influence which factors are most important in driving FTs (Farley 2010, Klooster 2003, Meyfroidt and Lambin 2011, Perz 2007). Accordingly, Chapter 5 analysed forest resource development trends in Ghana, using the five generic FT pathways of economic development; forest scarcity; globalization; state forest policy; and smallholder, tree-based land use intensification. The results showed that trends that (partly) relate to the five pathways as well as similar processes of forest development in FT countries such as Costa Rica, South Korea and Vietnam exist in Ghana (Chapter 5 Table 5.6). However, there are important differences in scale, effectiveness and characteristics of the trends in Ghana compared to those FT countries. Based on this, it was concluded that the existing trends in Ghana that relate to forest area increase are either too small-scale or too ineffective yet to initiate a full scale forest transition in the country. This conclusion is consistent with what other studies have reported about forest cover trends in Ghana (FAO 2010a, Hosonuma et al. 2012).

Examining the trends in national forest area as reported by FAO (2010a) shows that about 9 tropical countries were likely to have passed through their national forest transitions between the period 1990-2010 (Table 6.1). These include countries such as Costa Rica, India and Vietnam for which forest transitions have already been documented in the FT literature (Hect et al. 2006, Kull et al. 2007, Lambin and Meyfroidt 2010, Mather 2007). However,

Keenan et al. (2015) using the results of the 2015 Global Forest Resources Assessment (FRA) noted that 13 tropical countries, including Ghana, Burundi, Laos, Dominican Republic and the countries listed in Table 6.1, were likely to have passed the threshold towards a national forest transition in the period 1990-2015. The observation that Ghana is likely to have gone through such a FT (Table 6.2) is however somewhat different from what was shown in Chapter 5, and what others have also reported about forest cover change and FT in Ghana (see e.g. FAO 2010a, Hosonuma et al. 2012).

Table 6.1: Trends in forest area in countries where a national forest transition between 1990 and 2010 is likely (1,000 ha).

Country	1990	2000	2005	2010
Gambia	442	461	471	480
Rwanda	318	344	385	435
Bhutan	3,035	3,141	3,195	3,249
India	63,939	65,390	67,709	68,434
Philippines	6,570	7,117	7,391	7,665
Vietnam	9,363	11,725	13,077	13,797
Cuba	2,058	2,435	2,697	2,870
Costa Rica	2,564	2,376	2,491	2,605
Puerto Rico	287	464	508	552

Source: FAO 2010a.

The difference may be a result of two main reasons. First, in conducting the analysis in Chapter 5, data from various sources, including the results of the 2010 Global Forest Resources Assessment (FRA), which relied heavily on forests within the high forest zone of Ghana, were used (FAO 2010a, Chapter 5, Table 5.2); and the analysis also mainly focused on the high forest zone being the scope of this thesis. Second, Ghana's submission to the 2015 FRA was, for the first time in its history, based on a 'wall to wall' land cover assessment that relied on the 2006 IPCC classification of land cover analysis. The implication was that additional areas, particularly in the forest-savanna transition zone, which previously did not qualify as forest in FAO assessments, now positively affected the total forest area (by more than 4.2 million ha over previous 2010 estimates) as reported in the 2015 FRAs (Affum-Baffoe 2015). Thus, the previous figures for 1990, 2000, and 2010 were adjusted based on the new land cover analysis

(Table 6.2). The forest area of Cote d'Ivoire also showed an increasing trend from 10.2 million ha in 1990 to 10.4 million ha in 2015 indicating that forest transition might have occurred in the country. However, this is not certain, due to potential errors in statistics; uncertainty around the turning point itself; and the quality of the data used for the analysis (Grainger 2010, FAO 2015, Keenan et al. 2015).

