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Drivers of Change in Farming Systems and Forest Cover in Ghana

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Statement of the Contribution of Others

Chapter number of thesis	Details of publication(s) on which chapter is based	Nature and extent of the intellectual input of each author, including the candidate
3	Acheampong, E. O., Macgregor, C. J., Sloan, S., & Sayer, J. (2019). Deforestation is driven by agricultural expansion in Ghana's forest reserves. *Scientific African, 5*, e00146. doi:10.1016/j.sciaf.2019.e00146	Acheampong developed the research and conceptualized the research. This was refined by Macgregor, Sloan, and Sayer. Acheampong collected the data and wrote the first draft of the manuscript which was revised with editorial inputs and constructive comments provided by Sloan, Macgregor, and Sayer.
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5	Acheampong, E. O., Sayer, J., Macgregor, C., & Sloan, S. (2020). Application of Landscape Approach Principles Motivates Forest-fringe Farmers to Reforest Ghana’s Degraded Reserves. *Forests, 11*(4), 411. doi:10.3390/f11040411	Acheampong and Sayer co-developed the research question and concept. Acheampong collected the data and wrote the first draft of the manuscript which was revised with editorial inputs and constructive comments provided by Sloan, Macgregor, and Sayer.
6	Acheampong, E. O., Sayer, J., Macgregor, C. J., & Sloan, S. (2021). Factors influencing the adoption of agricultural practices in Ghana’s forest-fringe communities. *Land, 10*(266), 11-22. doi:https://doi.org/10.3390/land10030266	Acheampong developed the research question. Acheampong collected the data and wrote the first draft of the manuscript which was revised with editorial inputs and constructive comments provided by Sloan, Macgregor, and Sayer.

7	Acheampong, E. O., Sloan, S. Sayer, J., & Macgregor, C. J., (submitted). Ghanaian forest-fringe farmers benefit from adoption of modern farming practices regardless of environmental impacts. *Tropical Conservation Science.*	Acheampong and Macgregor co-developed the research question and concept. Acheampong collected the data and wrote the first draft of the manuscript which was revised with editorial inputs and constructive comments provided by Sloan, Macgregor, and Sayer.
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Abstract

Although there are claims of expanding non-farm economy in rural Ghana, farming is still the main economic activity for over 70% of Ghana's rural residents. Various factors influence farmers to diversify their farming systems, increase or decrease their land holdings, cultivate certain crops, adopt certain agricultural technologies, and engage in varied farmland management practices. Of critical concern is the decisions that farmers in forest-fringe communities take toward their farming operations. I examined the decisions that farmers in forest-fringe communities of Ghana take concerning their livelihoods and the extent to which these decisions affect their farming systems and practices and the sustainability of the forests within and around where they farm. I used the Ashanti region which contains 58 of the 256 forest reserves in Ghana as the study area for this research.

I adopted a combination of three research approaches, namely, desk study, surveys, and action research. The desk study had two foci. First, to assess the land cover change patterns within the study area by means of Landsat satellite images processed using IDRISI Terrset and ArcGIS to identify the main causes of deforestation in the study area. Second, to review Ghana's agricultural development policies from 1997 to 2017 to identify the progress that has been made in the agricultural sector. The survey aspect involved data collection from 291 farm households in the Ashanti region about their farming operations and livelihood dynamics. Data were also collected from five stakeholder groups to source their opinions about the costs and benefits of some agricultural practices identified from the survey. These stakeholder groups are foresters, agricultural extension officers, environmental NGOs, crop/ natural resource researchers, and farmer representatives. The data from the survey were processed using a range of softwares including SPSS, Microsoft tools, and V.I.S.A multi-criteria analysis tool. The action research was carried out as an intervention to one of the identified problems – deforestation and forest degradation.

The major findings from this research have demonstrated that, first, agricultural expansion is a major cause of deforestation and forest degradation in the study area. Second, farmers in forest-fringe communities encroach forest reserves for fertile land to increase crop production because they cultivate on infertile farmlands, a contributory factor to low production. Consequently, farmers will participate in forest restoration

projects so far as they will have access to the fertile forestland to cultivate their food crops. Third, the application of the landscape approach principles for forest restoration and rural livelihoods improvement is possible at a micro scale. In addition, collaboration among all stakeholders, especially farmers within and around forest landscapes, is key to ensure effective restoration and sustainable conservation and management of forest landscapes. Fourth, while some farmers rely only on slash-and-burn cultivation because they perceive agricultural inputs to be expensive, not useful, and difficult to adopt, other farmers adopt these inputs to control weeds, pests and diseases in farms, and increase crops yields. Several other factors influence the adoption and intensity of adoption of agricultural inputs. These include farmers' age and farming experience, distance to sources of inputs, and access to extension services. Finally, reducing the use of inorganic inputs and encouraging the adoption of more organic inputs will improve the economic welfare of farmers while minimizing the environmental consequences of chemical usage. These findings aim to inform policies on sustainable farming practices to improve the wellbeing of rural residents while sustaining the remaining forest resources in the Ashanti region of Ghana.

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Chapter One: General Introduction

1.1 Background of Research

Rural Ghana has diverse livelihood systems. However, farming is the main economic activity for over 70% of the residents (Bawakyillenuo et al., 2016; Ghana Statistical Service, 2013a). Farming systems in Ghana include subsistence, commercial, small-scale, large-scale, mixed cropping, and mixed farming. Various factors such as access to infrastructure, services, and farm inputs influence farmers' decisions to diversify their farming systems, increase or decrease farm size, introduce different cash or food crops, and engage in varied farmland management practices (Acheampong et al., 2019; Acheampong et al., 2018; Acheampong et al., 2021; Asfaw et al., 2012; Barrett, 2008).

Farmers change their farming systems and operations for varied reasons. In favourable economic and environmental conditions, farmers operate to accumulate wealth, build their household capitals, and secure their livelihoods against future stresses and shocks (Belay et al., 2017; Béné et al., 2016; Gautam & Andersen, 2016). These operational decisions may include intensive use of inputs and expansion of farms to maximize outputs. In declining economic and environmental conditions, farmers operate to survive (Antwi-Agyei et al., 2014; Soini, 2005). These unfavourable conditions may include situations such as lack of access to complementary agricultural inputs due to farmers being resource-poor. Survival strategies may include continuous cultivation on poor soils resulting in low production, and encroaching adjoining forests for fertile lands to increase production. Whether farming is for survival or accumulation (Ellis, 2000), the decisions farmers take to sustain their livelihoods and the influence of their farming activities on the sustainability of the natural resources on which they depend should be of concern. Factors influencing farmers' livelihood decisions have been well-documented (Chambers, 1995; Chambers & Conway, 1992; Dossa et al., 2008; Ellis, 1998; Ellis & Freeman, 2004; Loison, 2015; Zezza et al., 2009). The consequences of farming practices and systems on the farmed environment and the natural resource such as forest from the perspectives of farmers and other environmental stakeholders have however received less research attention, at least in Ghana.

Access to natural resources such as land and forest is central to the livelihoods of smallholder farmers especially in Africa (Sayer, 2010). Analyzing the trade-offs between the sustainability of the natural resource and the livelihood system of the farmers will help to identify feasible ways that will not be detrimental to either (Sayer & Cassman, 2013). Examining the sustainability decisions these farmers take concerning their livelihoods and the environment will determine the extent to which the natural resource could be sustained. This research seeks to examine the livelihood patterns of crop farmers in communities adjacent to forest reserves in rural Ghana and the influence of their farming systems on the natural resource especially the forest within and around which they cultivate.

This research utilized ideas from the concept of sustainable livelihood (Chambers, 1989; Chambers & Conway, 1992; DFID, 1999; Ellis, 2000) and qualitative change (Macgregor, 2009) to assess factors that influence farmers' livelihood decisions, and affect farmers' adoption of various agricultural practices. These conceptual underpinnings also guided the assessment of (a) the social, economic, and environmental costs and benefits of the farming practices, and (b) the determinants of farmers' participation in forest restoration and its effects on farmers' livelihoods and the forest environment. The above components of the study were carried out using desk study, survey, and action research designs employing mixed methods of data analyses for presentation and reporting. Chapter two presents the details of the conceptual framework while the detailed methodologies are presented in the subsequent chapters. The findings from this research seek to provide insights into sustainable farming systems in a conserved multi-functional forest landscape. That is, this research aims to inform policies on sustainable farming practices within forest landscapes to improve the wellbeing of rural residents while not compromising the sustainability of the remaining forest resources.

1.2 Research Questions

The research seeks to answer the following questions.

i. In what ways do the farming systems of crop farmers affect forest reserves in Ghana?
ii. What policies will encourage farming systems that are sustainable, improve livelihoods and diminish pressure on forest reserves?

1.3 Scope of the Research

Ashanti region of Ghana is the study area. This area covers about 10% of Ghana's land and contains almost a quarter (58) of the forest reserves in the country, making it the second largest in terms of forest cover after the Western region (RMSC, 2016). This region was chosen for the study because it has a significant deforestation rate in the country and the north part is gradually transitioning from dense forest to savannah vegetation. Even though other regions in Ghana also portray these characteristics evident in the Ashanti region, this study region hosts 23% (3,785 km^2) of the country's forest reserves making it the second largest host of forest reserves in Ghana. Secondly, the Ashanti region hosts the most forest-fringe communities in Ghana and majority of the inhabitants are farmers depending on the forest environment for their livelihoods. Carrying out the research in this region will provide insight into the factors of deforestation and possible measures that can be employed to manage the reserves for the benefit of the people and the environment. The specific study areas used for this research are detailed in the data chapters.

Contextually, this study covers the drivers of deforestation in the Ashanti region and the extent to which agricultural practices contribute to forest-cover change. The study further examines the feasibility of engaging farmers in forest restoration without any financial benefit sharing arrangements. This research again assesses the farming practices the farmers in the study area have adopted and what factors influence the farmers' adoption of those practices. Expert opinions are then sought concerning the social, economic, and environmental costs and benefits of the various farming practices adopted. The study finally concludes with the kind of policies that are needed to ensure sustainable agriculture in a conserved multi-functional forest landscape.

1.4 General Research Process and Approach Adopted

This research followed the scientific process by first identifying the research problem relating to the interrelations of farmers' livelihoods, farming practices and forest-cover change. Most farmers in forested areas farm within and at the fringes of forests. Encroachment of forests for fertile lands for food crop cultivation is evident in forest-fringe communities. Farmers' livelihood security is one major cause of forest degradation. With this background, I reviewed relevant literature on sustainable livelihoods in general but with emphasis on rural livelihoods. I then narrowed my literature review focus to farmers' livelihood strategies, farming practices, and sustainability decisions with the aim to establishing the theoretical framework for the research. Through the findings of the literature review, I established the research questions as indicated under section 1.2.

The nature of the research questions warranted the adoption of a combination of three research approaches, namely, desk study, survey, and action research. The desk study was carried out to have preliminary information about the land cover in the study area, with emphasis on agricultural land and forest cover. I spatially examined the trends in land cover changes in the study area using Landsat satellite images. This gave me insights into where to conduct the survey and what variables to consider in the survey.

The survey aspect required data collection from farmers and institutional representatives. Questionnaires were designed for data collection and observable variables were captured through photographs. Pre-test was initially carried out to see how the response and the entire exercise would be. This helped to make the necessary adjustments in the questionnaires to enhance ease of data collection and understanding of the questions. The data collected were processed and analysed for easy interpretation. The action research was lastly carried out as an intervention to one of the identified problems.

Based on the trends in forest and agricultural land use identified in the desk study, I used the operations of the farmers in forest-fringe communities as the phenomenon under study. I conducted surveys to assess how the livelihood systems and farming practices of the farmers affect the integrity of the forest reserves fringing the cultivated lands of the farmers. I adopted quantitative methods to examine the factors that influence the farmers to adopt various agricultural practices and the extent to which they are motivated to adopt more or less of the practices. I then assessed the cost and benefits of the farming practices the farmers adopt through social, economic, and environmental dimensions. This was done to suggest possible recommendations for sustainable and forest-friendly agriculture.

The survey confirmed the findings of the desk study about the deforestation problem in the study area. I identified through the survey that some of the farmers cultivate illegally in the degraded portions of the forest reserves due to scarcity of fertile farmlands. These farmers had challenging situations with the foresters because forest protection law does not permit farmers to farm illegally in forest reserves. Farmers can however be engaged in forest restoration projects through which they can cultivate on the land while maintaining young trees. I therefore employed participatory action research to involve willing farmers in restoring degraded portions of one forest reserve and assessed whether their participation has improved their livelihoods. The landscape approach was adopted for this action research.

1.5 Ethical Considerations

This research was carried out ethically. James Cook University's Human Research Ethics Committee granted the ethics approval for this research (application ID: H7199). Community entry protocols were followed in each community I carried out surveys. Information sheets were given to the leaders of each community whose farmers were surveyed. Written informed consent containing the purpose of the study were given to each participant for their consent to be sought before the survey. However, most of the farmers preferred verbal informed consent. As a result, their consents were audio-taped.

1.6 Structure of Thesis

My thesis is made up of nine chapters with the main data chapters (3, 4, 5, 6, 7 and 8) prepared as standalone publications although not all of them have been published as at the time of thesis submission.

Following from chapter one, the general introduction, chapter two presents the conceptual framework for the research laying emphasis on the decisions farmers take to secure their livelihoods and the influence of those decisions on the sustainability of the natural resource. Chapter two forms the conceptual basis for the entire thesis.

Chapter three examines the ways in which agricultural expansion, as one decision of farmers to increase outputs, causes deforestation in the studied forest reserves.

Chapter four lays emphasis on the fact that forest-cover increase that has been witnessed in Ghana from 1990 to 2015 in the midst of deforestation is actually a forest transformation through the maturity of tree crop plantations and commercial planted forests.

Chapter five demonstrates through an action research that while farmers contribute to deforestation, the same farmers can be engaged in forest restoration without any benefit sharing arrangements. This chapter shows that the application of the landscape approach for forest restoration and rural livelihood improvement is possible at a micro scale.

Chapters six presents the rationale behind farmers' adoption or non-adoption of complementary agricultural practices as well as the factors that influence the intensity of adoption. This chapter emphasizes how adoption and non-adoption of agricultural practices can both influence farmers' encroachment of forest reserves.

Chapter seven builds on chapter six by demonstrating through multi-criteria analysis that agricultural innovation through the use of agricultural inputs is more beneficial to farmers and the farmed environment than practicing traditional slash-and-burn farming.

Chapter eight reviews five agricultural policies spanning 1997 to 2017 to identify the progress of agricultural development in Ghana, especially strategies put in place to address issues of agricultural innovations identified in this research.

Chapter nine concludes my thesis with a summary of the major findings, major recommendations for sustainable farming in a conserved forest landscape, the general concluding remarks for this research, and finally, the areas that require further research. Figure 1.1 diagrammatically shows the research questions to which each of the chapters belong.

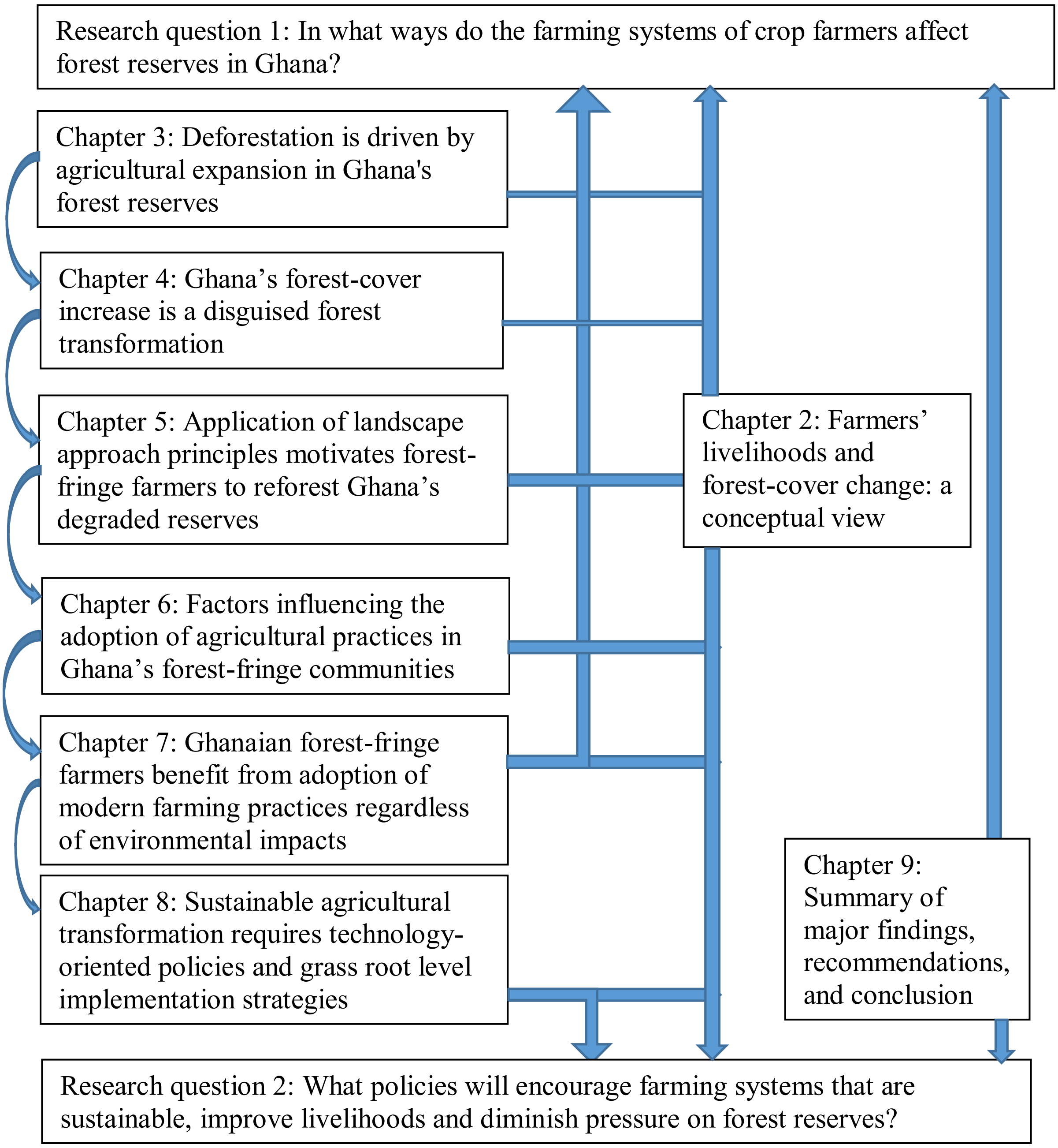


Figure 1.1 Thesis Structure for Main Data Chapters

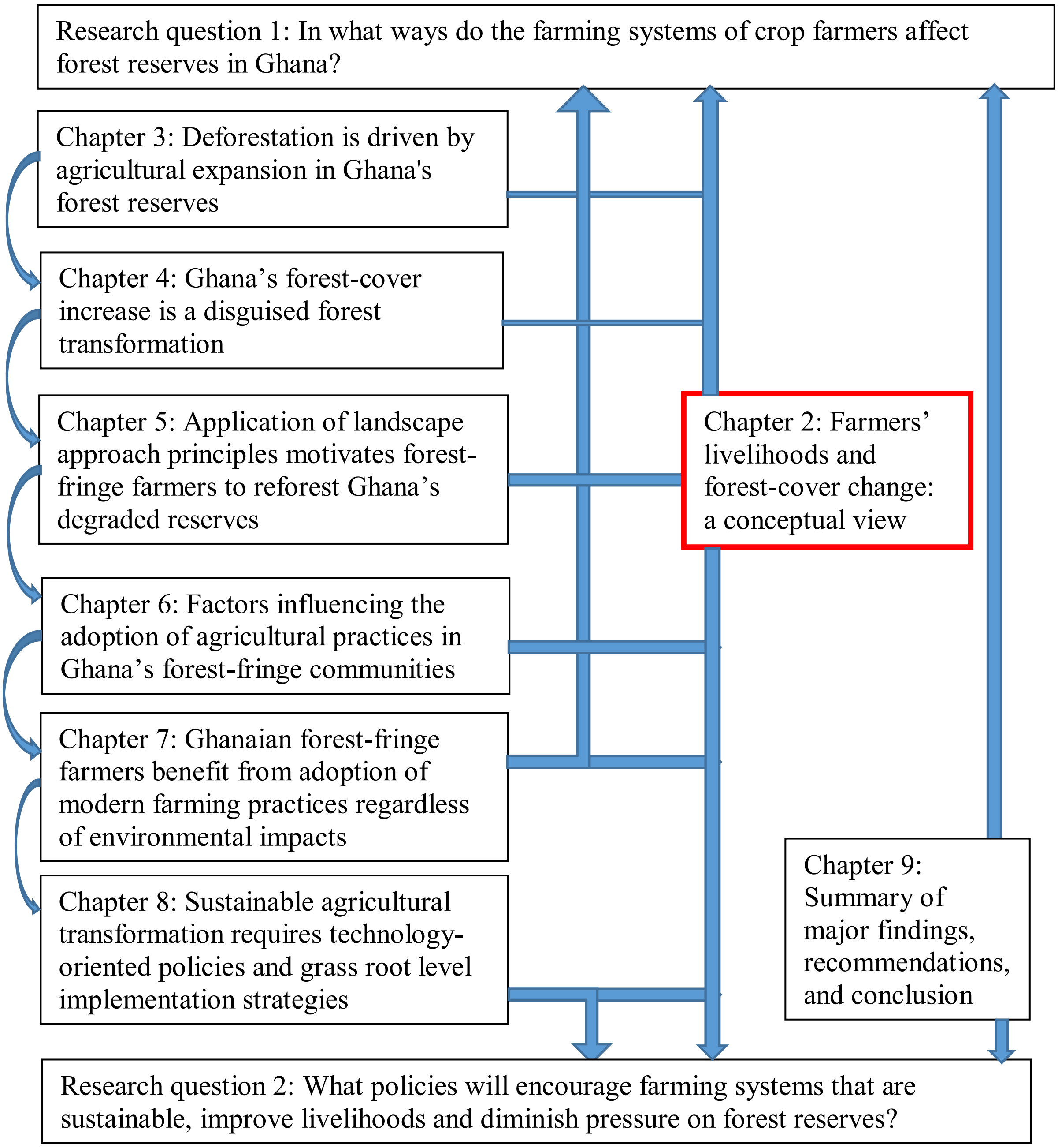
The research publications from this thesis (and those to be submitted soon) are below.

Chapter three:	Acheampong, E. O., Macgregor, C. J., Sloan, S., & Sayer, J. (2019). Deforestation is driven by agricultural expansion in Ghana's forest reserves. *Scientific African, 5*, e00146. doi:10.1016/j.sciaf.2019.e00146
Chapter four:	Acheampong, E. O., Sloan, S. Sayer, J., & Macgregor, C. J., (to be submitted). Ghana's forest-cover increase is a disguised forest transformation. *Journal of Sustainable Forestry.*
Chapter five:	Acheampong, E. O., Sayer, J., Macgregor, C., & Sloan, S. (2020). Application of landscape approach principles motivates forest-fringe farmers to reforest Ghana's degraded reserves. *Forests, 11*(4), 411. doi:10.3390/f11040411
Chapter six:	Acheampong, E. O., Sayer, J., Macgregor, C. J., & Sloan, S. (2021). Factors influencing the adoption of agricultural practices in Ghana's forest-fringe communities. *Land, 10*(266), 11-22. doi:https://doi.org/10.3390/land10030266
Chapter seven:	Acheampong, E. O., Sloan, S. Sayer, J., & Macgregor, C. J., (to be submitted). Ghanaian forest-fringe farmers benefit from adoption of modern farming practices regardless of environmental impacts. *Tropical Conservation Science.*
Chapter eight:	Acheampong, E. O., Macgregor, C. J., Sloan, S., & Sayer, J. (to be submitted). Sustainable agricultural transformation requires technology-oriented policies and grass root level implementation strategies

Although each journal has a different formatting style, for the purpose of consistency in this thesis, I have formatted all the published chapters in accordance with James Cook University's thesis formatting style. With the exception of the formatting, none of the contents of the published chapters has been changed or removed. I acknowledge that there are very few repetitions in some of the published chapters, specifically in the methods sections where the study area and sample size selections are described. I intentionally left them to avoid inconsistency with the standalone published contents.

What Next?

Chapter two presents the framework upon which the entire thesis answering the two research questions is based. The framework is based on how farmers take livelihood decisions based on different circumstances.



Chapter Two: Farmers' Livelihoods and Forest-Cover Change: A Conceptual View

Abstract

Rural livelihood diversification has been the norm in most developing countries especially Africa. Farming is the main economic activity in rural Africa. The diversification of farmers' livelihoods may affect their farming operations with consequences on the natural resource base. For instance, a farmer may engage in non-farm economic activity and use their income to purchase farm inputs to intensify their agriculture. These inputs may consequently have effect on the farmed environment and the forest within and around where they farm. I reviewed literature on four Sub-Saharan African countries to identify the factors that influence smallholder farmers to diversify their livelihoods and whether the sustainability of the natural resource is considered in their diversification decisions. I identified that environmental sustainability was mostly neglected in smallholder farmers' diversification decisions. I argue that farmers can sustain their livelihoods for a longer period if their farming activities do not deplete the natural resource base.

Keywords: Africa; sustainable livelihood framework; smallholder farmers; rural livelihoods improvement; farm households; developing countries.

2.1 Introduction

The concept of livelihood has received much consideration in rural development discourse. A significant characteristic of the concept is the means through which assets link to activities, and the utility of agencies and/or institutions and external environments in defining the uses of and returns to assets (Tanle, 2014). Households are rational economic actors maximising outputs and minimising costs. Hence, the returns to labour to some extent determine the livelihood diversification decisions of the household. The rationale behind livelihood diversification is sustainability of the livelihood system mainly the outcomes of economic activities and the environment (DFID, 1999; Scoones, 1998).