Interestingly, the report of the wall-to-wall land cover assessment in Ghana indicated that deforestation in Ghana has slowed down and the trend of an increase of forest land area is stemming from the expansion of open forests, while Ghana's closed forest area is decreasing as a result of forest degradation in the closed forests (PASCO CORPORATION 2013). What remains to be seen is whether the reported net increase in forest area (Table 6.2) is a result of more areas in the forest-savanna transition zone being re-classified as forests or whether reforestation rate has actually increased such that there is indeed a net forest area expansion. From the analysis in this thesis, it is concluded that the latter is not likely to be the case considering the low establishment rates of existing forest plantation development schemes (Chapters 2 and 5) and the reported annual change rate of about 28,000 ha (Table 6.2). Further analysis would need to be conducted to determine the actual effect of re-classifying additional areas as forests for a possible FT in Ghana. Yet the notion that deforestation rates in Ghana may have slowed down shows consistency with results of other studies. For example, Hosonuma et al. (2012) classified Ghana among countries in a late-transition phase, where a rather small fraction of remaining closed forests exhibit a slowing deforestation rate, and where a post-transition phase is eventually nearing, in which the forest area change rate becomes positive and forest cover increases through reforestation.

Table 6.2: Extent of (new) forest area in Ghana 1990-2010 (1,000 ha).

Forest area			Annual change rate			
1990	2000	2010	1990-2000		2000-2010	
			1,000 ha/year	%	1,000 ha/year	%
8,627	8,909	9,195	28.2	0.3	28.6	0.3

Source: Affum-Baffoe 2015, FAO 2015.

Sloan and Sayer (2015) indicate that those tropical countries that have been undergoing forest transitions have perhaps also undergone similar national development processes. For

example, these FT countries are usually characterized by forest policy and management reforms, improvements in agricultural practices, and by significant expansions of forest plantations. In line with that thought, forest resource development trends in Ghana was compared with other FT countries in order to determine what Ghana needs to do to achieve FT (Chapter 5). Forest area expansion in Vietnam, for example, resulted from among other factors, clear definition of tenure arrangements and huge investments in industrial forest plantation on both productive and unproductive agricultural lands driven by economic development and industrial market demand (Lambini and Nguyen 2014, Meyfoidt and Lambin 2008, Payn et al. 2015). India also instituted Joint Forest Management programmes and encouraged private forest plantation development, giving communities economic incentives for forest production and conservation (Foster and Rosenzweig 2003). In Ghana, the incentives for the conservation of trees in the agricultural landscape has however been lacking in most cases. In order to accelerate a forest transition in Ghana, there is a need for policy reforms and incentive schemes that will encourage and support integration and conservation of forest trees in agricultural production systems. Tenure reforms recognizing ownership and use rights for communities and farmers are also important considerations for tree conservation and integration into farmlands that have the potential to lead to forest transition (Chapters 4 and 5).

Ghana needs to take advantage of the existing National Forest Plantation Development Programme and the newly developed national Forest Plantation Strategy to accelerate FT in both degraded forest lands and in agricultural lands through an appropriate mix of policy reforms, incentive schemes, capital investments and strong government commitment. Considering the existing huge gap between timber demand and supply, forest plantation programmes should focus on meeting industrial demand for timber as well as offering opportunities for poverty reduction, job creation, and economic development for rural communities, as has been the case in other tropical FT countries.

Accelerating FT in Ghana through forest plantations would be similar to the global trend because forest plantations account for much of the world's total forest-cover change. In 2010, FAO reported 264 million ha of planted forests worldwide. In 2015, FAO estimates indicate that planted forests contribute substantial proportion to forest area gains since 1990. In many of the tropical FT countries forest plantations have played an important role in the transition process (Figure 6.1), suggesting that planted-forest expansion is a significant factor in forest transitions (Sloan and Sayer 2015). However, as shown in Figure 6.1, the annual gain in forest cover through forest plantation development is far from sufficient to offset the annual forest

cover loss in Ghana. Although forest plantations establishment has been ongoing since 2000, the total area of planted forests is too low compared to the total area of forest loss. In comparison with countries such as India and Vietnam, Ghana would need to establish about 0.5 million ha of plantations by encouraging more private sector involvement in the establishment and maintenance of forest plantations. In Ghana, as in many African countries, forest management institutions remain weak, leaving forests highly vulnerable to clearance and degradation (Keenan et al. 2015, Romijn et al. 2015).