Diversification is the norm in rural areas especially in developing countries (Babulo et al., 2008; Belay et al., 2017; Gautam & Andersen, 2016; Sunderlin et al., 2005). Rural livelihood diversification is "the process by which rural families construct a diverse portfolio of activities and social support capabilities to survive and improve upon their standard of living" (Ellis, 1998, p. 4). Diversification is not necessarily a pathway out of poverty. It depends on the type of activity in which a household engages and the motivation and capacity for diversification (Macgregor, 2009). Asset-rich households can diversify into high return activities to accumulate wealth and sustain their livelihoods while vulnerable households may be incapable to do so (Gautam & Andersen, 2016). A livelihood is considered sustainable when it can manage stresses and shocks using the available assets without negatively impacting on the environment for future generations (Carney, 1998). This review examines whether environmental sustainability is considered when diversification decisions are taken.

Livelihood diversification does not only concern rural livelihoods. It is recognized as a survival plan for urban households in third world countries, and farm households and labour markets in developed countries (Eroğlu, 2013; Méndez-Lemus & Vieyra, 2014; Moser, 1998; Rakodi & Lloyd-Jones, 2002). This review however limits its scope to rural livelihood diversification with much focus on African farmers. This review lays emphasis on the concept of livelihood by looking at the various components in the livelihood system and the relationships between the components. The various factors that influence households to diversify are also reviewed. Case studies from four Sub-Saharan African countries emphasising on smallholder farmers' livelihood diversification are discussed. The review concludes by drawing on the case studies to conceptualise a feasible way of ensuring sustainable livelihood diversification that does not neglect the sustainability of the natural resource.

2.2 Conceptualising Livelihood

After criticisms from various angles on the concept of livelihood, Karl Polanyi and Harry Pearson gave the concept a more theoretical foundation through their book "The Livelihood of Man". Linking to livelihood, Polanyi and Pearson (1977) explained that the economy is socially, culturally and historically embedded and not only concerned with the economic maximisation behaviour of individuals. They stated that people need material resources to satisfy their needs and wants but to understand their livelihoods, one must look beyond the material resources. Since then, livelihood has been defined in various ways to include economic, social, physical, and environmental dimensions.

According to Chambers (1989, p. 7), a livelihood means "adequate stocks and flows of cash to meet basic needs". Chambers' explanation is however limited in scope. It does not provide the means of measuring the adequacy of what stocks, neither does it show the means through which cash flows and is stocked. To expand and clarify this, Chambers and Conway (1992) in a broader dimension defined livelihood as the capabilities, assets, and activities needed to operationalize survival strategies. Scoones (1998) after reviewing the various definitions of livelihood arrived at a comparable definition but geared towards the idea of sustainability. Still building on previous definitions, Ellis (2000, p. 10) defined livelihood as "the assets (natural, physical, human, financial, and social), the activities and the access and returns to these (mediated by institutions and social relations) that together determine the living gained by an individual or a household".

Niehof (2004) sees livelihood as a system with the following components which have already been explained by various researchers.

- Inputs: The immediate resources and assets needed to generate livelihoods. These inputs could be human (such as cognitive and other skills), material (e.g. money, agricultural inputs and equipment, and transportation facilities), and ecological assets both natural and man-made (Engberg, 1993).
- Activities: The livelihood choices undertaken using assets and resources to achieve livelihood goals (DFID, 1999).
- Outputs/Outcomes: The achievements from livelihood strategies (DFID, 1999).
- Purpose: A sense of adequacy of stock to meet basic needs (Chambers, 1989).
- Agency: The networking of, for instance, farmer households or individual families towards achieving sufficiency or adequacy.
- Quality: The extent to which the produced livelihood becomes vulnerable or sustainable (Ellis, 2000).
- Environment: The setting within which the livelihood system operates (Niehof, 2004).

Most of the discourses around the concept of livelihood are geared towards sustainability. As argued, a livelihood is sustainable when it can deal with and recuperate from pressures and shocks and retain or improve its capabilities and possessions both now and in the future, while not damaging the integrity of the natural resource on which the livelihood activities are based (Carney, 1998; DFID, 1999). The notion of sustainable livelihood forms the basis of different sustainable livelihood approaches (Babulo et al., 2008; Scoones, 1998). A sustainable livelihood framework (SLF) was developed by the British Department for International Development (DFID) which was integrated in its program for development cooperation in 1997 (DFID, 1999). Since then, the framework has been widely used in development practice.

The framework illustrates people with access to certain assets (human, natural, financial, social, physical) operating in the context of vulnerability. The assets increase in value or otherwise through the prevailing social, institutional and organisational structures and processes. This context determines and shapes the livelihood strategies open to people. The ability of people to draw from their assets and strategize through environmental, social, economic, and institutional circumstances to engage in various activities will determine the livelihood outcome of the people. A livelihood is sustainable when it is resilient to shocks and stresses and does not impose negative impacts on the environment (Carney, 1998).

The livelihood activities are also influenced by the various assets available to an individual or a household. These assets comprise a stock of capitals that can be stored, accumulated, exchanged, or allocated to income generating activities for livelihood benefits (Rakodi, 1999). These capitals can be held as a private or common property. The most important thing is that the poor has access to, and can use them. "Access is the process that brings stakeholders from endowment to entitlement" (Geiser et al., 2011, p. 317). Capitals are not only for making a living. Possession of capitals define the world of the possessor. Capitals give people the capability to be and to act, to reproduce, and to challenge or change the rules and regulations that govern the control, use and transformation of resources (De Haan, 2012). These capitals are in different forms and have different uses to different people.

Natural capital comprises of natural resources such as land, water, forest, and wildlife while financial capital composes money and savings which people depend on for their living or use it to purchase other capitals. Human capital covers skills, education and health. Social capital is the internal and external networks and associations, laws, policies, regulations, beliefs, norms, values and incentives enforced and managed by institutional structures that could have influence on livelihood capitals, strategies, and outcomes. Physical capital are the enabling facilities such as infrastructure that propel livelihood activities (Tanle, 2014). The use of these capitals is influenced by the vulnerability contexts within which people operate.

Vulnerability is an external component that influences the operation of capitals and activities to yield outcomes. Vulnerability is the change in environmental circumstances (ecological, social, economic, and political) in the form of shocks, trends, and seasonal cycles that pose insecurity threats on the wellbeing of an individual, a household, or a community (Moser & Dani, 2008). Through institutional structures and processes, a livelihood becomes resilient or vulnerable to stresses, shocks and seasonal cycles. Resilience (synonymous to sustainability) and vulnerability are factors that influence livelihood diversification. The succeeding discussions on livelihood diversification would be limited to farm households.

2.2.1 Livelihood Diversification of Smallholder Farmers

Two main approaches are used to analyse livelihood diversification behaviour of farm households. These are 'the household economic model' and 'the livelihood approach' (Chambers & Conway, 1992; Scoones, 2009; Singh et al., 1986; Taylor & Adelman, 2003). The household economic model considers farm households as production units that maximise utility and minimise cost. With a given assets, the returns to labour from farm activities compared to non-farm activities determines a household's diversification strategy. Despite the strengths of the household economic model, it has been criticised for not considering survival strategies of livelihoods under stress, and the social relationships between household members. The assumption of perfect markets especially for developing countries has also been criticised (De Janvry & Sadoulet, 2006).

The livelihood approach incorporates the weaknesses of the household economic model to analyse the livelihoods of people. The people-centred characteristic of the livelihood approach has broadened its applicability in various contexts. The approach mostly employs the sustainable livelihood framework (SLF) to analyse the livelihoods of people. Despite its weaknesses in measurement difficulties, the approach has proven useful in examining the diversity of farming systems and the influence of social factors on livelihood strategies and outcomes (Ellis & Freeman, 2004). Both approaches are however inclined to the sustainability of the farm household.

Sustainability is the capacity to muddle through and recover from stresses and shocks, while preserving or improving capabilities and assets (Chambers & Conway, 1992; Scoones, 1998). Vulnerable households may suffer from assets constraints resulting in difficulties with securing basic needs, creating surpluses, and coping with shocks. Contrariwise, sustainable households may have sufficient and stable assets to create more wealth to recover from crises, stress and shocks (Niehof, 2004). Diversification is an approach for decreasing livelihood vulnerability. It is the process through which smallholder farmers combine varied range of activities and assets to survive and improve their standard of living (Ellis2000).

Smallholder farmers combine various assets to engage in agricultural and non-agricultural activities for survival and to spread livelihood risks (Dossa et al., 2008; Zezza et al., 2009). Diversification is an outcome of dynamic adaptation to various livelihood constraints and opportunities. Households diversify for two reasons: to survive under deteriorating conditions or to increase security under improving economic conditions (Yaro, 2006). To increase security through diversification, rural households must be able to generate cash, build assets, and diversify across farm and non-farm activities. In some cases, rural households migrate to areas with economic opportunities to sustain their livelihood (Loison, 2015). Diversification can increase farm investment and productivity or impoverish agriculture through the sale of agricultural resources to sustain livelihood (Ellis, 1998). Rural livelihood diversification can reduce or increase rural inequality and can have either positive or negative effect on households' assets and wellbeing. Several factors contribute to the need for diversification.

2.2.2 Determinants of Livelihood Diversification of Smallholder Farmers

Smallholder farmers diversify either for accumulation or survival. The decision to diversify results from seasonal variations, labour market changes, risk mitigation in anticipation of shocks, and coping strategies aftershocks (Ellis, 2000). These factors are also influenced by institutional structures and processes. In favourable r ural economic conditions, diversification can have 'economy of scope' effect through the investment of resources across multiple scopes and reap higher per unit returns (Gautam & Andersen, 2016). For instance, subsistence farmers' diversification into non-farm enterprises may improve their income, enhance food security, increase agricultural production through capital investment, and be able to cope with environmental stresses (Belay et al., 2017; Béné et al., 2016).

Farm households also diversify due to necessity (out of desperation) or choice (voluntary decision). Diversification by choice leads to increase in wellbeing as the household does not diversify only for survival but also accumulation. Diversification by necessity is mainly for survival which can even lead households into a more vulnerable livelihood system (Ellis, 2000). The decision to diversity is based on the capitals available to a household. Rich households can diversify into high return non-farm activities while poor households get stuck in low returns non-farm activities based on their capitals (Antwi-Agyei et al., 2014; Soini, 2005).

To sum up, Macgregor (2009) laid emphasis on some factors that offer opportunities for encouraging and enhancing sustainable diversification. In his research, for qualitative diversification to occur there must be understanding (gained through access to human and social capital), motivation (through security of tenure, attitudes, pressure, and the desire to remain) and capacity (built through infrastructure, finance and skills). Once these factors are critically analysed and assessed, a household will then decide whether to diversify. The next section reviews literature on factors that drive diversification in Sub-Saharan Africa and how the natural resource and the livelihoods of the smallholder farmers are sustained.

2.3 Livelihood Diversification of Smallholder Farmers in Sub-Saharan Africa

Factors influencing livelihood diversification in four countries were briefly reviewed. These countries are Ethiopia, Kenya, Tanzania, and Ghana. These countries were chosen in addition to Ghana because, first, they have similar vulnerability issues including climate variability, exploitation and depletion of natural resources, unfavourable production environments, and land degradation. Second, over 70% of the rural households in these countries are farmers and are faced with yield reduction issues, occurrence of crop pests and diseases, household food insecurity, and subsistence cultivation with little to no adoption of agricultural inputs. Third, farmers in these countries have similar constraints to farm innovation and diversification due to factors such as inadequate access to agricultural extension services and farm inputs which partly lead to low adoption of improved technology (Antwi-Agyei et al., 2014; Balama et al., 2016; Belay et al., 2017; Béné et al., 2016; Debela et al., 2015; Djokoto et al., 2017; Mathenge & Tschirley, 2015; Mshenga et al., 2016; Tesfaye & Seifu, 2016). This review was limited to available literature on rural livelihood diversification of smallholder farmers since farming is the predominant economic activity in rural Africa. The review did not cover urban areas because agriculture is not the major economic activity in urban Africa.

In Ethiopia, 80% of the rural households are farmers and smallholder farms account for 95% of the total area under cultivation (Rehima et al., 2013). For the past century, the agricultural sector has been exposed to climate variability with consequences on the farmers' livelihoods. Climate change in Ethiopia has resulted in erratic rainfall patterns, seasonal flooding, yield reduction, and occurrence of pests and diseases. These anomalies have resulted in household food insecurity, soil degradation, and a lock up in subsistence farming (Belay et al., 2017; Debela et al., 2015; Regassa, 2011; Tesfaye & Seifu, 2016).

Some of the studies stated that the affected farmers are willing to diversify but are constrained by several factors including lack of information on climate change forecasting, lack of irrigation facilities, poor access to extension services and market infrastructure, and low investment in soil management. Notwithstanding these challenges, resilient farmers diversify their livelihoods through non-farm enterprises, crop diversification, migration, small-scale irrigation, and communal resource pool. These farmers diversify based on the assets at their disposal (Debela et al., 2015; Regassa, 2011; Rehima et al., 2013).

The Kenyan case is not different from that of Ethiopia. Livestock and crop farmers have been facing unfavourable environmental and climatic conditions for decades. A study of 1324 agricultural households in Kenya identified that rural households engage in off-farm work as a long-term livelihood strategy to counter climate effects on their farming operations (Mathenge & Tschirley, 2015). Farmers sometimes migrate, rely on remittances, or engage in agricultural wage labour as short-term coping strategies (Matsumoto et al., 2009). Farmers exposed to land degradation practice sustainable land management (SLM). These practices include grass reseeding and agroforestry (Schwilch et al., 2014).

Farmers in Kenya are making use of SLM technologies due to the multiple benefits. The growing of multi-purpose trees and grass that can withstand high temperatures and low rainfall provide fodder for livestock, fuel, timber, medicine and food for household use, and green manure for soil enrichment (Mganga et al., 2015). Before the incorporation of SLM technologies, farmers sold their livestock during the dry season due to high livestock mortality rate. With the adoption of grass reseeding and other SLM technologies, farmers could feed their livestock, feed the livestock of neighbours at a fee, and sell grass seeds for additional income which is channelled into household use (Mganga et al., 2015). Some farmers are however constrained by inadequate capital, land tenure insecurity, illiteracy, and lack of inputs and equipment to practice SLM technologies (Opiyo et al., 2015).

Aside from SLM technologies, some famers have diversified into the cultivation of African Indigenous Vegetables (AIVs). The reason is that the cultivation of traditional crops such as maize, beans and potatoes in Kenya require large parcels of land. The increasing climate variability coupled with population growth has resulted in small farm sizes making the enterprise less viable for income and food security. As these farmers are seeking to intensify agricultural production in the face of unfavourable environmental factors, climate resilient crops are the only option. Dynamic famers therefore cultivate AIVs with their traditional crops to sustain their production since these crops have market opportunities and could withstand harsh climatic conditions (Mshenga et al., 2016).

Climate variability and other external stresses and shocks are not affecting only crop and livestock farmers but also fishers. At the Kenyan side of Lake Victoria, fishing is the main livelihood activity. However, for the past 20 years, fishing has become less viable due to fishing pressure, water level reduction, and declining fish stock. Consequently, some fishers are diversifying into non-fish work to augment their income (Olale & Henson, 2012). Food crop cultivation, livestock farming, and non-farm enterprises are patronised by fishers as complementary livelihood strategies. Diversification however depends on the asset holding of the fishers. Asset-poor fishers have no option than to continue with their unsustainable fishing work (Olale & Henson, 2013; Omwega, 2006).

In Tanzania, households in the southern slopes of Mt. Kilimanjaro have been practicing the Chagga farming system for over five centuries (Hamilton, 1979; Moore et al., 1977). The Chagga people who descended from various tribes migrated to the forested foothills of Mt. Kilimanjaro and transformed the native forest by replacing less useful trees with new tree and crop species while retaining trees that provided fodder, fuel, and fruits (Von Clemm, 1964). The Chagga farming system involves intensive smallholder production of both subsistence and cash crops. The system integrates several multi-purpose trees and shrubs with food and cash crops and livestock on the same land, representing an intensive agroforestry land use model (Fernandes et al., 1985). Before the insurgence of climate and other unfavourable environmental conditions, this farming system was recognised as a sustainable land use system model. The growing of coffee which was highly profitable enhanced faster development in the area. Income from coffee was used to improve farming practices and water supply, establish public infrastructure and services, and invest in personal and household conditions (Moore, 1986). The Chagga farming system started experiencing several challenges at the beginning of the 20th century with adverse effects on local livelihoods. Farm sizes have been decreasing due to population growth and the viability of the system has declined due to coffee price reduction. Harsh climatic conditions have resulted in shortage of water supply for irrigation (Hastenrath & Greischar, 1997).

Chagga farmers have resulted to crop, livestock, and non-farm diversification. Aminu-Kano (1992) observed that banana plants were increasing in farms than coffee. The cultivation and sale of beans and vegetables were some of the substitutes for coffee. Other farmers complemented their crop farming with livestock rearing such that the income from the sale of livestock products could be invested in farming and support household basic needs (Soini, 2005). Vulnerable households that were unable to sustain their livelihoods with farming on their small parcels of land (< 0.5ha) sold their lands and engaged in non-farm enterprises. In all their diversification techniques, the asset holding of these farmers determined what they could do. Farmers with sufficient capitals engaged in lucrative off-farm jobs while asset-poor households often engaged in marginalised jobs (Soini, 2005).

Forest adjacent households in Tanzania did not sell their lands due to climate change but rather diversified their crops, changed cropping calendar, planted trees, and practiced irrigation (Sanga et al., 2013). Land tenure security however determined the adoption of these SLM technologies. Farmers with insecure land tenure often increased their reliance on non-timber forest products (NTFPs). NTFPs such as building poles were collected to reconstruct houses destroyed by floods, a consequence of climate change. The sale of NTFPs provided short term income to farmers during off farming seasons (Balama et al., 2016). In areas where forests were highly degraded or under strict protection, smallholder farmers planted viable trees on their farms. The sale of the produce from these trees provided additional income to the households. Additionally, the trees were used for firewood and timber for household use while stabilising soil fertility at the same time (Faße & Grote, 2015).

In Ghana, rural livelihood diversification has taken different forms for decades. Farm, non-farm, and crop diversification have been the norm for smallholder farmers. In the cocoa growing areas of Ghana, cocoa farmers have been diversifying into non-traditional export crops as a risk reduction strategy. Cocoa production is a long-term livelihood strategy. For these farmers to sustain their livelihoods, they intercrop cocoa with short maturity food crops to ensure food security (Kamiya & Ali, 2004). Some farmers even cultivate food crops on separate plots and sometimes engage in non-farm enterprises for income while waiting for the cocoa production season (Aneani et al., 2011). Commercial-oriented farmers engage in the production of high-income vegetables for export. These farmers cultivate throughout the year, shifting attention from cocoa to commercial vegetables during off cocoa seasons. These farmers invest a portion of their cocoa proceeds into the production of the other cash crops to accumulate wealth and sustain their living (Djokoto et al., 2017).

In northern Ghana where crop farming employs almost 90% of the rural households, climate variability has had several adverse effects on the farmers' livelihoods (Bawakyillenuo et al., 2016). Farm households had to employ a range of adaptation strategies to cope with climate change. These strategies included change of planting calendar, planting early maturing and weather resistant varieties, growing multiple crops, trading in food crops, and agro-processing (Kuwornu et al., 2014). The ability to adapt however differs based on the available resources a household possesses. For instance, farmers with no access to irrigation facilities could not cultivate during climate-harsh seasons. These farmers had to sell their assets such as livestock to survive. In extreme cases, the farmers migrate temporarily to bigger cities where environmental conditions are better and casual jobs are available (Antwi-Agyei et al., 2014).

It is not only farming communities that are faced with stresses and shocks. Like Kenya, Fishers in Ghana are also diversifying into pottery, wage labour, construction works, and food processing jobs. These fishers are diversifying due to the declining fish stock, pressure on fishing, and water level decline (Kuwornu et al., 2014). In forest-fringe communities, asset-poor farmers with no access to non-farm enterprises recognise NTFPs as a significant source of income as it smooths and buffers seasonal cash flow gaps. The transition from the reliance on NTFPs to engagement in high income activities depends on the resource base of the individual as well as access to external resources such as infrastructure and social networks and institutions (Malleson et al., 2014).

2.3.1 Livelihood Diversification: Lessons from Sub-Saharan Africa

Five main lessons have been drawn from the case studies. These lessons concern exposure and its consequences, constraints to diversification, time, decision making, and asset holding. The exposures can be broadly classified under weather shocks, over-exploitation of natural resources, and unfavorable production environment. These external forces result in seasonal flooding, yield reduction, extended drought, soil degradation, subsistence farming, occurrence of pests and diseases, household food insecurity, and poverty. Most smallholder farmers are unable to counteract these external influences due to factors such as lack of access to information (e.g. on weather), infrastructure (e.g. for irrigation), extension services, inputs and assets, and technology (Balama et al., 2016; Belay et al., 2017; Mshenga et al., 2016). These constraining factors make affected households more vulnerable to the exposures. Access to these 'factors of production' determines households' diversification choices (Watete et al., 2016).

From all the four countries, households were doing their normal livelihood activities until the time that external exposures emerged and impacted their activities. Time is a major factor in livelihood activities and decisions (Niehof, 2004). Households diversify their livelihoods at a time when external shocks and stresses emerge. The ability to predict exposures in a livelihood system is a major differential factor between resilient and vulnerable households. Strategic decisions about livelihood adaptation strategies are mostly taken by households who predict the timing of stresses and shocks.

Although livelihood diversification is the norm, it does not happen at a goal. Households make continuous decisions on what to do to survive. In the Tanzanian case for example when coffee production became less viable, the farmers initially supplemented coffee with banana, then substituted coffee with beans and other vegetables, and finally added livestock rearing (Soini, 2005). The Ghana case revealed that the cocoa farmers initially inter-planted cocoa with vegetables and other food crops, then got separate lands for vegetables, and even diversified within the vegetable crops (Djokoto et al., 2017). The continuous decision to diversify a livelihood strategy is based on the level of sustenance from the existing strategies, the viability of the diversified strategy, and the motivation for diversification. Decision making about diversification is based on external influences and the asset holding of the household.

Not all households are able to take pragmatic decisions about their livelihood strategies in the face of uncertainties. Households that can realise their decisions are the ones with stable resource base (Béné et al., 2016). In Tanzania, those households who could not sustain their livelihoods with their small farms sold their lands and engaged in non-farm enterprises. Households with stable financial assets bought these lands to accumulate wealth (Soini, 2005). In Kenya, while some fishing households diversified into farming and non-farm enterprises, asset-poor households continued with the unsustainable fishing job (Olale & Henson, 2013). In Ghana, the farm households in the northern territory who had limited assets had to migrate to cities for casual jobs while asset rich households engaged in agro-processing and other lucrative non-farm business to survive and keep their farms (Antwi-Agyei et al., 2014). Whereas some households dispose their assets to survive, others accumulate wealth through their existing assets (Béné et al., 2016).

Throughout the literature, the livelihood decisions of the smallholder farmers did not include the sustainability of the natural resource base. The SLM technologies practiced in Tanzania and Kenya were introduced after climate change has had adverse impacts on the livelihoods of the people. Even that, more attention was given to the sustainability of the livelihood system. Farmers diversified and invested some of the returns in farming. This investment could be in the form of chemical inputs to increase yield or expansion of farms to increase production. This investment may have consequences on the environment such as soil and water pollution (e.g. excessive use of chemicals) and deforestation (e.g. expanding farms into forests). With time, these livelihood strategies can have significant detrimental consequences on the natural environment to make the livelihood system less viable and consequently unsustainable. Diversification decisions should therefore not concern the sustainability of the livelihood activities alone. The natural resource should also be sustained so that it will not generate unfavourable conditions for the viability of the activities in the future.

Smallholder farmers make decisions about the sustainability of their assets and welfare. A farmer's livelihood is sustained when it is resilient to exposure, not reliant on external supports that are not financially and institutionally defensible, retains continuing efficiency of natural resources, and does not compromise the livelihood options available to others (DFID, 1999). Most environmental related exposures such as deforestation, land degradation, and drought may be caused by a neglect of environmental sustainability in the livelihood sustainability decisions of households or trade-offs between dimensions of livelihoods outcomes and environmental sustainability.

Access to natural resources is crucial because it underpins the livelihoods of smallholder farmers in Africa (Sayer, 2010). Analyzing the trade-offs between the sustainability of the natural resource base and the livelihood system will help to identify feasible ways that will not be detrimental to either (Sayer & Cassman, 2013). Although the implications of diversification strategies on smallholder farmers in times of stresses and shocks have been well documented, the consequences of the adaptation strategies on the natural resource base have not been adequately analyzed (Deligiannis, 2012). It is possible that smallholder farmers adapt to stresses and shocks emerging from the natural resource supporting their livelihoods. Examining the sustainability decisions these farmers take concerning their livelihoods and the environment will determine the sustainability of the natural resource. In this study, the focus on the sustainability decisions that would be accessed revolve around the farming systems and practices farmers engage in at a time. The sustainable agriculture framework (Figure 2.1) is a suggested model that could be used to analyse and recommend how a farmer's natural resource can be sustained when engaging in various farming systems and practices.

2.4 Sustainability of a Farmer's Livelihood: A Framework for Analysis

Smallholder famers engage in varieties of farming systems and practices to sustain their livelihoods. For farming households to secure their livelihoods, sustainability decisions should be taken concerning the capitals accessible to them and how they can utilize these resources for their benefits amidst exposure to external circumstances (Carr, 2013). Farming households require natural and financial capitals to form the foundation of their economic activity – farming. Farmlands and funds may be obtained from either the household's capital stock, other individuals, or institutions. Financial institutions may provide credit facilities to farmers while institutions owning lands may lease out portions to farmers. Some individuals with funds and land may also lend their resources to farmers on benefit sharing terms. The various forms of access to land and funds for farming will determine the farming systems and practices that would be adopted.

The farming systems and practices in which farmers would invest their capitals would depend on the farmers' extent of knowledge about the costs, benefits, and ease of application of those systems and practices, and terms and conditions associated with the land on which they cultivate. Intuitional influence on the agricultural practices farmers adopt is critical as wrong applications could be detrimental to the farmers and the farmed environment. Institutional influence could be in several forms. The commonest form are through education and collaboration. Agricultural education through institutions such as agricultural extension services could lead to correct application of practices. Institutional collaboration with farmers could lead to practices that would be beneficial to farmers in the long term without compromising environmental conservation, example, forestry institutions engaging farmers in land sharing and land sparing practices.

The decisions farmers take concerning their farming operations and the influence of institutions on farming would result in either positive or negative outcome of the farming operations. In the case of farms within and around forest reserves such as the case of this study, the negative outcomes of farming could be deforestation through illegal cutting of trees, forest degradation through encroachment by farmers, and land degradation through farmers' continuous cultivation without any soil management techniques. On the other hand, positive outcomes of farming operations could include improved yield and output and land replenishment through the adoption of agricultural innovations, and forest conservation and restoration through land sparing and land sharing mechanisms.

In summary, a farmer's decision to adopt or engage in certain farming systems and practices depends on three main components. The first component is the understanding of the systems and practices mainly through existing histories about the systems and practices known by the farmer as well as education provided by agricultural institutions (Khatun & Roy, 2012; Kuwornu et al., 2014). The second component is the motivation to adopt the systems and practices drawn from pull factors such as profitability and security, and push factors such as unfavourable environmental conditions (Macgregor, 2009). The third component is the capacity to adopt basically concerning the assets holding of the household.

Smallholder farmers engage in various farming practices both to sustain their wellbeing and their farming operations (Balama et al., 2016; Belay et al., 2017; Debela et al., 2015; Djokoto et al., 2017; Tesfaye & Seifu, 2016). Profitable systems and practices may result in more investment in farming which may have consequences on the environment such as forest, land and water bodies. Sustainability decisions should therefore not concern only the agricultural operations of the household but also the natural environment accepting the fact that trade-offs are possible. Sustaining household livelihoods and the environment requires the adoption of the landscape approaches for livelihood improvement and environmental conservation (Sayer et al., 2015; Sayer et al., 2013). Figure 2.1 presents a suggested framework for analysing sustainable agriculture in a conserved forest landscape.

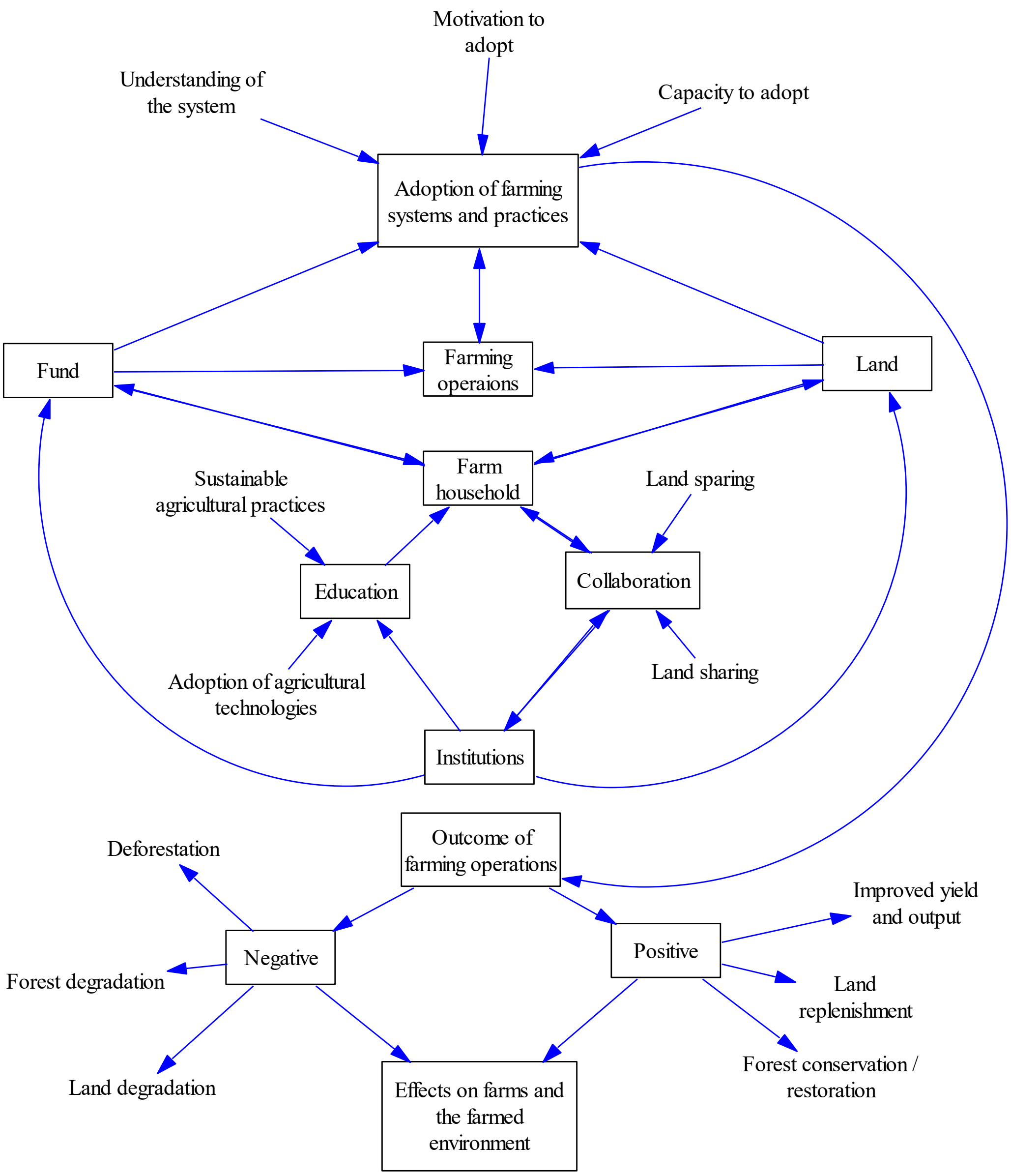


Figure 2.1 Sustainable Agriculture in a Conserved Forest Landscape: A Framework for Analysis

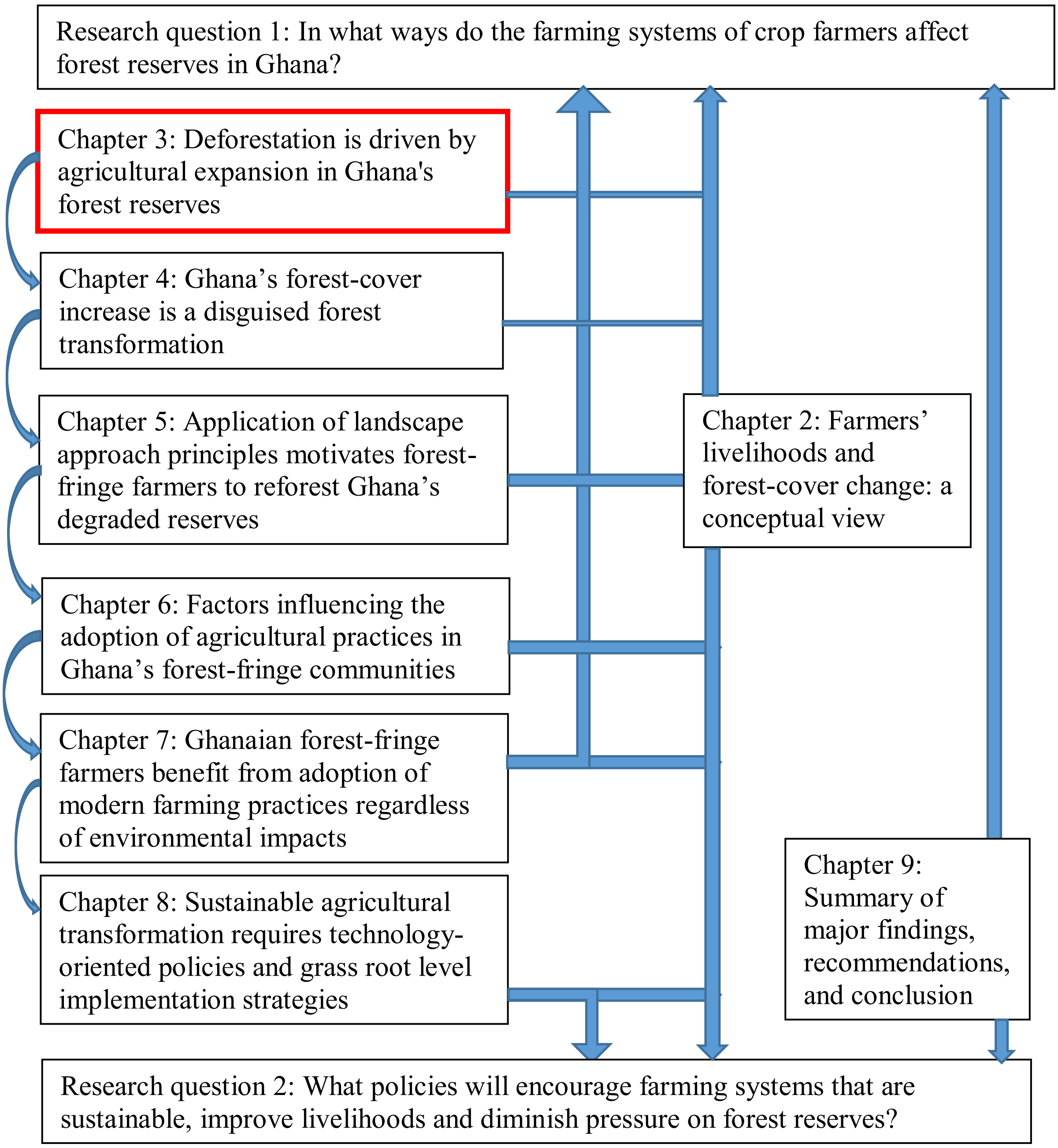
2.5 Conclusion

This chapter reviewed literature on livelihood diversification in rural areas in developing countries, laying much emphasis on Sub-Saharan Africa. The objective of the review was to examine the various factors that influence smallholder farmers in Sub-Saharan Africa to diversify their farming activities and whether their diversification decisions include the sustainability of the natural resource base. The results from the review revealed that household do not diversify until the time that they are exposed to unfavourable weather and environmental conditions. While resilient households diversify both to survive and accumulate wealth in times of stresses and shocks, vulnerable household diversify to survive and even sometime impoverish themselves.

Smallholder farmers are rational production units who try to minimise risk and maximise returns with the assets they have. Consequently, the decision to diversify is determined by the farm household's ability to address the challenges arising from exposure using the capital at their disposal. This ability is shaped by both sensitivity (the degree to which the household will respond- the sufficiency of assets) and adaptive capacity (the capacity of the household to adjust to actual or expected changes in the vulnerability context- a function of assets) (Carr, 2013). Diversification decisions of smallholder farmers however should not be limited to the sustainability of the livelihood activities alone as it was mostly found in the literature. Of equal importance is the sustainability of the natural resource base.

What Next?

I identified from the literature review that the livelihood decisions of smallholder farmers do not include the sustainability of the natural resource. This implies that depleting natural resource to sustain the livelihoods of farmers may not be much of a concern to the farmers. This is a critical issue to this research that focuses on the farming systems of farmers in forest-fringe communities of Ghana. Chapter three therefore examines whether agricultural expansion has contributed to the depletion of forests in Ghana.



Chapter Three: Deforestation is driven by Agricultural Expansion in Ghana's Forest Reserves

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Deforestation is driven by agricultural expansion in Ghana's forest reserves

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ABSTRACT

Ghana's protected forest reserves have suffered average annual deforestation rates of 0.7%, 0.5%, 0.4%, and 0.6% for the periods 1990–2000, 2000–2005, 2005–2010 and 2010–2015, respectively. The Ashanti region has recorded the second highest deforestation rates. Despite the government's efforts to maintain and protect Ghana's forest reserves, deforestation continues. We observed deforestation patterns in the Ashanti region of Ghana from 1986 to 2015 using Landsat imagery to identify the main causes of deforestation. We obtained and processed two adjacent Landsat images from the United States Geological Survey's (USGS) National Centre for Earth Resources Observation and Science at 30 m spatial resolution for 1986, 2002, and 2015. We then supported the results with findings from 291 farm household surveys in communities fringing the forest reserves. By 2015, dense forest covered 53.3% of the land area of the forest reserves, and the remaining area had been disturbed. Expansion of annual crop farms and tree crops caused 78% of the forest loss within the 29-year period. Afforestation projects are ongoing some of which employ the participation of farmers, yet agricultural expansion exerts more pressure on the remaining dense forest. Agricultural intensification on existing farmlands may reduce farm expansion into the remaining forest areas. Strengthening and enforcing forest protection laws could minimise the extent of agricultural encroachment into forests. Mixed tree-crop systems could reduce the effects of arable farming on deforestation, limit the clearance of trees from farmlands, enhance the provision of ecosystem services, and improve the soil's fertility and moisture content. A forest transition may be underway leading to more trees in agricultural systems and better protection of residual natural forests.

Abstract

Ghana's protected forest reserves have suffered average annual deforestation rates of 0.7%, 0.5%, 0.4%, and 0.6% for the periods 1990-2000, 2000-2005, 2005-2010 and 2010-2015, respectively. The Ashanti region has recorded the second highest deforestation rates. Despite the government's efforts to maintain and protect Ghana's forest reserves, deforestation continues. We observed deforestation patterns in the Ashanti region of Ghana from 1986 to 2015 using Landsat imagery to identify the main causes of deforestation. We obtained and processed two adjacent Landsat images from the United States Geological Survey's (USGS) National Center for Earth Resources Observation and Science at 30 m spatial resolution for 1986, 2002, and 2015. We then supported the results with findings from 291 farm household surveys in communities fringing the forest reserves. By 2015, dense forest covered 53.3% of the land area of the forest reserves, and the remaining area had been disturbed. Expansion of annual crop farms and tree crops caused 78% of the forest loss within the 29-year period. Afforestation projects are ongoing some of which employ the participation of farmers, yet agricultural expansion exerts more pressure on the remaining dense forest. Agricultural intensification on existing farmlands may reduce farm expansion into the remaining forest areas. Strengthening and enforcing forest protection laws could minimise the extent of agricultural encroachment into forests. Mixed tree-crop systems could reduce the effects of arable farming on deforestation, limit the clearance of trees from farmlands, enhance the provision of ecosystem services, and improve the soil's fertility and moisture content. A forest transition may be underway leading to more trees in agricultural systems and better protection of residual natural forests.

Keywords: Forest transition, deforestation, agricultural expansion, farm intensification, multi-functional forest landscapes, Ashanti region of Ghana.

3.1 Introduction

The tropical forest areas of Ghana form part of the Guinea Forest Region of West Africa, one of 34 severely threatened World Biodiversity Hotspots (Arcilla et al., 2015). Human activities have degraded about 85% of Ghana's Guinea Forest Region. Meanwhile, more than 10% of Ghanaians live at the fringes of forest reserves and benefit from timber and non-timber forest products (Ahenkan & Boon, 2011). Forest resources contribute up to 38% to the income of Ghana's forest residents and about 6% annually to the Gross Domestic Product of the country (Ahenkan & Boon, 2011; Appiah et al., 2009). The decline of the resource will impact on the livelihoods of those who depend directly on the forest and the economy of the country as a whole. With the current rate of deforestation, Ghana's forests could completely disappear in 25 years (Boafo, 2013). One means to curb deforestation in Ghana is to identify and tackle the drivers of forest loss – the physical human-induced and location-specific drivers of deforestation such as agriculture.

Global biodiversity and other ecosystem services have declined markedly over the last three decades (FAO, 2015; Hansen et al., 2013). Much of this loss has resulted from human-induced degradation and deforestation (Sloan & Sayer, 2015). In North America for instance, wood removal and fire are the major causes of deforestation (Hansen et al., 2010). In the Asia Pacific region, fire, wood removal, and expansion of estate crops are dominant causes of degradation and deforestation (Indarto et al., 2015; Katovai et al., 2015). Protected areas have been created in an attempt to curb deforestation and biodiversity loss (Damnyag et al., 2013; Joppa & Pfaff, 2011). Assessments of global trends of deforestation in protected areas have shown the extent to which protected areas could reduce forest clearing (Joppa & Pfaff, 2011; Lui & Coomes, 2016). The extent to which forest reserves (these are just one category of protected area) curb deforestation in African countries however have not been adequately assessed (Céline et al., 2013). Mapping the trend of deforestation within forest reserves demonstrates the effectiveness of forest reserves in reducing deforestation and the spatial factors causing deforestation in the continent.

Africa has a relatively high rate of deforestation compared with other continents (FAO, 2015; Hansen et al., 2013). Assessments in West and Eastern Africa demonstrate the highest rate of deforestation. West Africa has had average annual net loss of 0.13% from 1990 to 2015 while Eastern Africa has had annual net loss of 0.19% from 1990 to 2015 (FAO, 2015). Pastoralism, small-scale farming, and expansion of industrial tree crop estates have contributed to forest-cover loss on the continent (Rudel, 2013). Much of the forest in the western part of the continent, especially in countries such as Ghana and Cote D'Ivoire, are now mosaics of agricultural crops and modified natural vegetation (Damnyag et al., 2013; Rudel, 2013).

During the early 1900s, Ghana's natural forest covered a third of the country's land area (Wagner & Cobbinah, 1993). Over-exploitation of timber prompted the colonial government to reserve some portions of the natural forest from the 1920s to the 1940s. This was done mainly to limit timber exploitation to outside the forest reserves (Kotey et al., 1998). The country has over 256 forest and nature reserves for sustainable production and protection purposes (RMSC, 2016). Deforestation in Ghana, including in forest reserves, continued to increase even after the reservation of the forests. By 1989, about 80% of the forest had been converted to other land uses (Repetto, 1990). Ghana recorded annual deforestation rates of 0.7%, 0.5%, 0.4%, and 0.6% for the periods 1990-2000, 2000-2005, 2005-2010 and 2010-2015 respectively (annual deforestation rate = total deforestation for a period / period of deforestation * 100) (FAO, 2015) and various studies have demonstrated similar trends especially within Ghana's forest reserves (Damnyag et al., 2013; Kusimi, 2015). The forest reserves were created to protect the remaining biological diversity for continual flow of environmental benefits, yet deforestation continues in most reserves.

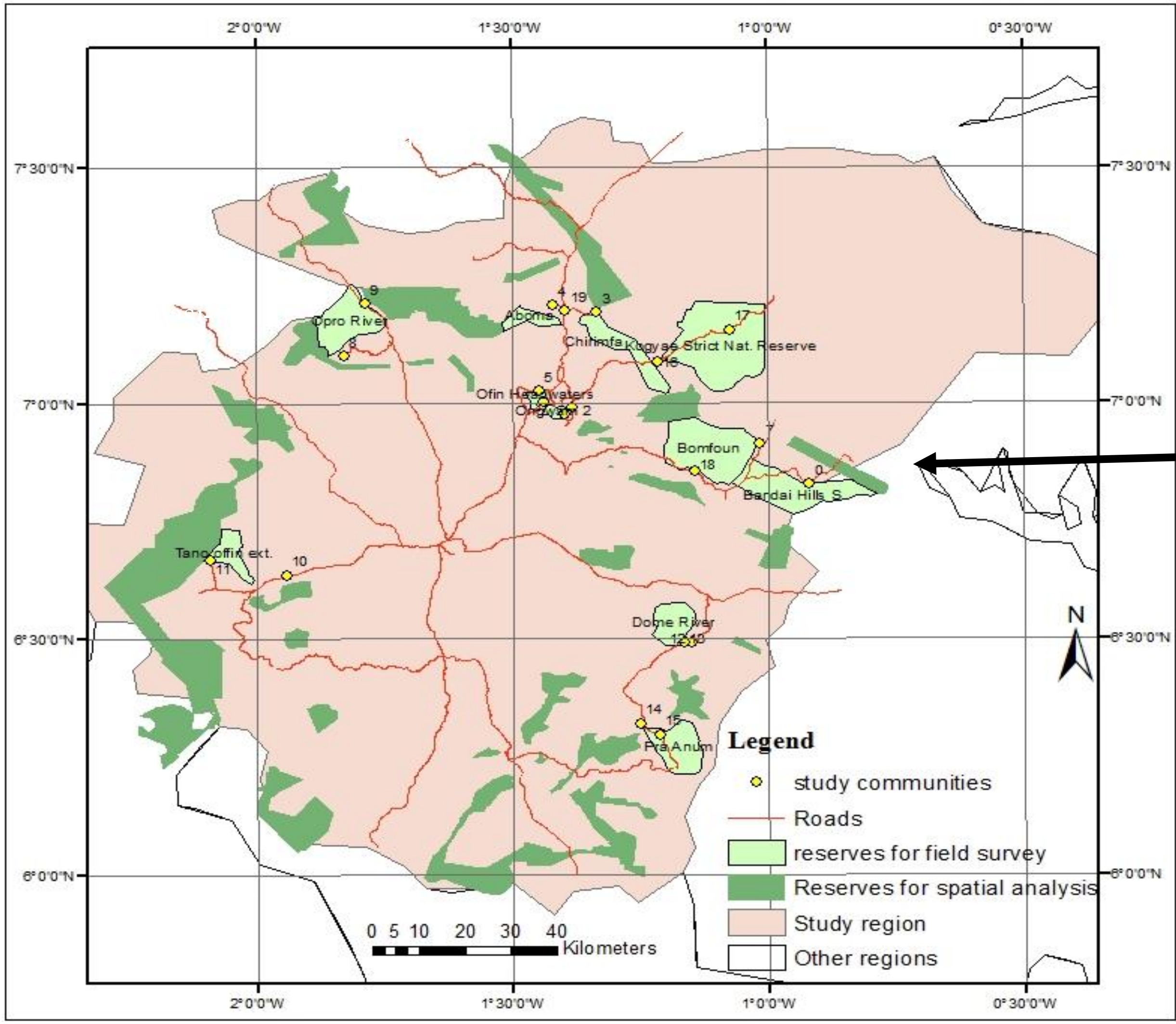
Deforestation in Ghana is attributed to overexploitation of natural resources through illegal and unsustainable logging and mining, and agricultural expansion, coupled with land tenure insecurity (Appiah et al., 2009; Schueler et al., 2011; Tsai et al., 2019). Most of these causes have been identified in studies utilising interviews with forestry officials and residents of forest-fringe communities (Appiah et al., 2009; Danquah & Tetteh, 2016; Derkyi et al., 2013). However, these findings do not have spatial attributes and they reveal subjective opinions of respondents. The extent of deforestation over a period cannot be known without spatially analysing land cover changes within the reserves. Land cover change studies are available mostly for the western and eastern regions of Ghana, (Damnyag et al., 2013; Kusimi, 2015; Tsai et al., 2019). Almost 23% of the country's forest reserves (3,785 km^2) are located in the Ashanti region, making the region the second largest host of forest reserves in Ghana (RMSC, 2016). The forest reserves in the region also have the most fringe communities in the country some of whom depend on the forests for their livelihoods (RMSC, 2016). Mapping the extent and trend of forest-cover loss in forest reserves in the Ashanti region will provide insight into what management strategies could apply to which reserves in order to reduce deforestation and sustain the remaining forests while not depriving the residents of their livelihoods. We define deforestation, the focus of this study, as the replacement of forest cover with other land cover such as agriculture.

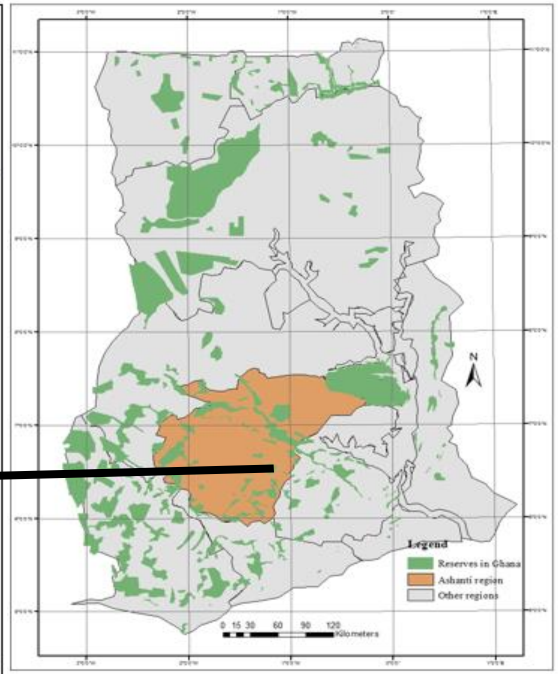
3.2 Materials and Methods

We mapped land cover changes in forest reserves in the Ashanti region of Ghana from 1986 to 2015 to determine the extent and trend of change in dense canopies and other land covers using satellite imagery. We then cross-referenced the change patterns of forest cover with household data on farming systems, farm size, and location of farms to assess the influence of agricultural practices on the transition from dense forest to croplands.

3.2.1 Study Area

The Ashanti region of Ghana (Figure 3.1) occupies a total land area of 24,389 km^2, and is centrally located in the middle belt of Ghana between longitudes 0.15°W and 2.25°W, and latitudes 5.54°N and 7.46°N (Ghana Statistical Service, 2013b). The region falls within three ecological zones. The moist and dry semi-deciduous zones cover more than half of the region while the savannah zone covers some portions of the north due to extensive agricultural and other human induced activities. The region has mean annual rainfall of 1,270 mm and two rainy seasons: April-August and September-November. The region covers about 10% of the land area of Ghana and contains 58 of the 256 forest reserves in the country (Figure 3.1). We chose this region for the study because of its increasing deforestation gradually transitioning the northern part of the region from forest vegetation to savannah woodlands (RMSC, 2016).