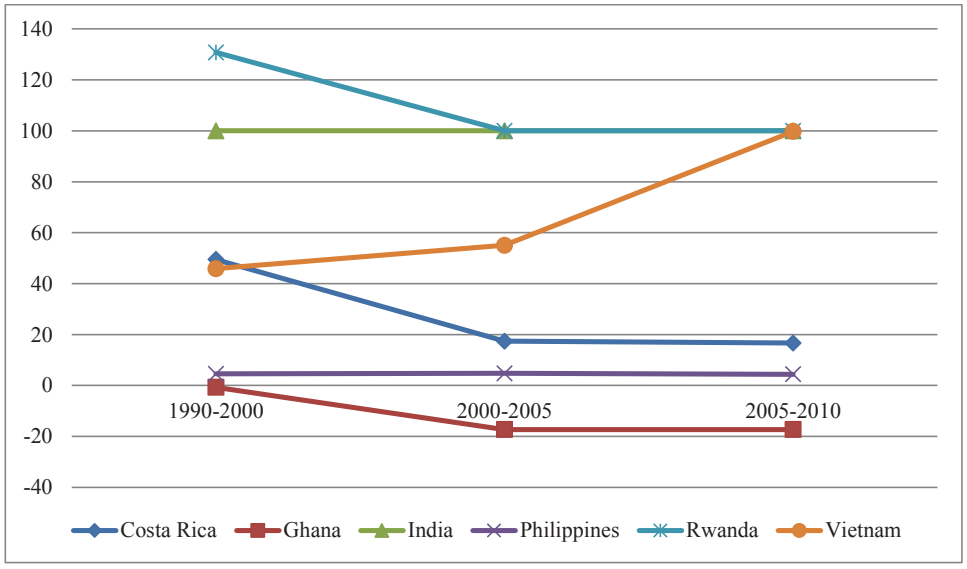

Figure 6.1: Change in forest plantation area as a percent of change in total forest area, for Ghana and selected forest transition countries for the period 1990-2010. Source: FAO 2010a, Hosonuma et al. 2012. Notes: Negative percentages indicate that the gain in forest plantation area occurred together with loss in total forest area.

6.5 Analytical and methodological reflections

In providing insights into the future developments of forest resources in Ghana, different analytical perspectives of forest resources developments are essential. This thesis used an interdisciplinary research approach that combines four different analytical methods: resource

assessment, scenarios matrix tool, socio-psychological model, and forest transition theory, to assess status of forest resources, explore the consequences of different scenarios for future timber resource developments, assess farmers' motivation for on-farm tree planting, and assess whether a forest transition is expected to occur in Ghana.

Drawing from the work of Wulf et al. (2010b), the scenario matrix tool offers a framework to explore future developments of forest resources. In reflecting on the forest resources developments trajectory, two key driving forces were considered: the forest governance system and the resource demand (See Figure 3.3). The assumption here is that if multiple trajectories are possible, then they will possibly be different in their focus, driving forces, strengths and weaknesses. Analyzing these differences, theoretically and empirically, is essential for exploring scenarios of future forest resources developments. Therefore, in this thesis, two key driving forces were combined in the matrix tool using a scale of low-high to conceptualize and explore four scenarios of forest resources developments. In addition, it was demonstrated in this thesis that it is possible to combine forest management issues and socio-psychological factors into one interdisciplinary model to know which socio-psychological variables can be used to increase farmers' motivation to engage in on-farm tree planting and management. Similarly, the forest transition theory (FTT) is a useful theoretical tool that helps in understanding forest cover changes. The assumption is that changes in the country's forest cover will follow a determinable pattern of decline and later re-expansion over time (see Rudel 2010). In order to understand the trends that contribute to forest recovery from declining forests area, this thesis applied the FTT to examine forest resources developments trends in Ghana following various potential forest transition pathways.