Names of study communities

0 = Aberewapon
1 = Asuafu
2 = Abasua
3 = Bunuso
3 = Sekruwa
5 = Mprim
6 = Ninting
7 = Ananekrom
8 = Offinso Brekum
9 = Nkwankwaa
10 = Kwanfinfin
11 = Akantansu
12 = Atiemu
13 = Adanse
14 = Gyadam
15 = Banka
16 = Jeduako
17 = Kyekyebon
18 = Bahankra
19 = Bosomkyekye

Figure 3.1 The Ashanti Region of Ghana and its Forest Reserves
Source: RMSC, 2016

3.2.2 Satellite Image Processing and Analyses Techniques

The Ashanti region's 58 forest reserves have a total land area of 3,785 km^2. It is impossible to carry out field inventory to examine the land cover changes within these reserves from 1986 to 2015. There is inadequate historical data for the 29-year period for such a spatial analysis, although there are some land cover change studies that covered portions of the region for some periods (Adjei et al, 2014; Coulter et al., 2016). We therefore used Landsat satellite images from 1986 (Landsat TM 5), 2002 (Landsat ETM 7), and 2015 (Lnadsat 8 OLI /TIRS) for the land cover change assessment (see Table 3.1 for the properties of the images). We obtained the satellite images from the United States Geological Survey's (USGS) National Center for Earth Resources Observation and Science (http://glovis.usgs.gov) at 30 m spatial resolution. Two adjacent images (path 194 rows 55 and 56) were analysed for 1986, 2002, and 2015 separately thus covering a 29-year period. All six images of this time series were acquired between November and January based on availability and level of cloud cover and to ensure possible comparability of vegetation signatures over the time series. We performed radiometric calibration of spectral reflectance values in the images to correct for systematic differences arising from varied illumination conditions and the use of different satellite platforms and Landsat sensors.

Table 3.1 Properties of Landsat Images used for the Study

Image year	Path/Row	Acquisition date	Scene center time	Landsat scene ID	Spacecraft ID/Sensor ID
1986	194/055	29/12/1986	09:40:41.8500440	LT51940551986363XXX06	Landsat 5/TM
	194/056	29/12/1986	09:41:05.8730500	LT51940561986363XXX09	Landsat 5/TM
2002	194/055	15/11/2002	10:09:26.4275624	LE71940552002319EDC00	Landsat 7/ETM
	194/056	15/01/2002	10:10:38.2877436	LE71940562002015EDC00	Landsat 7/ETM
2015	194/055	29/12/2015	10:21:36.0447005	LC81940552015363LGN00	Landsat 8/OLI TIRS
	194/056	29/12/2015	10:21:59.9572520	LC81940562015363LGN01	Landsat 8/OLI TIRS

The images were geometrically corrected and geo-referenced by the USGS with reference system WGS 1984 UTM zone 30N but had different acquisition dates. We therefore resampled the 1986 and 2002 images to the 2015 image such that all the three satellite images have the same geographical position. We used linear mapping function and bilinear resampling type to resample the images. We employed an unsupervised classification technique (hard classifier called "cluster" with broad generalization level) in IDRISI TerrSet version 18.30 to categorise each image into suitable land cover classes with the aid of forest-cover maps from the Forestry Commission of Ghana (RMSC, 2016) and Google Earth maps. The land cover classes were dense forest, logged forest, regrowth/tree crops, annual crop farms, and settlements/bare soil/dry grass. Dense forest is the land area covered with closed canopy of intact forest. Logged forest is the land cover where the closed canopy has been significantly disturbed through the cutting of timber. Regrowth/ tree crops refers to land cover with young trees from plantations or forest regeneration. Annual crop farms refer to agricultural lands covered with food crops. Settlements/ bare soil/ dry grass refers to land areas with no trees or crops but either bare ground, covered with grass, or buildings.

We created 365 random sample points for each of the three land cover images (1986, 2002, 2015) using stratified sampling technique. We used these points to assess the accuracy of the classification through ground truth data from Google Earth and forest reserves map from the Forestry Commission of Ghana (RMSC, 2016). See Table 3.2 and Table 3.3 for the accuracy assessment results for the various land cover classes. We assessed the land cover change during the two shorter periods 1986-2002 and 2002-2015 and the single, longer period 1986-2015 using Land Change Modeller in IDRISI. This was done to assess whether the extent of land cover changes in the two shorter periods reflect the trends in the single longer period. We then computed the area of land cover transition between the periods to examine the extent of transition from forest to agriculture and other land cover types in the study area. The extent of transition from forest to agriculture and other land cover types was used to calculate the annual rate of deforestation over the 29-year period (annual deforestation rate = total km^2 of deforestation for 29 years / 29 years * 100). Figure 2 shows the trend and direction of forest-cover change in the study reserves as at 1986, 2002, and 2015. The land cover classifications for 1986, 2002 and 2015 were highly accurate when compared with the minimum acceptable accuracy level of 85% (Anderson et al., 1976).

Table 3.2 Accuracy Assessment Results for the Land Cover Classes in 1986, 2002, and 2015

Land cover classes	Dense forest	Logged forest	Regrowth/ tree crops	Annual crop farms	Settlements/ bare soil/ dry grass	Total	Error of commission
Error matrix analysis for 1986 land cover classification							
Dense forest	214	4	4	0	0	222	0.0360
Logged forest	4	76	2	0	0	82	0.0731
Regrowth/tree crops	1	3	25	2	0	31	0.1935
Annual crop farms	0	0	1	22	0	23	0.0434
Settlements/ bare soil/ dry grass	0	0	0	0	5	5	0.0
Total	219	83	32	24	5	363	
Error of omission	0.0228	0.0843	0.2187	0.0833	0.0		0.0578
Error matrix analysis for 2002 land cover classification							
Dense forest	39	0	1	0	0	40	0.0250
Logged forest	0	19	0	1	0	20	0.0500
Regrowth/tree crops	3	1	113	4	0	121	0.0661
Annual crop farms	0	0	3	137	0	140	0.0214
Settlements/ bare soil/ dry grass	1	0	0	1	42	44	0.0454
Total	43	20	117	143	42	365	
Error of omission	0.0930	0.0500	0.0342	0.0419	0.0		0.0411

Table 3.3 Accuracy Assessment Results for the Land Cover Classes in 1986, 2002, and 2015 Continued..

Land cover classes	Dense forest	Logged forest	Regrowth/ tree crops	Annual crop farms	Settlements/ bare soil/ dry grass	Total	Error of commission
Error matrix analysis for 2015 land cover classification							
Dense forest	97	0	4	0	0	101	0.0396
Logged forest	0	9	0	0	0	9	0.00
Regrowth/tree crops	2	0	142	3	0	147	0.0340
Annual crop farms	1	0	1	51	0	53	0.0377
Settlements/ bare soil/ dry grass	1	1	0	0	52	54	0.0370
Total	101	10	147	54	52	364	
Error of omission	0.0396	0.1000	0.0340	0.0555	0.00		0.0357
Kappa index of agreement						Overall accuracy	
1986	0.91	0.91	0.79	0.95	1.00	0.90	
2002	0.97	0.95	0.90	0.96	0.95	0.94	
2015	0.95	1.00	0.94	0.96	0.96	0.95	

3.2.3 Household and Institutional Data Acquisition and Analyses Techniques

We collected farm household data on farming systems and practices, years of farming, and farm sizes and locations to complement the results from the classified images. The farmers are in communities both within and at the fringes of most of the forest reserves. The forest reserves are scattered across the region and most of the reserves have numerous fringe communities. The classified image for 2015 showed that the reserves in the northern part of the region have undergone more significant changes than the south. We therefore divided the region into two such that there is a northern section and a southern section. We randomly selected six and four reserves from the north and south of the region respectively for farm household data collection. We selected six reserves from the north because, proportionately, the northern section of the region has experienced more deforestation than the southern section. Although the standard distance used by the Forestry Commission of Ghana is 5 km (FC, 2008a) we chose to use 3 km to capture the communities that were closest to the reserves. The closer a community is to the reserve, the more influence it has on the reserve, all other things being equal. This criterion resulted in 192 communities. Two communities were randomly selected for each reserve and used for the survey. There were however two selected reserves (Bomfuom and Bandai Hills) with no significant separation between them. Some communities fell within the radius of both reserves. As a result, one community (Ananekrom) was drawn for both reserves making them have three study communities instead of four. This method was applied here because the situation first occurred during the sample draws for Chirimfa and Aboma Forest Reserves.

Table 3.4 Sampled Reserves, Communities and Farmers used for the Study

Sampled reserves	Sampled communities	Total households	Farm households	Sampled farmers
Offin Headwaters	Mprim	252	177	17
	Ninting	364	254	25
Tano Offin	Akantansu	155	109	11
	Kwanfinfini	121	84	8
Chirimfa Aboma	Bunuso	116	81	8
	Bosomkyekye	172	121	12
	Sekruwa	138	96	10
Ongwam II	Kruwi/Abasua	199	139	14
	Asuafo	196	137	14
Bomfuom/Bandai Hills	Ananekrom	206	144	14
	Bahankra	84	59	6
	Abiriwapon	93	65	6
Kogyae	Jeduako	518	363	36
	Kyekyebon	450	315	31
Dome River	Adansi	269	189	19
	Atiemo Nkwanta	58	41	4
Pra Anum	Banka	265	186	18
	Gyadam	109	77	8
Opro River	Offinso Brekum	172	121	12
	Nkwankwaa	265	186	18
Total		4202	2942	291

Source: GSS 2014; RMSC, 2016; Author's construct, 2018

Farmers dominate almost all forest-fringe communities in Ghana, including the study area. More than 70% of the rural households in the study area are farmers (Ghana Statistical Service, 2013b). Based on this, we used a mean of 70% as the farm households in each community. Therefore, the total households for the 20 communities was 4,202 out of which 2,942 were farmers at the time of the survey (Ghana Statistical Service, 2013b). We sampled 291 farm households using a simple random sample formula with 95% confidence level and 5% error margin for survey sample size computation (Krejcie & Morgan, 1970) as shown.

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

s = sampled farmers;

N = total farmers in the study area

z = standard score at specific significant level;

P = probability of selecting a farmer

e = error margin

$s = [1.96^2 * 2942 * 0.7 (1-0.7) / [0.05^2 * (2942-1) + 1.96^2 * 0.7 (1-0.7)] = 291$ farmers.

The sampled farm households were proportionally distributed among the communities based on the total farm households in each community. We ensured that farmers selected for survey in each community were distributed across the entire community. This was done through randomly selecting houses from end to end of each community. Only one farmer was surveyed in each house since some communities had compound houses with more than one farm household. This helped to obtain a variety of information from different households. We finally contacted one forestry officer from the Forest Services Division of the Ashanti region for information about deforestation in the region. The data collected from the farmers were then analysed descriptively and related to the results from the forest-cover change analysis as well as the information from the forestry officer to examine the effects of agriculture on deforestation.

3.3 Results

3.3.1 Brief Background of the Farmers

Out of the 291 farmers surveyed, 27.8%, 28.2% and 21% have had 1-10, 11-20, and 21-30 years of farming experience respectively. The rest of the farmers have had between 31 and 61 years of farming experience. More than half (58.4%) of the farmers inherited their farmlands from their parents and grandparents. While 23.7% farmed leased lands given by other farmers, 10.3% of the farmers farmed on reserve land given by the Forest Services Division within their areas on condition that the farmers plant trees alongside their crops (Table 3.5). The rest of the farmers acquired their farmlands through outright purchase or by means of gift. Almost a quarter (22%) of the farmers have their farms within the forest reserves while another 51.9% are within 5 km distance from the reserves. Farms of the remaining farmers are more than 5 km away from the reserve. Two-thirds (66.7%) and 25.4% of the farmers practice mixed cropping and mono cropping respectively while 2.1% and 5.8% of the farmers practice crop rotation and a combination of mixed and mono cropping respectively. Cereals are the main food crop (40.9%) followed by tree crops (26.5%), tubers (24.1%), and vegetables (8.6%). These farming characteristics (see Table 3.5) partly shaped the land-cover changes that occurred within the reserves.

Table 3.5 Farming Characteristics of the Farmers in the Forest-Fringe Communities

Number of years the farmers have farmed		
Years of farming	Number of farmers	Percentage farmers
1 - 10	81	27.8
11 - 20	82	28.2
21 - 30	61	21.0
31 - 40	41	14.1
41 - 50	14	4.8
51 - 60	11	3.8
61+	1	0.3
Total	291	100.0

Acquisition methods for farmlands on which the farmers cultivate		
Lease	69	23.7
Inheritance	170	58.4
Purchase	2	0.7
Gift	20	6.9
Reserve land given to farmers by forestry officials	30	10.3
Total	291	100.0

Location of farmers' farmlands		
< 1km from reserve	45	15.5
> 5km from reserve	76	26.1
1-5km from reserve	106	36.4
In reserve	64	22.0
Total	291	100.0

Farming systems the farmers practice		
Mixed cropping	194	66.7
Mono cropping	74	25.4
Crop rotation	6	2.1
Mixed and mono cropping	17	5.8
Total	291	100.0

Main crops grown by the farmers		
Cereals	119	40.9
Tubers	70	24.1
Tree crops	77	26.5
Vegetables	25	8.6
Total	291	100.0

3.3.2 Status of Land Cover within Forest Reserves in the Ashanti Region

Forest reserves in the Ashanti region have passed through various trajectories of forest-cover change for the 29 years (Figure 3.2). By 1986, the forest reserves had already undergone some deforestation. About 80% of the land cover remained intact dense forest while the 20% had been disturbed (Figure 3.3). Out of the disturbed portion, logging caused 57% of the disturbance. Tree crops/regrowth within the forest reserves accounted for 29% of the disturbance while annual crop farms and settlements/ bare soil/ dry grass contributed 11% and 3% respectively to the disturbance within the forest reserves.

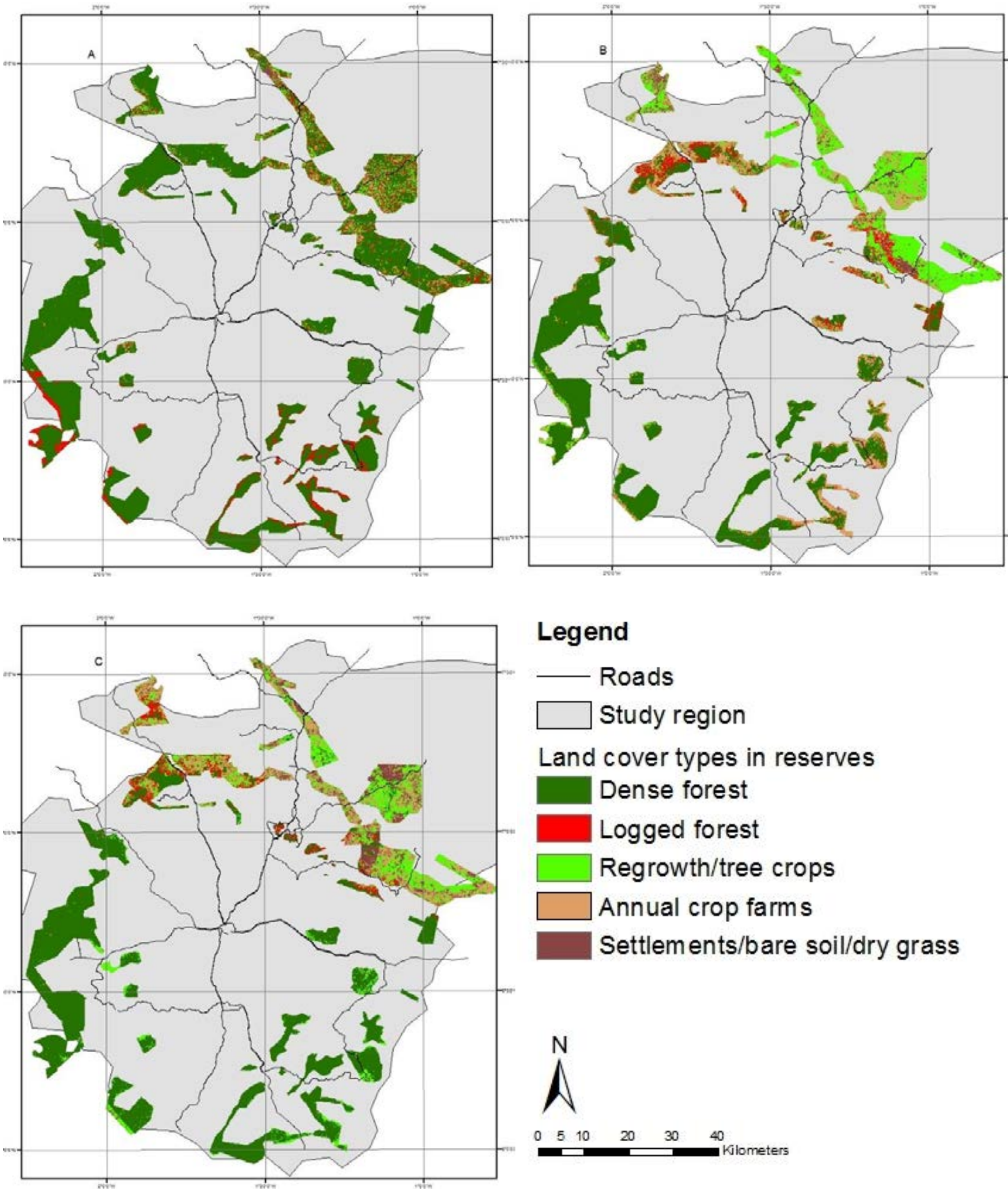


Figure 3.2 Status of Land Cover Change in Forest Reserves for 1986, 2002, and 2015

Note: The upper left figure (A) represents the initial state of the forest reserves as at 1986, the upper right figure (B) shows the change that occurred by the end of the year 2002, and the lower right figure (C) shows the state of the reserves as at 2015.

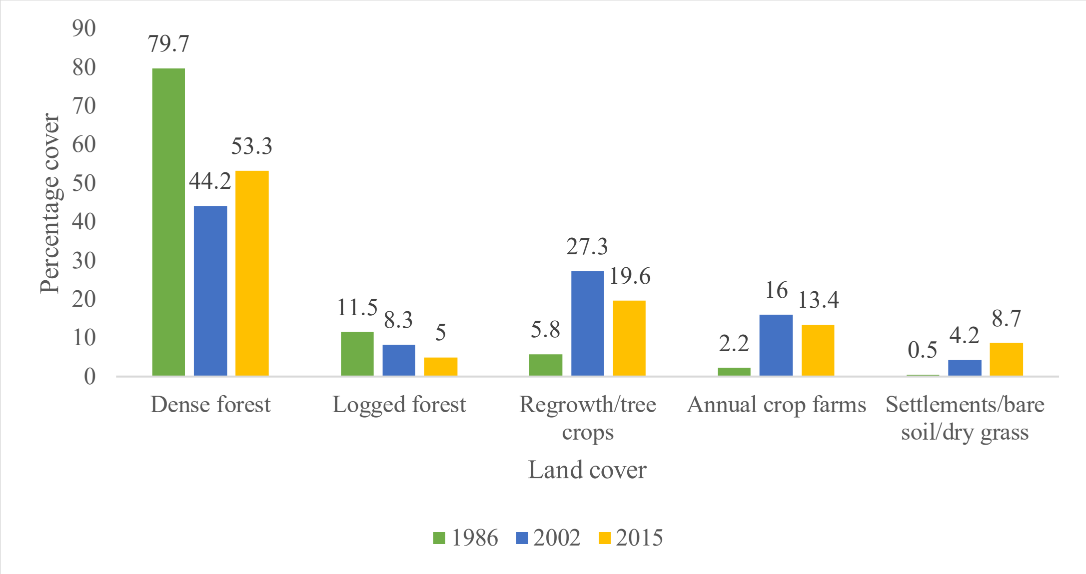


Figure 3.3 State of Land Cover within Reserves, 1986-2015

Between 1986 and 2002, the extent of remaining dense forest within the reserves declined further by 35.5%. While dense and logged forest areas declined within the 16-year period, regrowth/tree crops, annual crop farms, and settlements/ bare soil/ dry grass each expanded more than three times (Figure 3.3). A significant feature was the substantial increase in settlements/ bare soil/ dry grass in the study area within the 16-year period. Settlements expanded from 0.5% to 4.2% of the land area, more than 700% increment, followed by annual crop farms. Between 2002 and 2015, the downward trend in dense forest reversed while logged forest area continued to decrease. The land area occupied by regrowth/tree crops and annual crop farms decreased due to the increase in dense forest (Figure 3.3). Settlements/ bare soil/ dry grass continued to increase despite the decline in cultivation within the reserves. Overall (from 1986 to 2015), the extent of dense and logged forests had decreased while regrowth/tree crops, annual crop farms, and settlements/ bare soil/ dry grass had increased over the 29-year period (Table 3.6). The succeeding section presents the reasons for the land-cover change dynamics within the reserves.

3.3.3 Contributory Factors to Land-Cover Change Dynamics within Forest Reserves

The main factors causing deforestation within the reserves were the expansion of annual crop farms and tree crop plantations followed by logging. Out of the 1,344 km^2 of deforestation that occurred between 1986 and 2002, expansion of tree crop plantations (and some regrowth) (it was difficult to distinguish between regrowth and tree crops due to the resolution of the available images we used) and annual crop farms accounted for 78% (Table 3.6). Cross reference with the household data indicated that more than one-fifth (22%) of the farmers surveyed had their farms within the forest reserves and 42% of these farmers inherited their farmlands from their parents and grandparents. The inherited farmlands totalled 1.19 km^2 and were inherited between 1958 and 2015. These farms belonged to people living within the forest before the Forestry Commission of Ghana demarcated the areas as reserves. The Commission delineated the boundaries of the farms and gave them to their rightful owners. Most of these farms have however been expanded into the forest reserves.

Cocoa and oil palm were the major tree crops these farmers had planted amidst their food crops. According to the farmers, when the tree crops formed a closed canopy such that food crop cultivation was no longer possible, they extended their farms to areas with no tree cover to grow their food crops. This strategy had resulted in a gradual expansion of farms into the remaining forest reserves. According to the farmers, they extend their farms to areas of the reserves that have already been logged or where the tree canopy is not yet closed. The Landsat data showed that unsustainable logging (transition of dense forest to logged forest) and expansion of settlements (transition from dense forest to settlements/ bare soil/ dry grass) caused 15.3% and 6.8% of the deforestation that occurred between 1986 and 2002, respectively (Table 3.6). According to the household survey, these communities existed within the forest before the reservation took place from the 1920s to the 1940s. Since then, the communities have been expanding due to population growth and activities of humans within the communities such as extensive farming and illegal and unsustainable logging have partly contributed to the deforestation.

Table 3.6 Contributors to Land Cover Change for 1986-2002 and 2002-2015

	Dense forest		Logged forest		Regrowth/tree crops		Annual crop farms		Settlements/bare soil/dry grass	
1986-2002 contributors	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
Dense forest	-	-	205.49	169.9	637.69	78.3	409.66	80.4	91.44	64.6
Logged forest	-205.49	15.3	-	-	185.05	22.7	114.95	22.5	26.46	18.7
Regrowth/tree crops	-637.69	47.4	-185.05	-153.0	-	-	-3.32	-0.6	12.01	8.5
Annual crop farms	-409.66	30.5	-114.95	-95.0	3.32	0.4	-	-	11.53	8.2
Settlements/bare soil/dry grass	-91.44	6.8	-26.46	-21.9	-12.01	-1.4	-11.53	-2.3	-	-
Total net change	-1344.28	100.0	-120.98	100.0	814.05	100.0	509.77	100.0	141.44	100.0
2002-2015 contributors										
Dense forest	-	-	-120.15	-96.2	-67.81	-23.4	-152.39	-158.1	-0.93	-0.5
Logged forest	120.15	35.2	-	-	10.11	3.5	-18.87	-19.6	13.51	8.0
Regrowth/tree crops	67.81	19.9	-10.11	-8.1	-	-	94.85	98.4	136.84	80.8
Annual crop farms	152.39	44.6	18.87	15.1	-94.85	-32.8	-	-	19.94	11.7
Settlements/bare soil/dry grass	0.93	0.3	-13.51	-10.8	-136.84	-47.3	-19.94	-20.7	-	-
Total net change	341.28	100.0	-124.90	100.0	-289.39	100.0	96.34	100.0	169.37	100.0

Note: The upper half of the matrix (first six rows) represents the contributors to land cover change from 1986 to 2002. The lower half (last six rows) represents the contributors to land cover change from 2002 to 2015. The columns represent the changes that have occurred in a land cover. The rows represent which land cover contributed to the changes in the columns. The percentages are calculated as change/total net change of the particular period.

Land-cover change dynamics in the reserves demonstrates deforestation; however, there were also some forest gains. Dense forest recorded a net gain of 341 km^2 from 2002 to 2015 (Table 3.6). This gain was derived from previously logged forest that was not taken over by farmers and has naturally regenerated over the 13 years (35.2%), annual crop farms that were mixed with tree crops in 2002 and had fully grown to form dense canopy (44.6%), and 20% from regrowth/tree crop plantations (Table 3.6). The reason for the migration of annual crop farms into dense forest was, first, due to the growing of tree crops by the farmers who inherited their farmlands. The maturity of tree crops such as cashew, cocoa, mangoes, oranges, etc. to form dense canopy should be regarded as "deforestation in disguise" since these tree crops are seen as causes of deforestation in Ghana's forest reserves by the Forestry Commission of Ghana. The second reason was a planned reforestation strategy undertaken by the Forestry Commission of Ghana. According to the respondent from the Forest Services Division of the Forestry Commission, since the year 2001, the Commission has embarked on series of National Plantation Projects some of which involved the participation of farmers in forest-fringe communities.