As already stated in the methodological sections of each empirical chapter, this thesis combined various research methods for data collection and analysis. The research methods are semi-structured interviews and household surveys, inventory of on-farm trees, field observations, scenario planning, workshop participation, and document and literature review to give meaning to the analytical elements of the study. Triangulation of the various data sources was helpful in improving the credibility and validity of the results. Different data collection methods required different data analysis methods, depending on the research question at hand, and the methods complimented each other. The use of different research methods was useful in the analysis of the different aspects of forest resources development in the high forest zone of Ghana.

The interviews proved to be an important form of data collection, especially to understand farmers' motivation and barriers to their decision to engage in on-farm tree planting. By adopting a more conversational manner during the household surveys and interviews, a deeper understanding of respondents' behaviour towards on-farm tree planting and management was gained. The farm inventory offered the opportunity to determine the volume of trees on farmlands in order to be able to show the linkage between farmers' motivation and the volume of trees on their farms. The document and literature review were helpful in examining the trends and conditions associated with the forest resources, and it further deepened my knowledge and understanding of the research context. In addition, workshops participation offered the opportunity to study forest management and forest policy experts' actions, arguments, and presentation of their ideas on forest plantation development and on the driving forces affecting forest resources developments in Ghana. This was important for grasping the key issues and context within which forest resources develop in Ghana.

On the methodological limitations of the study, the research setting was initially designed to collect data for the entire high forest zone towards providing a country wide assessment of the status of the forest resource base in both on- and off-reserve areas. While this was successful with forest reserves using national forest inventories in Chapter 2, it was not fully possible for the entire off-reserve areas due to lack of data for the entire area. The 2004 off-reserve inventory only focused on Timber Utilization Contract (TUC) areas. Nevertheless, data from other sources were combined with the inventories data in the assessment to provide a good overview of the status of the forest resource base. In addition, the socio-psychological model in Chapter 4 was not well integrated with the data used. This is because the model slightly changed during the field research but efforts were made to make model, data and analysis as consistent as possible. Also, retrieving of correlation among farmers' motivations and standing volume became difficult because of some shortfall in data collection, but proxies were used to analyze the linkage between farmers' motivation and the volume of trees on their farms.

6.6 Recommendations for future developments of forest resources

Expand the resource base through investments in plantation development: Currently, commercial forest plantation activities in the country shows that forest plantation establishment efforts are not sufficiently successful to bridge the gap between demand and supply of timber

due to low rate of establishment and lack of management of the established plantations. There is the need to provide the necessary framework to expand the resource base through investments in commercial forest plantation developments (increase rate of establishment and productivity) in both degraded forest reserves and areas outside forest reserves. In this regard, a clear national reforestation strategy with private sector and local communities' partnership and with strong government commitment to its implementation is necessary. Tree planting campaigns, especially in the savanna zone of Ghana, are also more likely to accelerate a forest transition in Ghana due to the availability of large tracts of land for tree planting. In addition, management of the established plantations and appropriate natural forest management practices that reduces the current degradation will need to be pursued.

Law enforcement: As mentioned earlier in this thesis, poor law enforcement is a key driving force of deforestation and forest degradation in Ghana. Clarifying access and property rights to land and forests, and strengthening the capacity of the national agencies in charge of forest control are necessary to improve law enforcement. In addition, there is the need to enforce laws on sustainable harvesting in the production systems by aligning the annual allowable cut and actual timber harvests to the capacity of the production areas. In the meantime, it would be prudent to pursue alternative sources, such as import of timber and timber substitutes, to bridge the gap between demand and supply in Ghana. Alternatively, arrangements should be made to meet the domestic demand for timber since the conventional sawmills are currently fully focused on the export market and have neglected the domestic market. To address this, the policy option may include measures to allow both formal industry (sawmills) and artisanal millers (re-organized and registered chainsaw operators) to be allocated timber harvesting rights to supply the domestic market with timber.

Incentive mechanisms to support on-farm tree planting and management: One of the major weaknesses of the forest management framework in Ghana has been the lack of an appropriate mechanism to provide incentives for on-farm tree planting, management and conservation. Incentives in the form of provision of grants, farming inputs, seedlings, capacity building, and access to markets for agricultural produce are factors that motivate on-farm tree planting in Ghana. There is an urgent need for policy reforms and incentive schemes that will encourage and support integration and conservation of native trees in agricultural production systems.

Reform on-farm tree tenure rights and benefit-sharing arrangements: Securing land and tree tenure is considered important for reducing deforestation and for increasing the forest resource base through on-farm tree planting by smallholder farmers. Tenure reforms that recognize management and commercial use rights for communities and farmers are important considerations for building and protecting on-farm timber resources. Furthermore, current benefit sharing arrangements that ignore the efforts of farmers' contributions to the development of forest resources should be revised. Concerted efforts to ensure equitable distribution of benefits to include farmers and local communities should be undertaken. In this regard, there is a need to increase stumpage fees, ensure effective revenue collection and distribution to encourage local participation in forest management and protection.

Restructure industry and improve industry resource use efficiency: The high capacity of the timber industry should be reduced and industry resource use efficiency improved. The low recovery rates within the timber industry contribute to the intense pressure on the already degraded resource base. The industry requires significant re-tooling to increase their milling efficiency, which will in turn increase the volume of wood available for consumption. There is also the need to align industry-installed capacity to the sustainable capacity of the production forests. One of the strategies will be to expand the manufacturing component of the industry in order to encourage processing of finished or partially finished products.

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Summary

Summary

Deforestation and forest degradation in the tropics have been receiving both scientific and political attention in recent decades due to its impacts on the environment and on human livelihoods. Reducing tropical deforestation and forest degradation is therefore of global importance for the sustainable production of timber and non-timber forest products, the mitigation of climate change, and the conservation of biodiversity. In Ghana, the continuous decline of forest resources and the high demand for timber have raised stakeholders concerns about the future timber production prospects in the country. The principal drivers of deforestation and forest degradation are agricultural expansion (50%), wood harvesting (35%), population and development pressures (10%), and mining and mineral exploitation (5%).

Various measures are being pursued that are targeted at addressing the drivers of deforestation and forest degradation and at increasing the forest resource base. However, the measures being pursued in forest management today will have an impact on forest resources for decades to come and so insights into the future outlook of the Ghanaian forest resource base is important. The main objective of this PhD research was to provide insights into the current status of the forest resource base in Ghana and into its likely and possible future developments. We assess the current resource availability situation in the timber production systems in the country, both off- and on-farm, explore the consequences of different scenarios for future timber resource developments and assess whether a forest transition is likely to occur in Ghana in the next decades.

Chapter 1 introduces the broad themes of the thesis, which are assessing the current resource status and exploring future resource developments in the high forest zone of Ghana. The Chapter presents a brief overview of reforestation and tree planting activities in Ghana. In addition, it presents an overview of the drivers of deforestation and forest degradation and the major issues affecting forest resources developments in Ghana. It further introduces the conceptual framework used in the thesis showing the linkages among the various chapters of the thesis. The Chapter sets out the interdisciplinary methodology for the research, which are used to answer the research questions. Five research questions guide the research of this thesis: 1. What are the trends and changes associated with the growing stock in the timber production areas (Chapter 2)? 2. What driving forces account for current trends and future developments of timber resources in Ghana (Chapter 3)? 3. What different scenarios can be identified and how will these affect future developments of timber resources in the high forest zone (Chapter 3) 4.

What factors motivate farmers to engage in on-farm tree planting and management (Chapter 4)? and 5. To what extent do the current trends of forest resources drive forest transition in Ghana (Chapter 5)?