A cross reference with the household data indicated that out of the 64 farmers who farmed in the forest reserves, 47% had obtained their farmlands from the Forest Services Division in their respective areas. These lands belonging to the 47% (or 30 farmers) totalled 0.46 km^2 and were acquired between 1998 and 2018. The farmers explained that the Forestry Officers required them to take care of the young trees planted (mainly teak) while they tilled the land. This method of farmers' land acquisition is known as the Modified Taungya System (MTS) of farming in Ghana – a system whereby farmers interplant their food crops with specified tree species on degraded forest reserve, with the responsibility of the farmers being to maintain the trees to maturity and benefiting from the matured trees at harvest. According to the farmers, after three to four years of cultivating the land and nurturing the planted trees, they had to move to new lands since the trees begin to form a canopy. This strategy coupled with the regeneration of logged forest, and the maturity of tree crops (deforestation in disguise) to form dense canopy altogether contributed to the increase in dense forest cover over the 13-year period. Nevertheless, the extent of deforestation over the previous 16-year period had resulted in a 33.2% net loss of intact dense forest over the 29-year period (Table 3.7).

Results from Table 3.7 showed that within each land cover type there were both losses and gains over the study period. Dense forest cover for instance gained 2.8% extra land from other land covers but lost 47.3% of its cover to other land cover types within the same period of 1986 to 2002 resulting in 44.5% net loss for the 16-year period. However, between 2002 and 2015, dense forest recorded more gains than losses hence, registering 20.4% increase in land cover. The net gain of dense forest over the 29-year period was lower than the net loss and this resulted in net deforestation. Logged forest recorded more losses than gains through a mix of maturity to dense forest and conversion to tree crops, annual crop farms, and settlements/ bare soil/ dry grass (Table 3.6) throughout the 29-year period contrary to regrowth/tree crops, annual crop farms, and settlements/ bare soil/ dry grass (Table 3.7).

Table 3.7 Land Cover Change within Forest Reserves, 1986-2015

	1986-2002 (%)			2002-2015 (%)			1986-2015 (%)		
Land cover	Gain	Loss	Net	Gain	Loss	Net	Gain	Loss	Net
Dense forest	2.8	47.3	-44.5	31.6	11.2	20.4	7.3	40.5	-33.2
Logged forest	66.8	94.7	-27.8	47.8	87.6	-39.8	40.5	97.1	-56.6
Regrowth/tree crops	410.8	39.2	371.6	37.3	65.3	-28.0	304.1	64.6	239.5
Annual crop farms	620.9	84.1	536.8	66.1	82.0	-15.9	507.9	72.5	435.4
Settlements/bare soil/dry grass	845.3	55.6	789.7	1 90.7	84.4	106.3	1813.9	78.5	1735.4

By 2015, the forest reserves had recorded annual deforestation rates of 1.1% for dense forest and 2% for logged forest. Regrowth/tree crops and annual crop farms had recorded annual increases of 8.3% and 15% respectively over the same period within the forest reserves. Settlements/ bare soil/ dry grass that occupied only 0.5% of the land area of the forest reserves increased by 60% annually from 1986 to 2015 (Table 3.7).

3.4 Discussion

Forest resources support the livelihoods of rural residents and provide environmental and ecological services. A change in forest cover has impacts on the provision of forest goods and services. Deforestation threatens ecosystem services such as climate regulation, biodiversity conservation, water catchment protection and livelihood support to forest residents (Sassen et al., 2013). Sustaining the remaining forest in the tropics is paramount to continued provision of ecosystem services.

3.4.1 Land Cover Change within Forest Reserves, 1986-2015

Ghana's forest cover has been declining since before 1986 (Kotey et al., 1998; Repetto, 1990) and the protected forest reserves in the Ashanti region are an example (Figure 3.3 and Table 3.6). The decline in dense forest over the 29-year period was similar to what was recorded for the entire country between 1980 and 1985 (Repetto, 1990). The extensive deforestation that took place within the 5-year period (1980-1985) partly resulted in the state of the dense forest cover as at 1986 (Figure 3.3). Since 1990, the annual deforestation rate for Ghana has been estimated at 0.6% (FAO, 2015). The Ashanti region is the second largest host of forest reserves in the country and has recorded annual deforestation rate of 0.5% higher than the country's overall estimate (Forestry Commission of Ghana, 2016a). Although the estimates may differ due to different assessment methods used, evidence shows that deforestation in Ghana occurs more in the most forested areas and the Ashanti region is one of them (Damnyag et al., 2013; Kusimi, 2015). The continuous clearing of the forests in the study area will lead to loss of biodiversity and other ecosystem services and threaten the livelihoods of forest dependent communities.

More than a tenth of Ghana's population live within and at the fringes of forest reserves (Kusimi, 2015). These residents collect non-timber forest products (NTFPs) for their livelihoods while some of them legally and illegally farm within the reserves for survival (Amoah & Wiafe, 2012). Others engage in plantation programs through which they get access to forestlands for their food crops production (Acheampong et al., 2018). Aside from access to farmlands, forest resources contribute 38% to the income of Ghana's forest residents (Appiah et al., 2009). The contribution of forest resources to the income portfolio of the people is also evident in other tropical countries. Marketing of wild foods from forests contributes between 15% and 40% to rural household income in Nigeria, Ethiopia, Sudan, Togo, and South Africa (Malleson et al., 2014; Yemiru et al., 2010). Forest resources could serve as safety nets for forest dependent communities in off-farming seasons. Nonetheless, this safety-net role of forests will eventually end if the current trend of deforestation continues.

Human activities mainly agriculture, and illegal and unselective logging have degraded 85% of Ghana's Guinea Forest Region, a severely threatened World Biodiversity Hotspot (Arcilla et al., 2015). In addition, unsustainable logging and agricultural activities that occurred between 1993 and 2010 had led to a 50% decline in forest understory birds (Arcilla et al., 2015). The maintenance of forest biodiversity in Ghana is contingent upon the regulation of human activities within the forests. Strict enforcement of environmental laws is key to effective regulation of human activities such as illegal logging and farming that trigger deforestation and subsequent biodiversity loss.

3.4.2 Contributory Factors to Deforestation within Forest Reserves

Population growth coupled with increasing rural poverty, resulting in agricultural expansion, has dominated the global discussion on the causes of deforestation in the tropics (Sassen et al., 2013). Between 1986 and 2015, a third of the intact dense forest within the study reserves was converted to mainly tree crop plantations and annual crop farms. Agricultural expansion has caused 78% of the deforestation in the study reserves while expansion of settlements and other human activities has caused 6% of the deforestation. The reason for the existence of farms and settlements in the forest reserves is that, before the demarcation of the areas as forest reserves, these settlements and farms already existed within the forests. According to a respondent from the Forest Services Division, The Forestry Commission of Ghana allowed the settlers (known as "admitted settlers") and their farms (known as "admitted farms") to remain in the forest reserves. The Commission delineated the boundaries of the settlements and the farms so that encroachment of the forest reserves would not occur.

However, population growth and weak enforcement of forest protection laws have led to gradual expansion of the admitted settlements and farms into the remaining forest reserves over the 29-year period. The majority of the settlers have their inherited farms within the forest reserves and tree crops such as cocoa, cashew, oil palm, avocado, mango, and citrus are the main cash crops they grow. These admitted settlers interplant their food crops with the cash crops and depend on natural soil fertility to increase output. According to the farmers surveyed, when the tree crops form a canopy, they encroach the adjoining forest for fertile land to cultivate their food crops for consumption. The forested areas fringing farms serve as land banks for fertile soil for most farmers in the hinterlands owing to their inability to buy farm inputs to enrich the existing soil (Acheampong et al., 2018). Since the tree crops are the main source of income for the farmers, in about two years of producing food crops on the newly cleared land, the farmers would start inter-planting the food crops with tree crops. After about five years of continuous cultivation on the new land, the need for more fertile land for food crops cultivation would emerge. This process of forest clearing for agriculture coupled with unsustainable logging has been the major cause of deforestation in the Ashanti region and Ghana as a whole (Appiah et al., 2009).

Our method of classification of the Landsat images was not able to clearly distinguish between tree crops and forest trees due to the close similarities. As a result, tree crops and regrowth were merged to achieve some level of accuracy and consistency. Even though, different methods of classification such as using image-fusion on vegetation indices (VI) and a digital elevation model (DEM) to distinguish tree-crop plantations from forest and other vegetation types (Asubonteng et al., 2018; Benefoh et al., 2018) may have resolved this limitation, our classification accuracy assessment was over 85%.

The economic benefits from tree crops drive their expansion but not their intensification thereby causing more forest clearing especially in areas with weak enforcement of forest protection laws (Acheampong et al., 2018). A major challenge for conservationists and agriculturalists in the forest frontiers of Ghana has been how to balance the economically driven agricultural expansion with conservation priorities to maintain ecosystem integrity and species viability (Asare et al., 2014). The Forestry Commission of Ghana has implemented afforestation programs more than two decades ago to reverse deforestation in the country (Forestry Commission of Ghana, 2016a). Part of these programs allowed farmers to be given degraded forestlands to interplant their food crops with specific trees (Acheampong et al., 2018) and this was evident in the study area. Yet, agricultural expansion has continuously exerted pressure on the remaining forest cover since 1986. Agricultural intensification is needed to improve yield and increase output without necessarily increasing farm size to cause deforestation. According to the farmers surveyed, those whose farms were in the reserves have not been using any modern technology to improve yield and increase output. Just as farmers at fringes of off-reserve forests in Ghana use the forests as land banks to increase agricultural production (Owubah et al., 2000), farmers within the forest reserves have relied solely on the reserves for fertile soil. Intensifying agriculture with fertilisers and other soil-enriching techniques would help improve yield, increase output, and consequently spare the remaining forest.

Lands with agricultural potential are available in many developing nations including Ghana, but they mainly consist of forests whose conversion would mean loss of biodiversity and ecosystem services (Garnett et al., 2013). For farmers who farm in forest reserves, the only option to produce more without causing deforestation is to apply modern farm techniques. The use of improved seeds, fertilizers and soil enrichment techniques have proven to double yield on the same piece of land (AGRA, 2013). However, farmers would require education and training on the use of modern farm methods for high yielding results. Producing more on the same piece of land would be one way of contributing to food supply without causing forest loss but this would require strict enforcement of forest protection laws.

Africa's population is expected to quadruple in the 21st century (FAOSTAT, 2015). This will create demand for increased agricultural land to meet food demand. It has been suggested that agricultural production would have to increase by 70-110%, implying that about 1 billion hectares of land would have to be converted to agriculture (Edwards et al., 2014). Agricultural expansion means loss of forest cover, a phenomenon well demonstrated in the study area over the 29-year period. An alternative to increasing yield without expanding farms would be to intensify farming (Sayer et al., 2015). Farm intensification involves using high-yielding varieties of seeds and spacing for planting, acceptable methods of controlling pests and diseases, and the right quantity of organic and inorganic fertilizers to boost the yield of crops. Farmers are willing to adopt farm intensification techniques to increase yield but the cost involved and the lack of farmer education and training programs make them continue to practice traditional farming methods. Agricultural intensification could double or even triple smallholder farmers' output (AGRA, 2013). The remaining forest in Ghana could be conserved and the food requirements of the populace could be met if farmers intensify their farming. The surplus yield resulting from the intensification could be marketed and contribute to the farmers' household income.

3.5 Conclusion

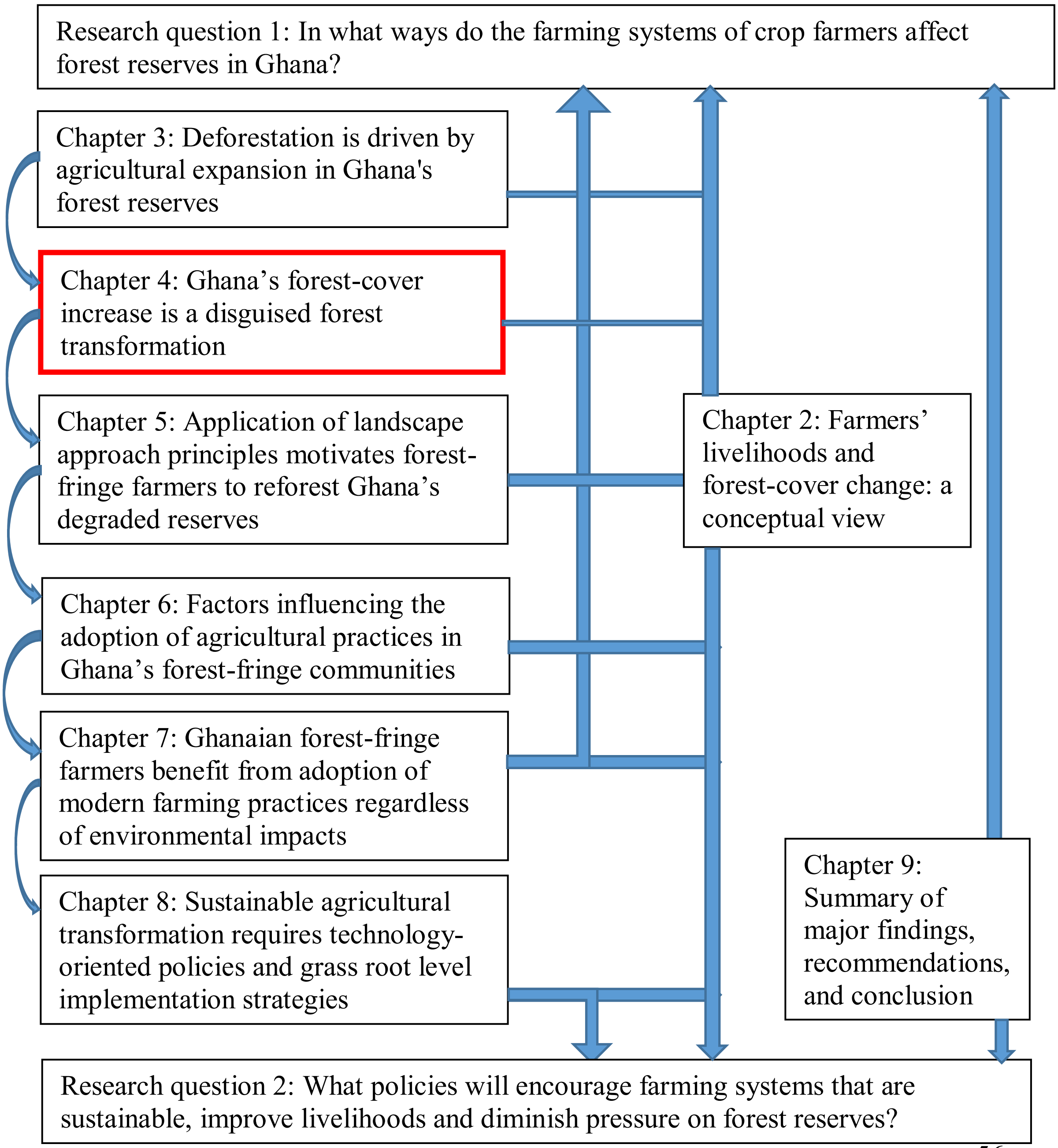
We examined the patterns of deforestation in the Ashanti region of Ghana to identify the main factors causing forest loss in the region. Through the images' change detection process, we showed that agriculture is expanding to dominate land cover in the Ashanti study area and this has been and remains a major threat to the remaining dense forests. Forest extent has been declining annually and tree crops and planted forests are replacing the original dense forests. Each of the study periods recorded a loss and a gain, but the amount of the annual losses has reflected the decline in dense forest cover over the 29-year period. Agricultural expansion into forests, the main cause of deforestation in the study area, will not provide a sustainable long-term solution to food security and poverty reduction. Agricultural intensification through the adoption of sustainable agricultural practices is the only viable long-term solution for achieving food security while minimising effects on the environment.

Agricultural intensification could offer a wide range of benefits. First, it could save the forest and its biodiversity since farmers would no longer depend on forest as a source of fertile land for agricultural production. Second, the food needs of smallholder farmers would be met and the surpluses could be marketed to increase the income portfolio of farm households. Third, agricultural intensification could allow smallholder subsistence farmers to transition to become commercial farmers without expanding their land holdings. Promoting agricultural intensification, employing technology to decrease post-harvest losses and wastes, and ensuring efficiency in the food chain system could be a significant pathway out of poverty, ensure sustained food supply to manage the increasing population, and minimize pressure on the remaining forests to provide biodiversity conservation benefits.

To sum up, this research has demonstrated that increased agricultural production is the main factor behind forest encroachment in Ghana, just as has been found in other developing countries (Appiah et al., 2009; Owubah et al., 2000). Addressing deforestation in developing countries therefore requires collaborative action between foresters and agriculturalists. While foresters continue to protect and sustain the remaining forests, further research is required to investigate how farmers, especially in forest-fringe communities in developing countries, adopt progressive but sustainable agricultural practices as a way to enhance yields but also restore the fertility of farmlands and subsequently lessen the pressure on forest for fertile land.

What Next?

Chapter three demonstrated that agricultural expansion into forest reserves has been one of the major contributors to deforestation in the study area, although there have been some forest-cover gains. However, further analysis has identified that some of these gains are a “deforestation in disguise”. In light of this, chapter four examines through review of relevant literature, government documents, and field survey data whether forest-cover gains in Ghana is a reflection of forest transition or forest transformation.



Chapter four: Ghana's Forest-Cover Increase is a Disguised Forest Transformation

Abstract

Since 1990, Ghana's total forest-cover has increased by 4% from 37% while primary forest has decreased slightly from 4.5%. Such dynamics in total forest-cover as well as specific forest-cover types have been unexplored in the forest transition paradigm. In response, we examined the composition of Ghana's re-established forests and the drivers of forest gain and loss. We obtained national forest and agricultural land-cover data from 1990 to assess forest-change dynamics and their relation to forest transition and forest transformation narratives. We found that government policies on forest protection and plantation development since 1990 have contributed to the restoration of some degraded forests but the rate of deforestation is more than twice the rate of reforestation in Ghana. This has made it impossible for Ghana to achieve net forest gain. However, a redefinition of "forest" by the Food and Agriculture Organization (FAO) seem to classify matured tree-crop estates as forest, culminating into forest-cover gain. We argue that Ghana's forest-cover has transformed from primary forests into "planted forests" made up of timber plantations and matured tree-crop estates. Indiscriminate use of the term "forest" and applying the broader definition of "forest transition" to assess forest-cover change may result in primary forest-cover loss without noticing. Strict protection of the remaining primary forests and effective implementation of afforestation and reforestation programs may lead to modest forest transition in a moderately transformed forest landscape.

Key words: Forest transition, multifunctional forest landscapes, forest transformation, deforestation, rural Ghana.

4.1 Introduction

Few tropical countries have recorded net increases in forest-cover since 1990. Notable among these countries are Vietnam, Mexico, Cosa Rica, Panama, and China (Arroyo-Mora et al., 2005; Meyfroidt & Lambin, 2008; Rudel et al., 2000; Sloan, 2015). The recent forest-cover increase in these countries partly resulted from strategies including government-led, smallholder participation, and private plantation schemes. Recent forest-cover dynamics has prompted research into the types of dynamics through which forest-cover can change in its extent and composition (Austin et al., 2017; Gaveau et al., 2016; Locatelli et al., 2017). Most researchers have relied on the forest transition theory (the state where forest-cover declines to a point, halts, and then increases with time) to assess the general movement of national, regional, and global forest-cover from net loss to net gain (Mather & Needle, 1998; Rudel et al., 2000; Rudel, 2005). Recent research also shows that forest-cover may transform as it transitions depending on the factors that lead to the transition (Austin et al., 2017; Gaveau et al., 2016). Ghana's total forest-cover has increased by 4% from 37% since 1990 (FAO, 2015) after decades of forest-cover decline; this generally portrays forest transition (Rudel, 2005). However, the drivers of the forest-cover increase, the composition of the new forest-cover and the transformation that has taken place in the existing forest-cover have not been adequately studied (Oduro et al., 2015).

Forest, in the Ghanaian context, is land with area of at least one hectare, a canopied tree-cover of 15% minimum, and have the potential to or have reached a height of at least five meters at maturity in situ (Forestry Commission of Ghana, 2017a). Ghana's forest is generally categorized into primary forest (close intact, dense canopy), modified natural forest (other naturally regenerated forest, open canopy), and planted forest. Primary forest refers to naturally restored forest of indigenous tree species where there are no clearly noticeable signs of human actions and the biological diversities are not significantly impacted. Modified natural forest refers to forest areas that have experienced observable anthropological effects. Planted forest refers to forest primarily made up of trees established via planting and/or deliberate seeding. Forest–cover change dynamics especially through plantations establishment can transform different forest-cover types and sometimes achieve modest net gains in tree-cover (Sloan et al., 2019). This is evident in Malaysia, Cambodia and Indonesia where the establishment of tree plantations promoted in extensive primary forests led to transformations in the forest-cover (Austin et al., 2017; Gaveau et al., 2016). Forest transition could occur in such transformed forests due to the drivers of the forest transformation; however, primary forest-cover will experience significant loss.

Ghana's forest-covers have undergone significant changes for more than a century. During the 1900s, primary forests covered about a third of the country's area (Wagner & Cobbinah, 1993). Forest reserves were established from the 1920s to the 1940s to halt the rapid deforestation that was taking place in the early 1900s and preserve the remaining primary forest estate (Kotey et al., 1998). Despite the reservations, deforestation was increasing. For instance, between 1955 and 1972 Ghana lost a third of its primary forest (Hall, 1987). While some challenge this assumption (Fairhead & Leach, 1996), others assert that forest clearing in Ghana peaked during this period (Kotey et al., 1998). While deforestation slowed from the 1980s, by 1990 ~80% of Ghana's primary forest was cleared (IUCN, 1992). Although there are inconsistencies in Ghana's forest-cover data, available estimates point to continuous deforestation (FAO, 2010; Oduro et al., 2015). Reversing deforestation has been a global priority for decades due to the impact of forests on carbon emissions, biodiversity, livelihoods and other ecosystems services (Meyfroidt et al., 2010).

Since 1990, the government of Ghana through the Forestry Commission has implemented various strategies to achieve forest transition through natural restoration, tree plantation establishments, and agroforestry (Forestry Commission of Ghana, 2016b; Oduro et al., 2015). Between 1990 and 2015, Ghana's total forest (primary forest, modified natural forest, and planted forest) area to total land increased from 37% to 41% out of which ~4% is primary forest-cover (FAO, 2015). We examine the dynamics of Ghana's forest-cover increase to assess whether the forest-cover has transitioned or transformed.

4.2 Forest Transition and Forest Transformation: A Theoretical Overview

The forest transition theory (FTT) states that forest-cover in a particular area changes as societies undergo economic and industrial development, and urbanization (Mather, 1992; Mather & Needle, 1998). The theory asserts that initially forest-cover will decline, halt at a point, and then begin to increase. Forest transition does not follow a single historical path (Rudel, 2005). Researchers have proposed economic development, forest scarcity, State forest policy, and smallholder tree-based land use intensification as some of the pathways to forest transition (Lambin & Meyfroidt, 2010; Rudel, 1998; Rudel et al., 2005). These pathways are not mutually exclusive and the transitions may not be predictable as some researchers presume (Mather, 1992; Mather & Needle, 1998; Walker, 1993) due to competing land uses whose values may change in the course of time. Varied interests of different stakeholders may influence the combination of pathways that will cause forest-cover to transition. Forest-cover often transforms in the course of forest transition and may contain forest-cover types that are different from the previously existing forest (Austin et al., 2017; Gaveau et al., 2016). The transformed forest goes unnoticed because forest transition narratives do not account for dynamics within the forest-cover.

Forest transformation is a political-economic term whereby economic scarcity, not forest shortage, triggers reforestation mostly in devalued or degraded forests (Sloan et al., 2019). Forest transformation leads to rapid gains in net tree-cover (often less than 20 years) but remains modest relative to gross reforestation and corresponding forest loss. During forest transition, there is less pressure on and high protection for primary forest due to forest scarcity and declining ecological services, and natural reforestation often revolves around these forests (Locatelli et al., 2017; Sloan, 2015). However, during forest transformation primary forest devalues due to economic and market distortions that increase the incentives for plantation forests and overlook the ecological services of primary forests (Sloan et al., 2019). Although both forest-transition and forest-transformation narratives have attributes of government interventions, subsidies for reforestation is common and generous with the forest-transformation narrative and this partly devalues primary forests. Government interventions in forest-transition reforestation reflect local responses to forest scarcity and declining ecological services (Wilson et al., 2017). Again, timber plantations inter-relates with agro-forestry plantations in both narratives, the inter-relation is more geographic, temporal, and commercial in the forest-transformation narrative. The inter-relation between timber plantations and agro-forestry plantations in forest transition is uncertain and less commercial unless local responses to forest scarcity triggers the establishment of mixed tree plantations (Sloan et al., 2019).

Ghana's forest-change dynamics reflect attributes of both the forest-transition and the forest-transformation narratives for two reasons. First, Ghana's primary forest has declined continuously until 1990. The country's total forest-cover started increasing from the 1990s but primary forest has still been decreasing. Examining the various attributes that drive forest-change dynamics in Ghana will contribute to the realities about forest transition and forest transformation.

4.3 Materials and Methods

We examined whether Ghana's forest-cover has transitioned or transformed through the tree-cover change dynamics that have occurred from 1990 to 2015. To do this, we analysed forest-cover and permanent tree-crop cover data from the Food and Agriculture Organization (UN-FAO). We complemented these data with tree-cover change data for Ghana from Hansen (2013), annual progress reports on forest plantation from the Forestry Commission of Ghana, annual reports on tree-crop plantations from Ghana's Ministry of Food and Agriculture, and farmer household data on tree-crop plantations to assess the changes that have occurred in the forest landscape of Ghana.