Chapter 2, assesses the trends associated with the growing stock in the main timber production areas of Ghana. The Chapter uses national forest inventory data, timber harvesting data and forest plantation establishment data to assess the current status of forest resources in the high forest zone. The Chapter reports that the growing stock in both on- and off-reserve production areas have seriously been declining since 1990. The timber harvesting records also indicate that in recent decades total timber harvests have mostly been substantially higher than the annual allowable cut. These trends have resulted in an increasing gap between national timber demand and supply, which drives illegal logging. Additionally, the Chapter reports that current plantation establishment efforts are not sufficient to bridge the gap between demand and supply of timber, partly due to low establishment rates and lack of appropriate management of newly established plantations. The Chapter concludes that secure tenure including rights to on-farm trees appears to be a key condition to stimulate large scale planting of forest trees by farmers and other investors. It suggests that reform in the management practices is required to align timber harvesting levels to sustainable timber production capacity of the production forests.

Chapter 3 explores the future developments of timber resources through the use of scenarios. It does so by first identifying and describing the key driving forces that affect development of timber resources in the high forest zone. The two most important driving forces were then used to construct scenarios using a scenario planning process, to explore the future of timber resource developments. The results show that forest governance system and resource demand are the two key driving forces that affect the current trends and future developments of forest resources. Key elements of the governance system that drive the shrinking resource base include insecure land and tree tenure system, inequitable benefit sharing arrangements, insufficient supply of sawmill lumber to the domestic market due to low timber prices at the domestic market, poor law enforcement and introduction of new cocoa variety into the agricultural landscape. Under resource demand, rapid population growth, urbanization, increasing disposable income, poverty and increasing demand for timber and energy are the key driving forces affecting the developments of forest resources. The developed four scenarios, namely: (1) legal forestry scenario with emphasis on improving the resource base to meet high demand; (2) forest degradation, which implies a business-as-usual scenario; (3) forest transition,

with emphasis on expanding the resource base in response to environmental concerns; and (4) timber substitution scenario seeking to provide wood substitutes to conserve the resource base. The Chapter recommends that to ensure a sustainable future for timber resources, policy reform is needed, focusing on land and tree tenure, revenue capture, benefit-sharing arrangements and satisfying the domestic demand for timber.

Chapter 4 focuses on farmers' motivational factors and barriers to engage in on-farm tree planting and management. The Chapter provides an overview of current on-farm tree management and conservation practices in Ghana. It combines both internal and external factors in a socio-psychological model to understand farmers' motivation under two on-farm tree planting schemes. The results show that farmers' were motivated to engage in on-farm tree planting and management by the following incentives: financial benefits, educational campaigns by project teams, knowledge about current environmental issues, ownership of timber for family use and access to land, grants, farming inputs, seedlings, capacity building, and market for agricultural produce. Also, the farmers considered high financial costs and low knowledge of proper techniques in managing planted trees in agricultural production systems as barriers to the development of tree stock on farms. The Chapter takes a step further to link standing volume on farmland to farmers' motivations. The results seem to indicate that the on-farm tree planting schemes have generally triggered higher levels of motivation among farmers to plant and manage on-farm trees than in comparable regions in the rest of the country without such schemes. The Chapter concludes that on-farm tree planting programmes are more likely to succeed if the programmes incorporate policies that acknowledge and address motivational factors and barriers which underlie farmers' reasons for engaging in on-farm tree planting.

Chapter 5 focuses on the forest transition debate to analyze forest resources developments trends in Ghana. The chapter provides inputs to support ongoing national policy debates to halt deforestation, particularly Ghana's policy efforts on REDD+. Forest transition pathways were used to assess the extent to which forest resources developments trends drive forest recovery in Ghana. The Chapter found no strong force toward a forest transition through any of the five generic pathways (economic development; forest scarcity; globalization; state forest policy; and smallholder, tree-based land use intensification). This is because the existing trends in Ghana are either too small-scale or too ineffective. In order to accelerate a forest transition in Ghana, it is recommended that policy and management options should target measures that reduce current degradation of natural forests, increase the area and productivity of commercial

forest plantations, promote sustainable forest management, and support and encourage forest conservation and integration of trees into farming systems.

Chapter 6 presents the main conclusions, and a synthesis of the major findings of the research chapters within the wider frame of societal development in Ghana to assess future developments of timber resources in the high forest zone. The Chapter discusses various driving forces affecting timber resources developments and how these driving forces can interact to promote forest transition in Ghana. The results indicate that Ghana needs to take advantage of the existing National Forest Plantation Development Programme and the newly developed national Forest Plantation Strategy to accelerate FT in both degraded forest lands and in agricultural lands through an appropriate mix of policy reforms, incentive schemes, capital investments and strong government commitment. The results of the thesis clearly shows that there is an existing huge gap between timber demand and supply. Therefore forest plantation programmes should focus on meeting industrial demand for timber as well as offering opportunities for poverty reduction, job creation, and economic development for rural communities. Finally, the Chapter presents some recommendations for both science and policy practice to ensure future forest resource developments in the high forest zone.

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Short biography

Kwame A. Oduro was born on 19th July 1975 at New Tafo Akim in the Eastern Region of Ghana. He attended CRIG L/A Primary School and CRIG Junior Secondary School. In 1993, he obtained his secondary school certificate from Pope John Secondary School, Koforidua. From 1995 to 1999 he studied Natural Resources Management at the Institute of Renewable Natural Resources at the Kwame Nkrumah University of Science and Technology, Kumasi. He graduated with Bachelor of Science degree in Natural Resources Management with a major in Forestry. In 2000 he enrolled at the Oxford Forestry Institute at the Oxford University, UK for his master's degree and completed in 2001 with an MSc in Forestry and its Relation to Land Use. For his thesis, he researched into the effect of plot size and shape on the efficiency of a woodland inventory.

In 2002, he was employed by the Council for Scientific and Industrial Research-Forestry Research Institute of Ghana (CSIR-FORIG) as a Research Scientist. In 2003, he was appointed as a Junior Scientific Coordinator for the Tropenbos International (TBI) Ghana programme, with a duty station at the Forest Ecology and Forest Management (FEM) Group at the Wageningen University. He was responsible for assisting with programme development and coordination within the TBI Ghana programme. He was also responsible for project monitoring and supported the integration, synthesis and dissemination of TBI Ghana research results.

In 2006, he rejoined CSIR-FORIG where he conducts his research within the Forest Policy, Governance and Livelihoods Division of the Institute. Past projects carried out by him include woodfuel resources development and management, preparation of REDD+ pilot schemes in off-reserve forests and agroforests, analysis of incentive mechanisms to support farming communities to adopt sustainable land use practices under a REDD+ implementation, and development of benefit sharing mechanisms for REDD+ in Ghana.

In 2008 he started a Sandwich PhD studies at Wageningen University in the Forest Ecology and Forest Management Group. During the PhD he attended several international meetings and had the opportunity to present and discuss his research with other researchers. Kwame is married to Amma and have three sons: Kwabena, Yaw and Kwaku.

List of publications

Published/accepted articles

Oduro, K.A., Mohren, G.M.J., Peña-Claros, M., Kyereh, B., Arts, B. 2015. Tracing forest resource development in Ghana through forest transition pathways. *Land Use Policy* 48: 63–72.

Oduro, K.A., B. Arts, B. Kyereh, M. A. Hoogstra-Klein, and G. M. J. Mohren. 2014. Exploring the future of timber resources in the high forest zone of Ghana. *International Forestry Review* 16 (6): 573-585.

Oduro, K.A., G. M. J. Mohren, K. Affum-Baffoe, and B. Kyereh. 2014. Trends in timber production systems in the high forest zone of Ghana. *International Forestry Review* 16 (3): 289–300.

Acquah, S.B. and Oduro, K. A. 2012. Traditional Cloth Dyeing Enterprise at Ntonso: Challenges and Opportunities. *West African Journal of Applied Ecology* 20 (1): 25-36.