The Forestry Commission of Ghana provides periodic forest inventory data to the UN-FAO toward the preparation of the FAO's Forest Resources Assessment. The forest data are classified according to FAO's classification of forests, namely, primary forest, planted forest, and other naturally regenerated forest. The Forestry Commission of Ghana adopts FAO's definition of forest (Forestry Commission of Ghana, 2015), hence, we used the data on these classifications of forests to assess the forest change patterns in Ghana. Hansen (2013) mapped global tree-cover change from 2000 to 2012 to quantify the losses and gains in tree-cover in each country. Hansen's definition of tree-cover agrees with Ghana's definition of forest. We therefore supported the country's forest-cover data with the tree-cover data of Hansen (2013). The Forestry Commission of Ghana launched and started implementing the National Forest Plantation Development Program (NFPDP) in 2001 with specific targets of forest plantations to establish each year. We reviewed the annual progress reports from 2002 to 2015 to assess the achievements from the program.

Ghana's definition of forest captures lands covering at least one hectares with trees 5 meters minimum and a tree crown cover of more than 15% or trees able to reach these thresholds in situ as forest (Forestry Commission of Ghana, 2017a). When working with FAO's (2015) definition of forest together with this definition, then in the Ghanaian context some tree crops such as oil palm, cashew, mangoes, citrus, and cocoa may be classified as forest depending on the land size, height and canopy cover at the time of assessment. The Forestry Commission of Ghana however does not classify tree crops as forest (Forestry Commission of Ghana, 2017a). For the purpose of land-cover change however, we assessed the annual reports on tree-crop plantations and productions to examine Ghana's tree-crop cover change. We complemented the tree-crop cover data with data from 591 farmers on the proportions of their farm plots used for tree-crop plantations overtime.

We obtained 300 farmer household data in 2015 from the Western, Ashanti, and Brong-Ahafo regions of Ghana and 291 from the Ashanti region in 2018 (See Table 4.1). The data collected from the farmers included the years they acquired their farm plots, number of plots they farm, number of plots with tree crops, total farm size, and proportion of farm covered with tree crops. We used these data to assess the extent of tree-crop cover in the three regions of Ghana. We used the farmer household data, tree-crop cover data, annual progress reports on the NFPDP, forest inventory data from the FC/FAO, and tree-cover data from Hansen (2013) to examine whether Ghana's forest-cover change dynamics have resulted from forest transition or forest transformation.

Specifically, we calculated the increase or decrease in primary forest, planted forest, and other naturally regenerated forest from FAO's Forest Resources Assessment data from 1990 to 2015 to identify the changes that have occurred in these forest types according to FAO. We also calculated the percentage of tree-cover lost or gained from 2000 to 2012 from Hansen (2013) data to identify the pattern of forest-cover change from Hansen's perspective. We further compared the forest gained based on the Forestry Commission of Ghana's annual forest plantation establishment and the estimated annual loss of forest cover from 2001 to 2015 to assess whether there was a net forest gain. We again calculated the expansion of tree-crop plantations from 2010 to identify the extent of agricultural land-cover that has been transformed into tree-crop estates. This was complemented with farm size data from 591 farmers showing the proportions of their farm plots that have been converted to tree-crop plantations overtime. All these assessments were combined to examine whether Ghana's forest has transformed or transitioned.

Table 4.1 Study Communities and Number of Farmer Households Surveyed in 2015 and 2018

Sampled communities	Total households	Farm households	Sampled farmers
Farmer households surveyed in 2015			
Amoaku	172	120	30
Mumuni	174	121	30
Kofi Gyan	130	91	30
Bonsie	238	166	30
Adebewura	228	159	30
Anyinasuso	299	208	30
Sampronso	287	200	30
Koforidua	299	208	30
Kuntunso	267	186	30
Nkwankwa No.1	221	154	30
Total	2315	1612	300
Farmer households surveyed in 2018			
Mprim	252	177	17
Ninting	364	254	25
Akantansu	155	109	11
Kwanfinfini	121	84	8
Bunuso	116	81	8
Bosomkyekye	172	121	12
Sekruwa	138	96	10
Kruwi/Abasua	199	139	14
Asuafo	196	137	14
Ananekrom	206	144	14
Bahankra	84	59	6
Abiriwapon	93	65	6
Jeduako	518	363	36
Kyekyebon	450	315	31
Adansi	269	189	19
Atiemo Nkwanta	58	41	4
Banka	265	186	18
Gyadam	109	77	8
Offinso Brekum	172	121	12
Nkwankwaa No.2	265	186	18
Total	4202	2942	291

Source: GSS 2014; Author’s construct, 2015 and 2018

4.4 Results and Discussion

4.4.1 Smallholder Economic Development and National Economic Development Drive Deforestation and Reforestation

Forests in Ghana have experienced disturbances for centuries. In the early 20th century, Ghana's primary forest covered about 66% of the country's land area (Wagner & Cobbinah, 1993). Felling of timber for commercial and international markets led to massive decline in the extent of the primary forest (Hall, 1987; Kotey et al., 1998). The decline in primary forest-cover during the 19th and 20th centuries in Ghana and most developing countries was mainly due to excessive felling of timber and estate crop plantations taking over forestlands (Barbier et al., 2010; Hall, 1987). Migrants from some villages in Ghana, the then Gold Coast, started cocoa estates on sparsely populated areas of lowland rain forest in the early 1900s. These cocoa farmers constructed roads and bridges to transport their cocoa produce to the markets while replacing the remaining forests with cocoa plantations (Hills, 1963). The outputs from the old farms were declining due to gradual soil fertility loss compelling the smallholders to invest their profits in buying more old-growth forest in more remote areas. Smallholders, through this process, established cocoa plantations that spread across the forest frontiers over decades. This transformed the primary old-standing forests initially into cocoa farms, and later into areas of abandoned mosaic of cocoa plantations and scrubland. By 1930, Ghana contained active cocoa frontiers (Berry, 1975; Ruf, 2001).

Growth in the tropical timber trade changed the cocoa-led deforestation in the country, following World War II. Loggers built network of logging roads and smallholders established cocoa estates after the loggers moved (Ruf, 2001). By the end of World War II, the need for renovations in Europe augmented access to Ghana's hinterlands for the exploitation of timber. This subsequently led to massive expansion of the cocoa frontiers after timber extraction. The colonial government instituted a formal forest policy in 1948 to reserve some primary forests and regulate timber exploitation and cocoa production in the forest frontiers (Kotey et al., 1998). The implicit expectation of the colonial government was that all forests outside the protected forest reserves would subsequently convert to agricultural land (Kotey et al., 1998). The 1948 forest policy led to extensive utilization of forest resources without replacement. This caused the transformation of about 80% of the primary forest-cover to cocoa and other plantations by 1990. Annual round wood extractions increased from ~9 million hectares to over 14 million hectares from 1965 to 1990 and cocoa and other tree crops expanded rapidly into the logged areas (FAO, 2015).

Ghana's primary forest started experiencing transformation with the introduction of cocoa, oil palm and other tree-crops. The replacement of primary forests with tree-crop plantations is evident in other tropical countries. Indonesia and Malaysia for instance have had ~50-80% of their primary forests replaced with oil palm and planted forests (Austin et al., 2017; Gaveau et al., 2016; Hurni et al., 2017; Li & Fox, 2012). Similar experiences exist across Latin America and Peru where forest-frontier development has caused about 70% transformation of primary forests (Furumo & Aide, 2017; Gutierrez-Velez et al., 2011). Tree-cover gains in these countries may not reflect forest transition but forest transformation since the introduction of other tree-covers transformed the previously forested areas. The flaws in Ghana's 1948 forest policy that led to significant transformation of the primary forests prompted the government to amend the policy to accommodate sustainable management and restoration of forests (MLF, 1994).

4.4.2 State Forest Policy: A Potential Tool for Restoring Ghana's Forest-Cover

The 1948 State-led forest policy was replaced with the 1994 forest and wildlife policy that introduced participatory management of forest and wildlife resources both within and outside of reserves (MLF, 1994). There was a total shift from utilization without replacement to sustainable management of both reserved and unreserved forests. The Ministry of Lands and Forestry (MLF) implemented some measures to further control timber exploitation. These include levies on air-dried timber under Trees and Timber Amendment Act, 1994; a temporary ban on the export of round logs; and a bi-annual renewal of concession license. In addition, the MLF launched the "Interim measures" in 1994 to control illegal timber harvesting outside forest reserves (Forestry Department, 1994). The effective implementation of these measures made significant impact on reducing timber over-exploitation in the country in the first two years (Figure 4.1). Ghana is not the first country to have introduced measures to reduce timber felling. Between 1990 and 2005, Vietnam for instance implemented successive forestry policies to restrict logging in natural forests, ban the export of raw logs, develop a vibrant furniture manufacturing and export sector, and increase wood imports for the manufacturing industry, all to protect the natural forests (Meyfroidt et al., 2009). These forest policies increased Vietnam's forest area and volume but primary forest continued to degrade due to internal timber felling for the manufacturing industry.

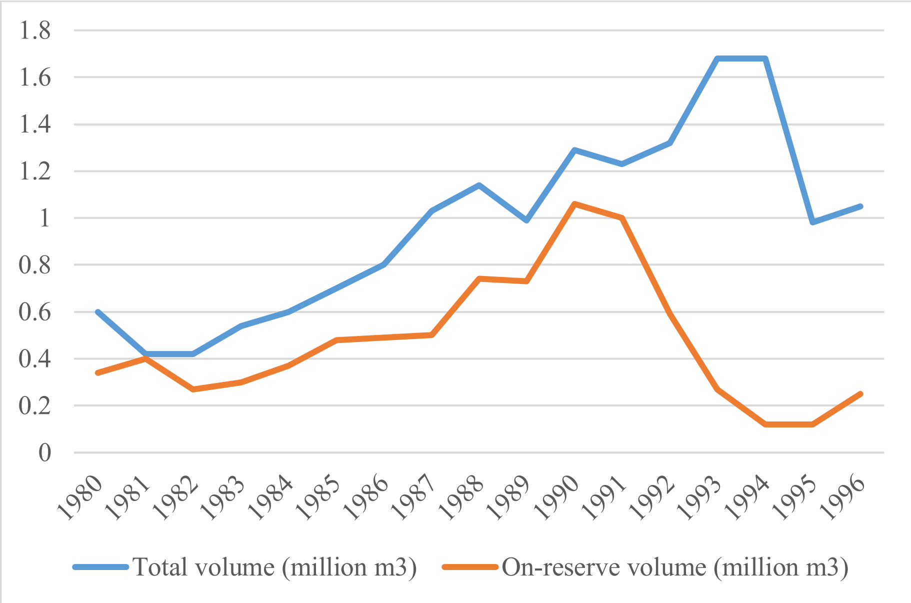


Figure 4.1 Annual Log Production in Ghana from 1980 to 1996

Source: Forestry Department annual reports, 1980-1989; Forestry Products Inspection Bureau and Forestry Department records, 1990-1996. Adapted from Kotey et al., 1998

After the 1994 measures, the Forestry Commission of Ghana introduced the National Forest Plantation Development Program (NFPDP) in 2001 to restore the degraded forest reserves and increase forest extent in Ghana (Forestry Commission of Ghana, 2003). The program aimed at planting 20,000 hectares annually through the Modified Taungya System (MTS), private plantation development, and government plantation development strategies. The MTS was the main reforestation strategy the government adopted from 2001 to 2009 (Forestry Commission of Ghana, 2012). With the MTS, farmers in forest-fringe communities are given portions of degraded forest reserves to inter-plant their food crops with specified tree species to gradually restore the reserves under some agreed benefit sharing arrangements (Acheampong et al., 2016; Ros-Tonen et al., 2013). Although, this strategy came with some challenges, it contributed between 40% and 80% to the planting target annually from 2002 to 2009 (Table 4.2) and benefited the farmers that participated in the program (Acheampong et al., 2016; Adjei et al., 2012). The government encouraged private plantation developers (timber companies) to participate in the NFPDP. This resulted in a joint and collaborative action towards reforesting degraded reserves in Ghana from 2002 to 2016 (Table 4.2).

Table 4.2 Achievements from Ghana's NFPDP, 2002-2016

	Degraded forest planted (in ha)				
Year	MTS	Private developers	Others*	Total	Jobs created
2002	17460.9	2239		19699.9	83068
2003	17691	4596.3	5650	27937.3	80884
2004	16250	5514	5509.8	27273.8	32033
2005	9105	4350	4477.9	17932.9	31500
2006	9401	1609	5006.5	16016.5	44144
2007	8711	1613	5678.8	16002.8	29850
2008	111	5373.8	4736.7	10221.5	12595
2009	2427.3	3281.5	5195.8	10904.6	-
2010		4000	18481.2	22481.2	28469
2011		5064.7	8899.4	13964.1	17200
2012		2052.1	5928.4	7980.5	29227
2013		2746.5	7000.7	9747.2	5184
2014		3674.5	8283.1	11957.6	2524
2015		3906.9	5494.7	9401.6	15842
2016		4237.8	6726.6	10964.4	-

*Includes the Community Forest Management Project (CFMP, 2005-2009), HIPC funded Government Plantation Development Program (GPDP, 2003-2009), Forestry Commission/Timber Industry Plantation Development Fund Plantations (TIPDFP, 2010-2015) and expanded program off reserve.

Source: Forestry Commission of Ghana, 2003-2017

Plantations establishment has been one of the means through which some countries have achieved net forest-cover gain but significant losses in natural forests. Planted forests in Indonesia, Malaysia and Cambodia were promoted within extensive but degraded natural forests (Sloan et al., 2019). These planted areas increased remarkably from 1990, replacing the devalued natural forests and culminating in a forest transformation (Austin et al., 2017; Gaveau et al., 2016). Establishment of tree plantations has gained prominence in the tropical forest-change literature but remains under-appreciated in the forest transition literature, which deals with aggregate unidirectional forest change as a response to forest scarcity (Rudel et al., 2005). Net tree-cover gain within natural forest does not reflect forest transition but rather forest transformation, a phenomenon that is overlooked within the forest transition narratives. Numerous multi-lateral forest restoration schemes are underway (Chazdon et al., 2017; The Bonn Challenge, 2016). Establishment of tree plantations may account for a significant share of these schemes (Rudel et al., 2019; Sloan, 2015). The forest restoration schemes will lead to a more transformed forest and modest net tree-cover gain.

Ghana has been implementing forest restoration schemes since 2001 and has achieved some successes. However, the increase in planted tree-cover of 232485.9 hectares within degraded forest reserves (Table 4.2) from 2001 to 2015 does not qualify Ghana to experience forest transition when the country has experienced deforestation more than twice the size of the planted tree-cover for the same period (FAO, 2010; Janssen et al., 2018; Owusu et al., 2012). Nevertheless, FAO (2015) has recorded an increased forest-cover for Ghana based on their definition of forest.

4.4.3 FAO Estimates an Increased Forest-Cover for Ghana but Primary Forest is decreasing

After decades of forest decline, Ghana's total forest area has increased from 38% in 1990 to 41% in 2015 (FAO, 2015). Other naturally regenerated forest constituted over 90% of the total forest-cover (Table 4.3). Planted forest resulted in the total forest-cover gain as it increased by 2.9% over the 25 years. Other naturally regenerated forest increased by 0.05% for the first 10 years but decreased by 2.6% for the subsequent 15 years. Primary forest-cover decreased throughout the 25 years by approximately 0.4% (Table 4.3). Forest-cover change data from Hansen et al. (2013) shows a net loss in tree-cover from 2000 to 2012 although there were some tree-cover gains (Table 4.3). Almost two-thirds (63%) of the tree-cover loss occurred in forests with 50%-100% canopy cover, mostly primary forests. The total forest-cover increase shown by FAO reflects forest transformation resulting from planted forest and smallholder expansion of estate crops.

Table 4.3 Forest' Share of Vegetation Cover from 1990 to 2015 and Hansen's Tree-Cover Change Data from 2000 to 2012 for Ghana

	FAO's classification of forests (% of total forest)			
Year	% primary forest	% planted forest	% Other naturally regenerated forest	% Total Forest
1990	4.58	0.58	94.84	37.91
1995	4.51	0.63	94.87	38.53
2000	4.43	0.67	94.89	39.15
2005	4.36	1.77	93.87	39.79
2010	4.30	2.83	92.88	40.41
2015	4.23	3.48	92.29	41.03

Hansen et al (2013) forest-cover change for Ghana from 2000 to 2012

Tree-cover as at 2000 (km^2)				Tree-cover change as at 2012 (km^2)		Loss within tree-cover as at 2012 (km^2)			
<25%	26-50%	51-75%	76-100%	Total gain	Total loss	<25%	26-50%	51-75%	76-100%
153157	36659	40464	2074	1345	5406	911	1099	2863	533

Source: FAO, 2015; Hansen et al, 2013.

According to FAO's definition of forest, tree crops such as cocoa, oil palm, citrus, mangoes, and cashew that have reached the various parameters were considered as forest. Tree-crop plantations have expanded by 45% (11.9% to 17.2% of Ghana's land area) from 1990 to 2015 (FAO, 2015). This is more evident in the high forest zone of Ghana where tree-crop plantations have replaced previously forested areas (Acheampong et al., 2019). In the beginning of the 20th century, primary forest covered the proportion of the total forest now occupied by other naturally regenerated forest (Wagner & Cobbinah, 1993). Tree crops and planted forests have transformed the previous primary forest-cover culminating in forest-cover gain.

4.4.4 Expansion of Tree-Crop Plantations is the Disguised Forest Expansion in Ghana

Expansion of tree-crop plantations has contributed to forest expansion in Ghana (Figure 4.2). Since 1990, permanent tree croplands have been increasing in Ghana. Smallholder and commercial farmers are extensively growing wide range of tree crops due to their market values (Anderman et al., 2014; Cerda et al., 2014). In most cases, farmers in Ghana mix food crops with tree crops until the time when the tree crops form canopy such that the shade will not allow subsequent food crops to grow well (Acheampong et al., 2018). When this happens, the initial arable land turns into a tree-crop field and a new arable land is required for food crop cultivation. After two to three years of cultivating the new arable land, the farmer may introduce tree crops on the land to harvest multiple benefits from the same land. This process continues until a farmer has no arable land to cultivate food crops. Farmers who reach this stage either cut their old tree crops to plant food crops or encroach forest close to their farms. Because old tree-crop fields are mostly less fertile for food crops, most farmers prefer to encroach forest for fertile lands (Owubah et al., 2000). The expansion of tree-crop plantations since 1990 has partly transformed Ghana's forest-cover which has resulted in the forest-cover gain presented by FAO (Figure 4.2).

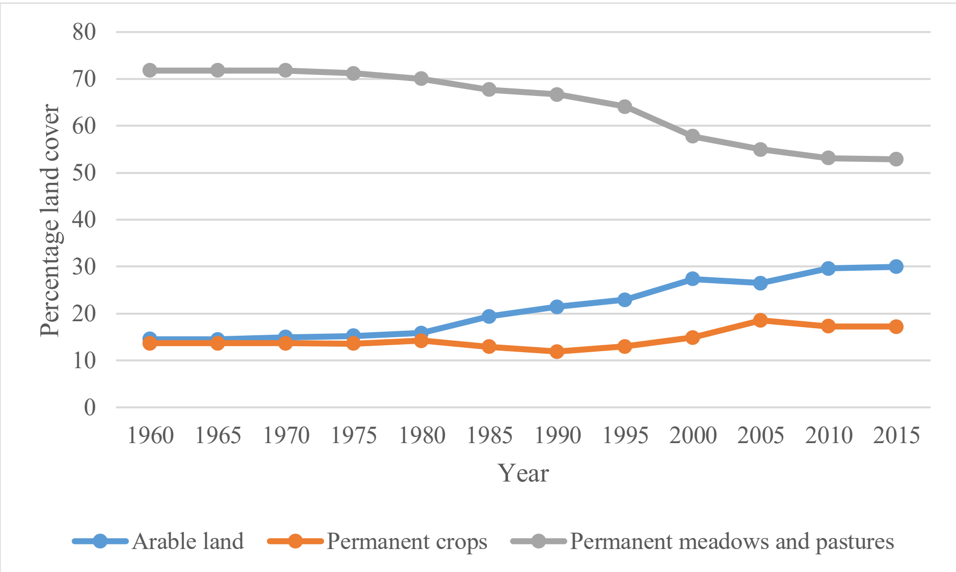


Figure 4.2 Arable and Permanent Tree-Crop Lands are expanding while the Extent of Permanent Meadows and Pastures is declining

Source: FAO, 2015

Agricultural expansion is one of the major causes of deforestation in Ghana but expansion of tree-crop plantations over the years is seen as addition to Ghana's forest area based on definition (FAO, 2015). Expansion of tree crops especially in forest frontiers is a disguised deforestation because natural forest has been replaced

(Acheampong et al., 2019). The planted area for major tree crops in Ghana has been expanding since 2010 with cocoa and oil palm leading (Figure 4.3). Most of these plantations are located in the forest zones of the country due to the favorable soil and climate (SRID/MoFA, 2016). Farm size expansion implies displacement of forest-cover unless there is available arable land for tree-crop cultivation.

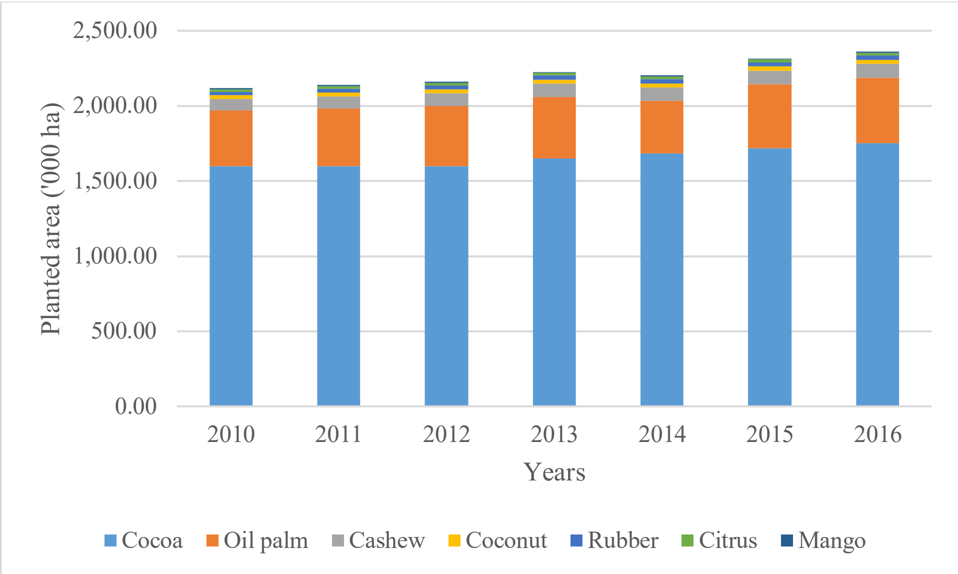


Figure 4.3 Annual Expansions in Tree-Crop Plantations in Ghana, 2010-2016

Source: SRID/MoFA, 2016

Cocoa and oil palm have played significant roles in the transformation of Ghana's forest-cover due to their economic values. The annual productions of cocoa and oil palm (Figure 4.4) imply the expansion of the planted areas for these tree-crops along with other tree-crops such as cashew, mango, and citrus that are gaining popularity in Ghana. This is evident from the farmer household field survey – tree-crops cover 57% of the 1892.4 ha of farmlands cultivated by the 591 farmers. Tree croplands the farmers had before 1990 spanned 249.5 ha but increased to 1078.9 ha as at 2018, registering 11.9% average annual increase in farm size for tree crops (Table 4.4).

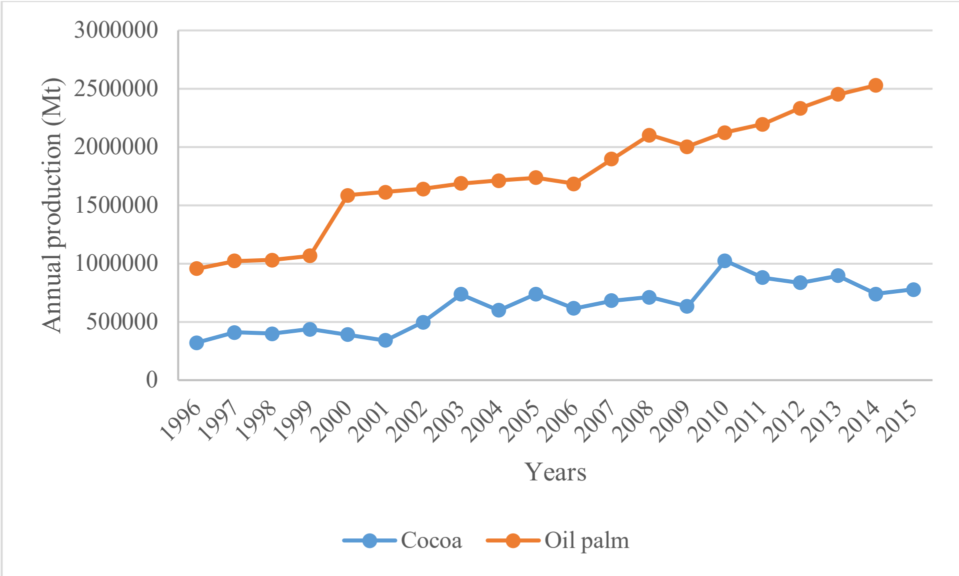


Figure 4.4 Annual Production of Cocoa and Oil Palm from 1996 to 2015, (Mt)

Source: SRID/MoFA, 2016

Table 4.4 Status of Farm Sizes Cultivated by the Farmers before and after 1990

Variable	Land size (ha)	% changes in farm sizes	
Total farm size in ha	1892.4	% tree cropland = 57%	
Total farm size for tree crops	1078.9		
Total farm size before 1990	419.3	Net increase in farm size = 351%	Mean annual increase in farm size = 12.6%
Total farm size after 1990	1473.1		
Total farm size for tree crops before 1990	249.5	Net increase in farm size for tree crops = 332.4%	Mean annual increase in farm size for tree crops = 11.9%
Total farm size for tree crops after 1990	829.4		
Number of farmers (N) = 591			

Source: Field survey, 2015 and 2018

Table 4.5 Number of Plots the Farmers Farm on and Number of Plots Covered with Tree Crops

Number of plots you farm on		Number of plots with tree crops					Total
		0	1	2	3	4	
1	Count	179	128	0	0	0	307
	% within number of plots	58.3	41.7	0.0	0.0	0.0	100.0
2	Count	62	39	71	0	0	172
	% within number of plots	36.0	22.7	41.3	0.0	0.0	100.0
3	Count	34	20	9	20	0	83
	% within number of plots	41.0	24.1	10.8	24.1	0.0	100.0
4	Count	9	5	2	5	7	28
	% within number of plots	32.1	17.9	7.1	17.9	25.0	100.0
5	Count	0	0	0	0	1	1
	% within number of plots	0.0	0.0	0.0	0.0	100.0	100.0
Total	Count	284	192	82	25	8	591
	% within number of plots	48.1	32.5	13.9	4.2	1.4	100.0

Source: Field survey, 2015 and 2018

The farmers have up to five farm plots with each plot planted with different crops such as cereals, legumes, tubers, or tree crops (Table 4.5). More than half (51.7%) of the farmers have tree crops on either one or more of their farm plots and 38.7% have tree crops on all their farm plots (Figure 4.5). These farms are located within and around the forest reserves in the study area. The tree crops that had formed canopies and covered a minimum of 0.5 ha as at 2015 were classified as forest during the survey for FAO's Forest Resources Assessment (Forestry Commission of Ghana, 2015). The expansion of the tree croplands especially the plots within the forest reserves is deforestation in disguise rather than increase in forest-cover.