Oduro, K.A., Marfo, E., Agyeman, V.K. and Gyan, K. 2011. One hundred years of forestry in Ghana: a review of policy and regulatory discourses on timber legality. *Ghana Journal of Forestry* 27 (3): 15-32.

Oduro, K.A., Agyeman, V.K. and Gyan, K. 2011. Implementing timber legality assurance regime in Ghana: a review of stakeholders concerns and current institutional constraints. *Ghana Journal of Forestry* 27 (2): 1-10.

Submitted articles

Oduro, K.A., B. Arts, B. Kyereh, and G.M.J. Mohren. Farmers' motivations to plant and manage on-farm trees in Ghana.

Book chapters

Oduro, K.A., Foli, E.G., Mohren, G.M.J. and Dumenu, W.K. 2011. Management for sustainable forestry in other tropical countries: Ghana. *In: Werger, M.J.A. (Ed.). Sustainable management of tropical rainforests: the CELOS management system*. Tropenbos International, Paramaribo, Suriname. pp 242-254.

Books/handbooks

Agyei, K., Agyeman, V.K., Asante, W.A., Benefoh, T.D., Blaser, J., Damnyag, L., Deppeler, A., Feurer, M., Foli, E.G., Heeb, L., Kofie, W., Klossner, M., Kyereh, B., Kwakye, Y. and Oduro, K.A. 2014. REDD+ in agricultural landscapes: evidence from Ghana's REDD+ process. HAFL and CSIR-FORIG, Kumasi, Ghana. ISBN 978-9988-2-0238-5, vi+58pp.

Beeko, C., Oduro, K.A., Obeng, E.A. 2014. Development assistance in the forestry sector: impacts over the last two decades and implications for the future. CSIR-FORIG, Kumasi, Ghana. ISBN 978-9988-2-0206-4, xii+42pp.

Nutakor, E., Samar, B.S., Marfo, E. and Oduro, K.A. 2014. Barriers to sustainability of alternative livelihoods: a case study of a Forest Reserve in Ghana. Tropenbos International, Wageningen, the Netherlands. ISBN 978-90-5113-119-2, 60pp.

Oduro, K. A., A. Duah-Gyamfi, S. B. Acquah, and V. K. Agyeman. 2012. Ghana forest and wildlife hand- book: a compendium of information about forest and wildlife resources, forestry related issues and wood processing in Ghana. Forestry Commission, Ghana.

PE&RC Training and Education Statement

With the training and education activities listed below the PhD candidate has complied with the requirements set by the C.T. de Wit Graduate School for Production Ecology and Resource Conservation (PE&RC) which comprises of a minimum total of 32 ECTS (= 22 weeks of activities)

Review of literature (6 ECTS)

- Key driving forces affecting timber resources development in Ghana (2010)

Writing of project proposal (4.5 ECTS)

- Scenario analysis for sustainable management of Ghana's high forest

Post-graduate courses (6 ECTS)

- Competencies for integrated agricultural research; WGS (2007)
- Scenario development: understanding and tools; SENSE/PE&RC/WGS (2007)
- Basic statistics; WGS (2012)
- Companion modelling; PE&RC/WIAS/WASS (2014)

Competence strengthening / skills courses (7.6 ECTS)

- Improving forest governance; CIDT, University of Wolverhampton, UK (2011)
- Information literacy and introduction to EndNote; WGS (2014)
- Mobilising your scientific network; WGS (2014)

PE&RC Annual meetings, seminars and the PE&RC weekend (1.2 ECTS)

- PE&RC PhD Weekend – final years edition (2014)
- PE&RC Day – optimization of science: pressure and pleasure (2014)

Discussion groups / local seminars / other scientific meetings (7.7 ECTS)

- Forestry Research Institute of Ghana; weekly presentations (2008-2013)
- REDD+ discussion group (2014)

International symposia, workshops and conferences (5.6 ECTS)

- International union of forest research organizations; oral presentation (2010)
- International union of forest research organizations; oral and poster presentations (2014)

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