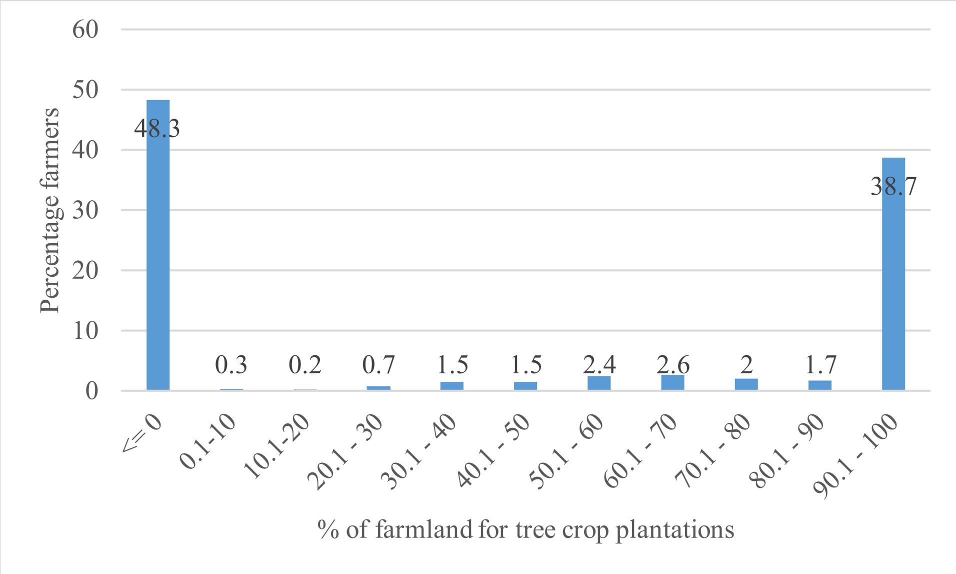


Figure 4.5 Proportion of Farmland the Farmers have planted with Tree Crops

Source: Field survey, 2015 and 2018

The use of broader definition of "forest" has resulted in an unnoticed loss of Ghana's primary forest and increased the risk of tree crops and plantation forests displacing primary forests. This resembles China's experience with rubber tree plantations that expanded and displaced more than 30% of natural forest-cover over 40 years, yet experienced forest transition (Zhai et al., 2017). Other similar trends have been documented in southern Chile, Thailand and India (Chazdon & Uriarte, 2016). The transition that has occurred in Ghana's forest is a transition from primary forests to planted forests made up of planted timber species and tree crops disguised as forests. The forest-change dynamics in Ghana is more of a forest transformation.

4.4.5 The Way Forward for Effective Forest Recovery in Ghana

Indiscriminate use of the term "forest" by FAO and in the forest transition paradigm has overlooked the changes that occur in the various land cover types broadly classified as forest. Disaggregating the dynamics of natural and planted forest-cover as well as matured tree crops from overall forest-cover will not only help identify tree-cover change dynamics but also the factors causing natural forest loss and displacement. Forest-cover dynamics can be misunderstood when overly general definition of "forest" is applied (Zhai et al., 2017). Ghana's forest-cover has increased based on definition but primary forest has transformed and decreased over the years. Effective forest management and recovery policies can help preserve the remaining primary forest and regenerate previously degraded forests.

Ghana has been implementing forest recovery policies since 2001. The implementation is however ineffective at driving forest transition since the rate of deforestation is higher than the rate of forest recovery (Oduro et al., 2015). One strategy to effectively implement the forest recovery policies could be voluntary participation of farmers in reforestation programs without any monetary benefits. Studies have shown that one reason why farmers encroach forest reserves is that fertile farmlands are scarce (Damnyag et al., 2012; Damnyag et al., 2013; Owubah et al., 2000). The Forestry Commission could use this opportunity to reforest degraded reserves by giving degraded forestlands to farmers who are willing to grow trees amidst their food crops according to prescribed conditions. This could be an alternative to the Modified Taungya System (MTS) but without any benefit sharing arrangements, except the lands the farmers will get to plant their food crops. Similar strategies have worked in other countries like China and India but in different context.

The “grain for green” program in China that gave smallholder farmers financial incentives to convert some of their fields to forest plantations increased the rate of afforestation from 1997, although state-led afforestation campaigns were ongoing since the 1980s (Rudel, 2009). The decentralization of control over many forests in India that gave villagers a share of the proceeds from the sale of local forest products led to the restoration of forests in India (Poffenberger & McGean, 1996). Similar applicable strategies can be considered in Ghana to restore and maintain the degraded forest and preserve the remaining primary forest rather than transforming the existing forest-cover. Afforestation and reforestation strategies alone cannot lead to forest transition in Ghana. The government should strengthen the enforcement of forest protection laws to sustain the remaining primary forest. The current trend of deforestation in the country does not warrant any prospect of forest transition (Damnyag et al., 2012; Damnyag et al., 2013; FAO, 1996; FAO, 2010; FAO, 2005) unless forest protection laws are strictly enforced to curb deforestation while implementing reforestation strategies.

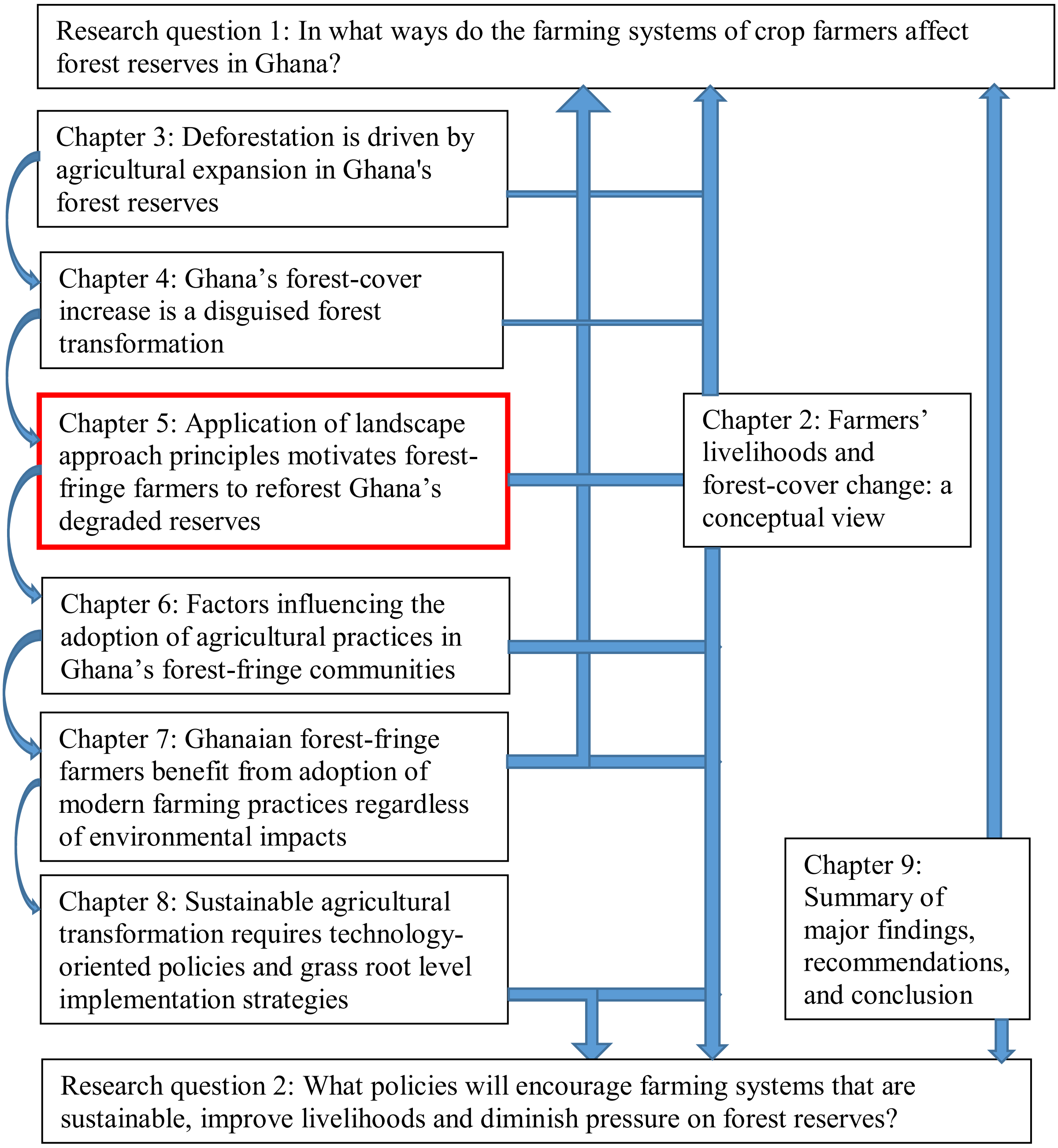
4.5 Conclusion

Establishment of tree plantations and expansion of tree-crops cover have caused total forest-cover gain in Ghana. Most of the gains occurred in forest frontiers depicting the transformation of previous primary forest mostly into tree crops and some planted forests. Since 1994, State forest policies have contributed to reforestation of degraded reserves but the remaining primary forest is still declining. The remaining primary forest forms ~4% of the total forest-cover in the country and this is continuously decreasing due to illegal and unsustainable logging, and tree-crop plantations taking over the logged areas, misinterpreted as forest-cover gain. Agriculture has been the main cause of deforestation, yet matured tree-crop plantations are classified as forest gain due to the use of overly general definition of forest. Smallholders need to survive but not at the expense of forests since forests play various roles for the survival and benefits of humans and the environment. The government could involve farmers to recover Ghana's lost forest while improving their livelihoods at the same time.

Smallholder tree-based land use intensification path to forest transition that was practiced in China and India could be adapted through which the government could engage farmers in reforestation. Fertile farmlands in forest frontiers are scarce in most fringe communities, causing farmers to encroach forests. Involving committed farmers in reforestation programs while protecting the remaining primary forest will reduce the pressure on primary forest and limit transformation of the primary forest. A forest transition may be underway leading to more trees in agricultural landscapes and moderately transformed forest-cover resulting from the restoration of previously degraded primary forest.

What Next?

Chapter four showed that expansion of tree crops cultivation has been counted as forest-cover gain according to the definition of forest Ghana adopted from FAO (2015). However, this increase in forest-cover was more of a forest transformation mostly caused by farmers. Chapter 4 argues that one strategy to achieve forest recovery at less cost is to encourage voluntary participation of farmers in reforestation programs. Chapter five demonstrates, for the first time in Ghana, whether this voluntary participation of farmers in forest restoration is possible. The landscape approach was adopted for this action research.



Chapter Five: Application of Landscape Approach Principles Motivates Forest Fringe Farmers to Reforest Ghana's Degraded Reserves

forests MDPI

Article

Application of Landscape Approach Principles Motivates Forest Fringe Farmers to Reforest Ghana's Degraded Reserves

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Abstract: Research Highlights: Landscape approach principles were developed to address competing claims on resources at local scales. We used the principles to address agricultural expansion in Ghana's forest reserves. Background and Objectives: Agricultural expansion is a major cause of Ghana's forest-cover loss. Cultivation has totally deforested some forest reserves. The situation in Ghana illustrates the trade-off between attaining the Sustainable Development Goals (SDGs). SDG 1—reduction of poverty, and 2—achieving food security, are in conflict with SDG 15—protecting and restoring forests. We examined how farmers in forest fringe communities could be engaged in restoring degraded forests using the landscape approach and whether their livelihoods were improved through the use of this approach. Materials and Methods: The Ongwam II Forest Reserve in the Ashanti region of Ghana is encroached by farmers from two communities adjacent to the reserve. We employed the 10 principles of the landscape approach to engage farmers in restoring the degraded reserve. The flexibility of the landscape approach provided a framework against which to assess farmer behaviour. We encouraged farmers to plant trees on 10 ha of the degraded reserve and to benefit through the cultivation of food crops amongst the trees. Results: Access to fertile forest soils for cultivation was the main motivation for the farmers to participate in the reforestation project. The farmers' access to natural and financial capital increased and they became food secure in the first year of the project's operation. Conclusions: Effective implementation of several small-scale reforestation projects using the landscape approach could together lead to a forest transition, more trees in agricultural systems and better protection of residual natural forests while improving farmers' livelihoods, all combining to achieve the SDGs.

Keywords: forest restoration; multi-functional forest landscapes; landscape approach; rural Ghana; forest-dependent communities; UN Sustainable Development Goals

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5.1 Introduction

The remaining natural forests in the tropics are under intense pressure due to competing land uses. Although conservationists are striving to preserve forests, farmers and extractive industries are encroaching on the forests for their livelihoods (Sayer et al., 2008; White & Martin, 2003). Human competition for land and consequent fragmentation of forests is a major cause of forest and biodiversity loss (Damnyag et al., 2013; Donkor et al., 2011; Janssen et al., 2018). Although some stakeholders are benefiting from deforestation, the socioeconomic and environmental problems resulting from their actions have drawn global attention to the need to restore and sustainably manage forests (Chomitz, 2007; MEA, 2005; The Bonn Challenge, 2016).

Protected areas are central to the global strategy for protecting and managing natural resources such as forests, yet many of the world's protected forests are being degraded (Curran et al., 2004; Dudley, 2008; Tranquilli et al., 2014). The rising demand for food due to population growth and the development of commodity fibre and oil crops are placing pressure on protected areas (Gerber, 2011). The world is predicted to need a 70% increase in food production to feed the growing population by 2050 (FAO, 2009; Sayer et al., 2013). However, agriculture and forests are two competing land uses that will have to co-exist in landscapes, and methods will have to be found in order to reconcile trade-offs. Could foresters adopt landscape approach in their conservation and management strategies in the forest–farm mosaic? Would such an approach benefit farmers who rely on forestlands for crop production? We examined the extent to which farmers in forest-fringe communities of Ghana could be involved in reforesting degraded reserves and whether their involvement could help secure their livelihoods using the landscape approach.

Forest landscapes are diverse, with multiple functions and myriad management regimes. For instance, in Southeast Asia, forest governance and zoning have aimed to restrict human access to forests and have encouraged forest-dependent peoples to move to less forest-reliant and involve in more off-farm activities (Dressler et al., 2016; Li 2008; Rigg, 2005, 2006). Exploitation of forests in Scandinavia and Europe has been mechanized during the 20th century, and the focus on a few commercial species has led to declines in floral and faunal diversity (Berg et al., 1994; Michanek et al., 2018; Siitonen, 2001). In some parts of Africa, however, forest patches exist in agricultural landscapes especially where livestock are present (Duriaux Chavarría et al., 2018). In Southern Ethiopia, participatory forest management has resulted in increased incomes from forest products for community members, and now provides 35%–50% of household income (Yemiru et al., 2010). About 80% of the West African forest area lies in an agriculture-forest mosaic, with biodiversity persistence linked to the livelihoods of local people (Chapman et al., 2004; Norris et al., 2010). The diversity of the functions and management of forest landscapes is varied and highly context-specific.

Ghana's forest landscapes are diverse and portray some complex features. Some forest reserves are allocated for timber production whereas others are for nature conservation (Forestry Commission of Ghana, 2008a). Most of these reserves contain legal settlements, and some farmers have legal farms within the reserves (Acheampong et al., 2018; Wiggins et al., 2004). Communities surround most of the forest reserves in Ghana (Sobeng et al., 2018). Some residents of the fringe communities have legal and illegal farms within the forests (Damnyag et al., 2013; Donkor et al., 2011). Forest encroachment has been difficult to control in Ghana due to the complexity of activities occurring within the forests (Janssen et al., 2018). Restoring Ghana's degraded forests requires a multi-stakeholder approach that reconciles the competing interests of stakeholders.

The Sustainable Development Goals (SDGs) 1, 2, and 15 target sustainable forestry and livelihood improvement (United Nations General Assembly, 2015). Eradicating extreme poverty (goal 1) in farming communities requires that farmers have access to physical, economic, financial, and natural capitals to allow them to produce food and become resilient and less vulnerable. The Forestry Commission of Ghana is responsible for protecting forest reserves from farmers' encroachment. We sought to demonstrate how these farmers could be involved in restoring the already degraded forests and the effect of their engagement on their livelihoods. Access to fertile farmlands could reduce the level of hunger in farming communities and achieve some level of food security among the farmers (goal 2). The Ongwam II forest reserve in the Ashanti region of Ghana has been under the management of the Forestry Department since the 1930s. However, illegal logging followed by illegal farming and fires set by hunters and farmers have degraded more than half of the reserve. The objective of this study was to assess the applicability of the landscape approach in the form of an adapted Taungya system in order to engage farmers in fringe communities of Ongwam II forest reserve in the reforestation of degraded areas for environmental conservation and livelihood improvement.

5.1.1 Revisiting the Taungya System to achieve the SDGs through the Landscape Approach

The Taungya system is a form of agroforestry where farmers combine agricultural crops with woody species during the early years of plantation establishment (Nair, 1985). The system was developed in Burma (Myanmar) in the 1800s and since then has spread to Southeast Asia and other tropical countries (Evans, 1992; Jordan et al., 1992). The British introduced the Taungya system to Ghana in the 1930s in response to deforestation and shortage of farmlands in farming communities fringing forest reserves (Agyeman et al., 2003). Under this system, participating farmers received portions of degraded forest reserves to plant trees amidst their food crops but were required to maintain the trees until canopy closure at which time food crop cultivation is no longer possible. This system initially improved household food security and led to forest restoration. Eventually the system ceased to function. Failure was attributed to insecure land tenure, lack of farmers' participation in decisions about forest management, lack of supervision and abuse of power by forest and public officials, and the fact that farmers did not benefit from the planted trees (Agyeman et al., 2003; Milton, 1994).

The Taungya system was officially stopped in 1987 but re-introduced in 2002 as the Modified Taungya System (MTS) (Forestry Commission of Ghana, 2008b; Milton, 1994). The difference between the old and the new system is that with the MTS (a) farmers are not evicted from the land after 3 years because they have to maintain the trees until maturity, and (b) farmers have a 40% share of the value of planted trees when harvested (Acheampong et al., 2016). The MTS however has some challenges. First, farmers do not get income from the MTS between canopy closure and harvest. Growing food crops is no longer possible after canopy closure but farmers have to continue maintaining the trees until harvest. Second, farmers are not paid for tree planting and maintenance activities. Third, there is delay in signing MTS agreements and absence of a clear mechanism for sharing the 40% timber benefit among individual farmers (Acheampong et al., 2016). These challenges make the farmers insecure about future timber benefits because they have no personal planting records that will specify how to share benefits. The recommendations from the assessment of the MTS made us adopt the landscape approach in our restoration project so that the farmers were fully engaged and had more decision making power in all the activities they undertook in implementing the project.

The landscape approach is a context-specific tool that is most effective for small-scale natural resource conservation and management projects and yet flexible enough to be applied to large-scale projects. Unlike the old conservation systems that are usually top-down, the landscape approach is a collaborative process that brings together different stakeholders with diverse interests and aims to achieve a balance between multiple and sometimes conflicting objectives in a landscape (Sayer et al., 2017). This approach attempts to make long-term improvements to conservation and livelihoods by engaging and empowering the stakeholders to maintain a sustained relationship between themselves and the landscape (Blomley & Walters, 2019; Estrada-Carmona et al., 2014;

Milder et al., 2014; Pfund, 2010). Learning, flexibility, adaptation, and the need for a holistic view of outcomes and impacts in a constantly changing landscape are key concerns of the landscape approach (Sayer, 2009). The landscape approach features most principles of the rights-based approach (Blomley & Walters, 2019). For instance, principle 5 emphasizes recognition of multiple stakeholders and the need for equity. Principle 7 focuses on the clarification of rights and responsibilities and principle 8 emphasizes monitoring and the right to access information by all stakeholders. The principles of both approaches (landscape approach and rights-based approach) work towards effective human-centred conservation of natural resources. When human rights are not recognized, conservation activities can generate negative impacts and minimal local benefits (Springer et al., 2011; Tauli-Corpuz, 2016).

The application of the landscape approach in this research aligns with actions towards the achievement of the SDGs 1—end poverty in all its forms everywhere; 2—end hunger, achieve food security and improved nutrition, and promote sustainable agriculture; and 15—protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt and reverse land degradation, and halt biodiversity loss. Each of these goals has specific targets related to this study (Table 5.1).

Table 5.1 Sustainable Development Goals (SDGs) and Targets Related to the Study

Goal 1. End poverty in all its forms everywhere	
Target 1.1	By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than USD 1.25 a day.
Target 1.4	By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services; ownership; and control over land and other forms of property, inheritance, natural resources, appropriate new technology, and financial services, including microfinance.
Goal 2. End hunger, achieve food security, improve nutrition, and promote sustainable agriculture	
Target 2.3	By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists, and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition, and non-farm employment.
Target 2.4	By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production that help maintain ecosystems, and which strengthen capacity for adaptation to climate change, extreme weather, drought, flooding, and other disasters and that progressively improve land and soil quality.
Goal 15. Protect, restore, and promote sustainable use of terrestrial ecosystems; sustainably manage forests; combat desertification; halt and reverse land degradation; and halt biodiversity loss	
Target 15.2	By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests, and substantially increase afforestation and reforestation globally.

Source: United Nations General Assembly, 2015.

The main stakeholders that have direct influence on forests in Ghana are the foresters, fringe communities, and timber companies. Farmers in forest-fringe communities require fertile lands for food crop cultivation and may be in conflict with foresters working towards sustainable management of the forests. Involving these farmers in forest restoration projects could help reduce poverty and hunger while re-establishing the degraded forest. Sayer et al. (2013) have proposed 10 principles of the landscape approach for applications in multi-functional landscapes. We assessed how these principles could reconcile forest restoration and livelihood development goals of farmers in forest-fringe communities of Ghana.

5.2 Materials and Methods

Application of the landscape approach to the Taungya system to restore degraded forest requires convening different stakeholders with varied objectives to make use of the land for different purposes in a complementary way. Four stakeholders were involved in this research project: forest managers (from the Forestry Commission of Ghana and Forest Services Division), forest technical officers (forest ranger, forest cartographer, both from the Forest Services Division), project team (research assistant—Environmental Conservation and Management Foundation (Ecomafghana), forest ranger—Forest Services Division at Mampong-Ashanti, forest guard—Forest Services Division at Mampong-Ashanti, field manager—experienced farmer and field assistant from Ecomafghana, and the lead author), and farmers. A research assistant from the Environmental Conservation and Management Foundation (Ecomafghana), a local not-for-profit Non-Governmental Organization (NGO), and the lead author consulted the district manager of the Forest Services Division at Mampong-Ashanti to advise which forest reserve required such an action-research approach. We chose Ongwam II Forest Reserve, where logging and agricultural encroachment has deforested almost half of the reserve. Illegal farmers are moving into accessible areas. According to the district manager, there is high biodiversity loss due to the degradation of the reserve.

We surveyed some degraded portions of the reserve with a forest technical officer, forest guard, and a cartographer. We then selected an area of 49 ha with very few trees and a thick cover of elephant grass (*Pennisetum purpureum*) (Figure 5.1and Figure 5.2). This area is close to two fringe communities, Hwidiem and Kruwi. We visited the leaders of these two communities to make our intention known to them. The leaders showed their interest and we announced our intentions to the community members through information centres. After the announcement, farmers were able to register their interest in the project with their leaders. We presented a report and official proposal to the district manager expressing our interest in initiating a forest recovery project in the reserve. After the manager's approval, we carried out a farmer household survey to identify the farmers that were willing to participate in the project. Thirty-one farmers expressed interest, 16 from Hwidiem and 15 from Kruwi. These farmers were either heads of their households or members of their households.

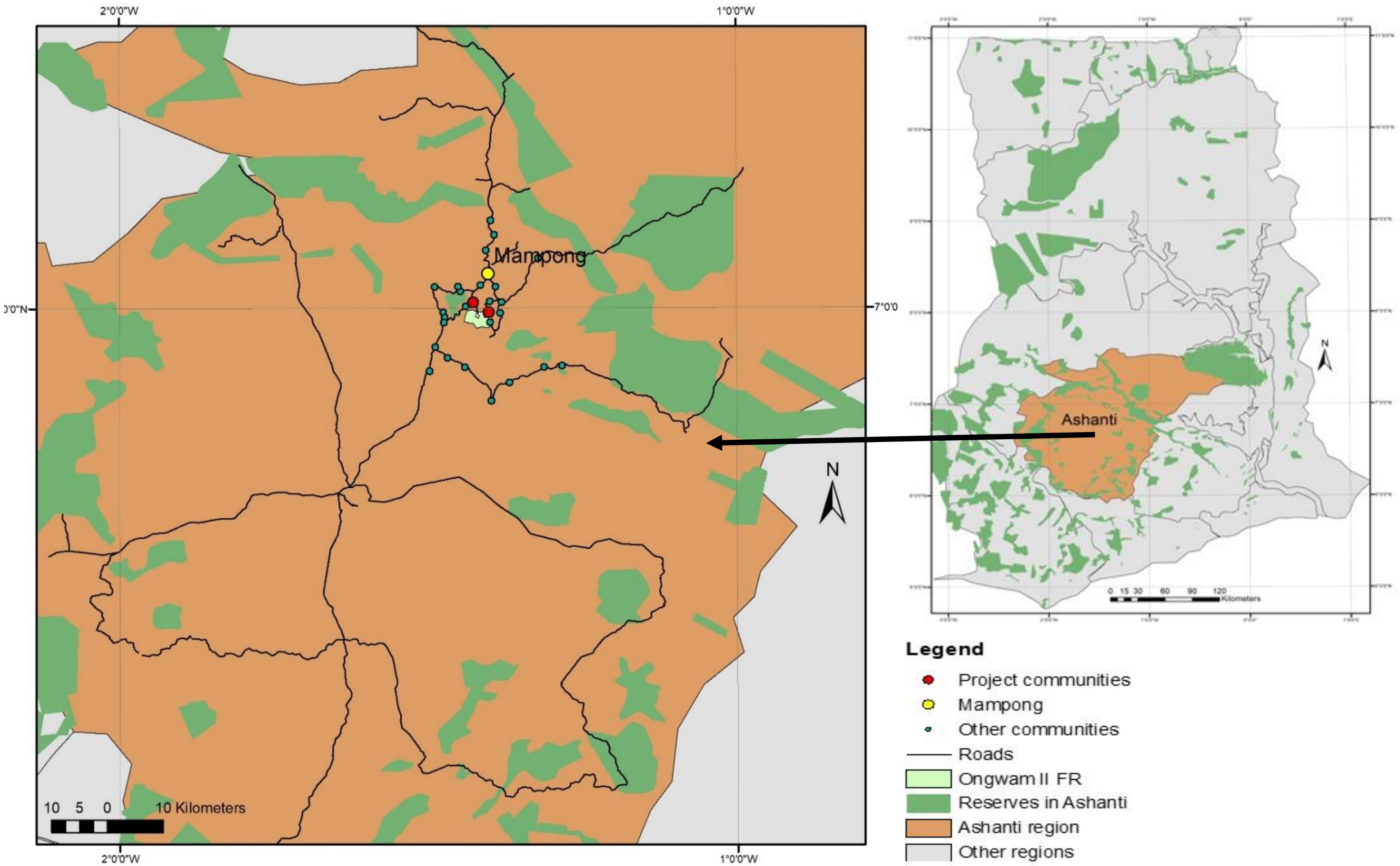


Figure 5.1 The Ashanti Region of Ghana showing the Study Reserve and Project Communities

Source: Resource Management Support Center, Kumasi (RMSC), 2016.

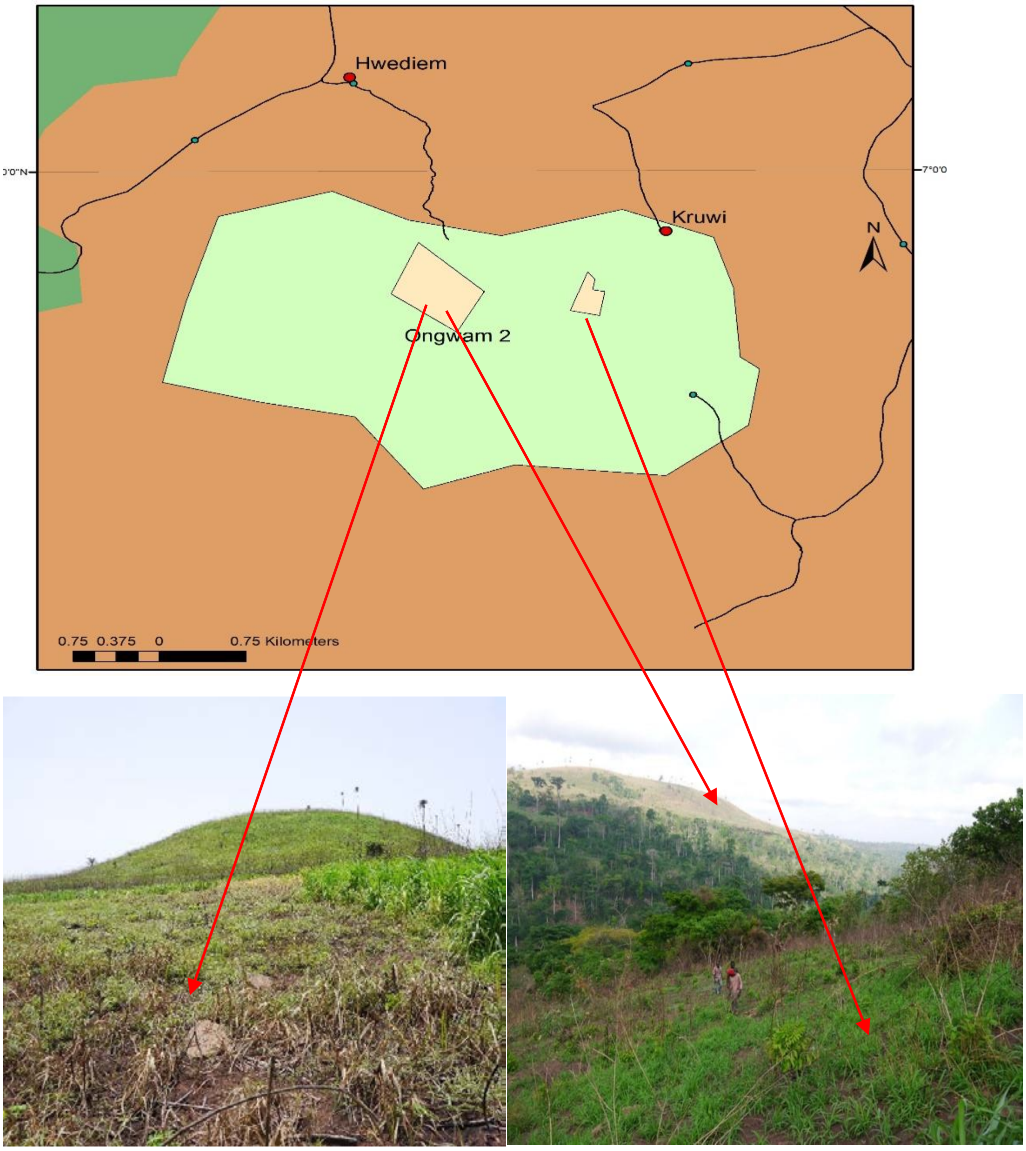


Figure 5.2 State of the Project Site in Ongwam II Forest Reserve as of 2017

The district manager forwarded the proposal to the Forestry Commission of Ghana for approval. The Forestry Commission reviewed the project plan and issued a letter approving the project. The first phase of the project started in December 2017 and ended in November 2018. The famers gave their verbal informed consent before they participated in the survey. The Human Research Ethics Committee of James Cook University, Australia, approved the study's ethical protocol (application ID: H7199). First, we collected data on the farmers' age, farm size, ownership of farmland, land tenure system, location of farm, farming experience, and motivation to participate in the project. These data were analysed to identify the factors that motivated the farmers, as well as their capacity to participate in the project. We then assessed the farmers' commitment to the project's implementation using the principles of the landscape approach (Sayer et al., 2013). Finally, we collected data on the quantity of produce the farmers harvested from both the project land and their other farmlands. We used the data to assess whether the livelihoods of the farmers improved through their involvement in the reforestation project and whether or not the project has contributed to the achievement of the SDGs.

5.3 Results and Discussion

5.3.1 Brief Background of the Farmers

The youngest farmer was 28 years old whereas the oldest was 69. Almost a third (32%) of the farmers were between the ages of 31 and 40 years old, and 26% were between 41 and 50 years old. More than half (55%) of the farmers had over 10 years of farming experience, and 29% had between 5 and 10 years of experience. No farmer had less than 2 years of experience. Almost two-thirds (61%) of the farmers had no other job aside from farming, whereas the rest had one or two other irregular income earning activities. The ages, years of farming, and farming as a main activity (Table 5.2) implied that the participants were experienced farmers, and hence were capable of assisting in the reforestation project.

Table 5.2 Brief Characteristics of the Farmers

Ages of the farmers (N = 31)		
Age	Number of Farmers	Percentage
28	1	3.2
31	1	3.2
32	2	6.5
33	2	6.5
35	1	3.2
36	1	3.2
37	2	6.5
39	1	3.2
43	4	12.9
44	1	3.2
45	2	6.5
46	1	3.2
51	2	6.5
52	2	6.5
53	1	3.2
55	2	6.5
63	1	3.2
65	2	6.5
66	1	3.2
69	1	3.2

Farmers' experience in farming on the basis of years of farming (N = 31)		
Years of Farming	Number of Farmers	Percentage
2	2	6.5
3	1	3.2
5	2	6.5
6	2	6.5
8	3	9.7
10	4	12.9
12	2	6.5
13	1	3.2
18	1	3.2
20	2	6.5
22	1	3.2
25	1	3.2
30	3	9.7
31	1	3.2
34	1	3.2
35	1	3.2
40	1	3.2
44	2	6.5

Occupations of the farmers (N = 31)		
Occupation	Number of Farmers	Percentage
Farmer	19	61.3

Farmer, block molder	2	6.5
Farmer, food vendor	1	3.2
Farmer, mason	1	3.2
Farmer, mason, labourer	2	6.5
Farmer, trader	4	12.9
Farmer, trader, labourer	1	3.2
Farmer, welder	1	3.2

5.3.2 Farmers' Motivation to Participate in the Reforestation Project

Access to fertile land to plant food crops was the main motivation for 48% of the farmers to participate in the project. An additional 36% indicated this same rationale, but also included the idea of the benefit that the community would get from the restored forest. One farmer stated, "The community will benefit from the dense forest again. We will also get land to farm on now that all our farmlands are infertile". Another farmer added, "I want to participate so that I will get land to farm and also help reforest the reserve for future generations". The farmers engaged in restoration in exchange for access to the forestland for farming, a phenomenon that is evident elsewhere (Adhikari et al., 2014; Adjei et al., 2012; Coulibaly-Lingani et al., 2011).

The survey found that 29% of the farmers had inherited farmlands, whereas 71% had insecure tenure under sharecropping arrangements or had encroached on the forest. However, 77% of the farmers had land that was infertile, a reason for them to join the project. Secure tenure and ability to cultivate crops are the main priorities of farmers in forest frontiers (Kansanga & Luginaah, 2019; Meaza et al., 2016). Willingness to participate in a reforestation project depends on the benefits attained. Farmers in forest fringes of Ghana would not participate in any forest recovery intervention that would not positively affect their livelihoods (Acheampong et al., 2018; Adjei et al., 2012).

Some of the farmers (16%) admitted that they farm illegally in the forest, and to avoid eviction they had to participate in the project. An illegal farmer stated, "This idea has come before but I could not take part because I was sick. Now that I have the strength and I farm in the forest, I have to grow the trees as my contribution to the project". Another illegal farmer said, "I have been planting the trees since 2008 although it was illegal for me to farm in the forest. Now that you have come for us to do the work, why will I not get involved?" Further enquiry revealed that all the farmers except two had farms within the forest reserve. However, they did not mention those farms as their main farms because they were illegal. Participating in the project was therefore an opportunity for them to farm legally on fertile forestland. The project initiators and the farmers had different short-term priorities but the long-term outcome for both parties was the same. The landscape approach brings stakeholders with different interests together to achieve a common goal (Sayer et al., 2017). The farmers were cultivating illegally in the forest reserve. Although some claim they were growing trees, their main interest was food crop production. The project initiators were interested in growing trees to restore the degraded forest. The implementation of the project would mean that the farmers would have to be evicted from the land and be deprived of their source of livelihood from the land. To prevent this negative impact on the farmers, we used the landscape approach to engage the farmers in the reforestation activity to ensure that both parties (the farmers and the project initiators) achieve their objectives. The farmers get the land for farming and the project initiators get the land planted with trees.

5.3.3 Assessing the Farmers' Commitments with the Principles of the Landscape Approach

5.3.3.1 Continual Learning and Adaptive Management

This principle states that progressive learning should be a characteristic of all stakeholders involved in making decisions towards a common objective. We assessed the application of this principle by engaging the farmers in establishing the nursery for the project. The project team organized a meeting to demonstrate the following nursery procedures to the farmers: making the beds, tending the seeds, and watering the plants. All the farmers were involved in preparing the nursery (Figure 5.3). The project team tasked one educated farmer to prepare a duty roster for watering the plants.

Figure 5.3 Farmers preparing Beds to Nurse Tree Seeds for the Reforestation Project.

The seeds started germinating after 3 weeks but were surrounded by weeds. The farmers could not differentiate between the tiny seedlings and the weeds. The expertise of the foresters became useful at this point. These experts assisted the farmers in removing all the weeds from the nursery beds. From then, the farmers maintained the seedlings until the time for transplanting. The farmers' willingness to learn new skills and their ability to adapt to new strategies on the basis of changing circumstances led to the success of the nursery. Continual learning and adaptive management is fundamental to the success of every multi-stakeholder activity (Sayer, 2009). We paid attention to the establishment of the nursery because the process entailed learning and adaptive management from the beginning to the end. Making the nursery beds for the tree seeds involved some techniques that the farmers would not have known without the advice of foresters. Weed removal from the newly germinated seeds was tedious. The establishment of the nursery served as a measure of the commitment of the farmers to the project.

5.3.3.2 Common Concern Entry Point

According to this principle, project managers should not neglect the values, beliefs, and objectives of different stakeholders in the process of achieving the common objective for the landscape. All the farmers had one reason to participate in the project—to get fertile land to farm. Each farmer had their preferred crops—plantain, cocoyam, yam, and maize, among others. The project team had one objective—to reforest the treeless portions of the forest. The forest managers of the Forestry Commission of Ghana and Forest Services Division at Mampong-Ashanti had one vision—to reconcile conflicting claims on the land. These diverse objectives provided a shared goal of restoring the forest through collective action. To achieve the common goal, the project team took the farmers to the project site to prepare the land for cultivation.

The first phase of the project used 10 ha and involved 16 farmers who were ready to start their farms. The other farmers were already cultivating illegally at other locations within the same forest but not on the project land. These farmers were encouraged to plant some trees on their already cultivated forestlands. The project team placed the 16 farmers at specific locations to weed to plant the seedlings. The farmers achieved their common goal—access to fertile land for cultivation. The project team achieved its objective of getting the land prepared for planting. The common concern entry point was therefore achieved.

5.3.3.3 Multiple Scales

Operational processes at different scales can shape the outcomes of projects at other scales through lessons learned from feedback, flows, and interactions. The foresters in the project team were involved in a Taungya system before the initiation of this project and were aware of the challenges involved in engaging farmers in forest restoration. The foresters advised the project team on how to motivate the farmers to ensure their total commitment to the project. The farmers were therefore given allowances (minimum of USD 5 per farmer for each day of work) for any activity they undertook that did not contribute directly to their livelihood, for example, maintaining the nursery, cutting pegs, and planting the seedlings. These allowances served as additional income for the farmers and motivated them to participate actively in the project's implementation. Lack of motivational packages has been one of the challenges of the MTS (Acheampong et al., 2016; Acheampong et al., 2018; Adjei et al., 2012). Lessons from previous projects helped resolve such challenges.

5.3.3.4 Multi-Functionality

Most landscapes provide multiple functions to diverse stakeholders. Trade-offs are inevitable in the attempt to reconcile the values accruing to the various stakeholders with the aim to achieving their goals (Sunderland et al., 2013). According to the foresters, cassava is one potential crop that hampers the growth of young tree seedlings, and hence cannot be grown on the project's land. However, cassava is a major cash crop for most farmers. Disallowing its growth on the project's land would not favour the farmers but would be the best solution to ensure the survival of the tree seedlings. The project team held a meeting with the farmers and agreed through consensus that cassava cannot be the main crop on the land. It can, however, be grown on the boundaries of the land for household consumption. The farmers accepted this idea because they had other options for cash crops.

Farmers use herbicides to control weed growth on their farms. Herbicides are not allowed in Ghana's forests because they kill some young tree species. Excluding herbicide use by the farmers would reduce the area that they are able to cultivate. Again, the farmers accepted this condition because they needed fertile land to farm. Effective reconciliation of conflicting issues in a multi-functional forest landscape strengthens stakeholders' commitment to forest restoration and conservation (Estrada-Carmona et al., 2014; Milder et al., 2014; Pfund, 2010). Farmers' active participation in reforestation declines when authorities fail to achieve consensus around grievances (Acheampong et al., 2018; Adjei et al., 2012).

5.3.3.5 Multiple Stakeholders

The reforestation project involved multiple stakeholders with different roles. The farmers were the main actors. They cleared the land, established the nursery, cut pegs, pegged the land, planted the seedlings, and nurtured the young trees while maintaining their farms. The project team facilitated the entire process. Figure 5.4 shows some of the pegs the farmers cut and the nursery they established at two sites for the project.

Figure 5.4 Pegs Cut from Bamboo (Bottom Right) and Nursery Raised at two Sites by the Farmers.

The district manager and the plantations manager of the Forest Services Division at Mampong-Ashanti indirectly participated in the project. The district manager oversees all activities in the Forest Services Division. He oversaw all the administrative works related to the project and gave advice where necessary. The plantations manager oversees all activities relating to plantations establishment in their catchment areas. He supported the project team with technical advice on tree species and planting techniques. Although these managers are foresters, the implementation stage of the project was carried out with the forest ranger and forest guard in the project team. The project team reported to the forest managers periodically and sought assistance when confronted with unforeseen obstacles. One such obstacle occurred when the farmers finished cutting the pegs and needed to transport them to the project site. There was no route through the forest to the site. The project team consulted the forest managers on the most convenient location to create a path. Another instance of the forest managers' participation concerned the type of trees to grow. Through their long years of experience in forestry and examination of the depth and nature of the soil, they recommended teak as the main tree to grow together with other indigenous tree species. In all, four stakeholders—farmers, forest technical experts, forest managers, and the project team—worked together to implement the project.

5.3.3.6 Negotiated and Transparent Change Logic

Transparency is the basis of trust and it is achieved through a mutually understood and negotiated processes of change. Good governance results in consensus on general goals, challenges, and concerns (Sayer et al., 2013). All stakeholders need to know why a course of action has been taken and the risks and uncertainties ahead. The project was managed by the project team. Management procedures included planning for uncertainties such as drought and continuous rainfall, organizing project activities in a participatory manner with the farmers, directing what is supposed to be done in cases where the farmers had no or little knowledge about an activity such as cutting pegs, and controlling the entire process of implementation. The governance of the project was based on two-way communication. Although the project team conveyed information to the farmers on the composition of the various stages of the project, the farmers provided feedback, inputs, and suggestions to the project team for refinement of actions towards the implementation of the project. The farmers were aware of any decision that was taken, and no change was imposed on them. The project team negotiated with the farmers on the use of chemicals and the planting of cassava. Days and times of communal work were agreed upon with the farmers. Transparency was key in the operations of the reforestation project.

5.3.3.7 Clarification of Rights and Responsibilities

Stipulation of rights and responsibilities are key components in adopting the landscape approach (Sayer et al., 2013) and achieving effective landscape governance (Blomley & Walters, 2019). Each stakeholder had rights to exercise and responsibilities to perform towards the reforestation project. The farmers had the right to grow food crops on their allotted plots until the trees form a canopy. They were required to maintain the trees while cultivating the land. The farmers carried out their duties as expected, and grew their crops as they wanted (Figure 5.5).

Figure 5.5 Farms on the Project's Land with Young Teak Trees Shown in Lines beside the Pegs.

The project team had the right to expel any farmer who violated conditions, for example, by applying herbicides or not maintaining the trees. Although it was the responsibility of the farmers to replant dead seedlings, the project team had to conduct survival surveys to check on the number of seedlings that did not survive in each farm and supply additional seedlings to the farmers. Finally, the Forestry Commission of Ghana had the right to withdraw the permit to carry out the project if conditions were violated. The Commission, on the other hand, had the duty to provide technical support to the project implementers.

Each stakeholder knew the rights and responsibilities attached to the project. As a result, there was no instance that a stakeholder violated their duties or impinged on another stakeholder's rights. Minor conflicts arose, but they were resolved through consensus. One instance was the replanting of dead seedlings, which the farmer had to do immediately when the seedlings arrived. However, there were some instances when the farmer was not present. When this happened, the project team placed the seedlings in the soil in a shady place so that they remained in good condition until the farmer arrived. This strategy worked for all the affected farmers.

5.3.3.8 Participatory and User-Friendly Monitoring

This principle emphasizes that there should be all-inclusive and participatory monitoring. No single person has sole access to any information. Trust is built when all stakeholders are involved in monitoring the operations of a project (Sayer et al., 2013). Because the farmers and the project team agreed on a common outcome, they all participated in monitoring the project. The project team monitored each field periodically. The farmers also reported unexpected developments to the project team wherever and whenever they occurred. This brought transparency and accountability throughout the execution of the project.

5.3.3.9 Resilience

Stakeholders should recognise that threats and vulnerabilities are bound to occur due to changing patterns and external events. Learning how to be resistant to threats is one means of building the capacity of stakeholders (Sayer et al., 2013; Walker & Salt, 2006). The main threat to the project was fire, which occurs during the dry season from December to February. The project team trained the farmers on how to create fire belts to prevent accidental fire outbreaks on the project's land. The farmers weeded 5-meter wide strips at the boundaries of the project as fire belts. Each farmer used their section of the fire belt to grow vegetables before the dry season.

By the end of November, the fire belt was void of weeds and needed no major weeding. Through this, the farmers were able to respond to fire threats. The project team did not impose this idea on the farmers. The team and the farmers developed this idea through consensus. The objective of the project was to reforest the degraded reserve while providing livelihood to the farmers. Any portion of the landscape the farmers cleared should contribute to this objective, and hence the fire belts were cleared in the rainy season and were cultivated until the onset of the dry season.

5.3.3.10 Strengthening Stakeholder Capacity

The first phase of the project required stakeholder capacity building, mainly focusing on the farmers. The farmers, the main actors of the project, were trained in all the activities involved in the project's implementation. The willingness of the farmers to undergo the training showed their commitment to the project. Environmental conditions kept changing. There were instances when the soils became dry due to continuous sunshine without rain and other instances where the soils became waterlogged due to continuous rainfall. The farmers were equipped with the knowledge of the right time to plant seedlings and replace those that died. The progress of the project was driven by climatic and environmental conditions of the area. This enabled the building of the farmers' capacity. They improved their skills as the project progressed.

5.3.4 Lessons from the Application of the Landscape Approach Principles

The 10 principles of the landscape approach were adapted and applied to the reforestation project. The use of these principles enabled stakeholders to achieve their varied objectives without any significant conflicts. We did, however, experience challenges. First, despite disallowing the use of herbicides on the project land, one farmer sprayed about half a hectare of his maize with a herbicide that does not kill maize, thinking that the young teak plants would survive the chemical. Almost 300 plants died due to the farmer's ignorance, but he replanted them in the next rainy season. This reduced our success rate. Second, another farmer accidentally burned almost 200 young trees after harvesting watermelons and while trying to prepare the land quickly to grow maize. Third, a farmer, after harvesting his beans and okra crops, left the land and never came back. We learned his intention of stopping farming when we asked him, at which time the weeds had already grown about half meter tall around the young trees. A new farmer, however, took over his land.

Because human behaviour is unpredictable, some challenges and failures in the application of any principles for conservation and restoration projects are inevitable. However, adoption of flexible strategies and learning from experience did improve the success rate of our restoration project. Our adoption of the landscape principles helped achieve greater success than the Taungya and Modified Taungya systems because the farmers were part of all decision making and they were motivated in cash to carry out any extra activity that did not directly enhance their livelihoods. The Taungya systems failed because there was no motivation, transparency, and accountability, and the farmers were not sufficiently involved in forest management decisions. The farmers were the recipients of instructions and not participants in decision-making.

5.3.5 The Contribution of the Reforestation Project to the Livelihoods of the Farmers

Of the 31 farmers who were involved in the first phase of the project, 16 cultivated their crops from the beginning of the project. Priority was given to the farmers who had small or no existing plots. We delayed involvement of the rest of the farmers to the next phase of the project because they had lands ready for cultivation. The land sizes apportioned to the 16 farmers constituted 50% to 100% of their entire farmlands and 38% of the farmers cultivated solely on the project's land. The project served as a source of land for the landless farmers and added to the holdings of the farmers who already had land.

Table 5.3 Monetary Values of all Outputs Harvested on Both Project and Non-Project Land.

Worth of harvested produce (USD)	Farms in the forest and on the project's land (number of farmers)		
	Yes**	No**	Total*
0	1	7	8
72.0	0	1	1
236.0	0	1	1
280.0	0	1	1
384.0	1	0	1
432.0	0	1	1
452.0	1	0	1
460.0	0	1	1
476.0	0	1	1
532.0	1	0	1
784.0	1	0	1
808.0	1	0	1
928.0	1	0	1
954.0	1	0	1
1,064.0	1	0	1
1,244.0	1	0	1
1,308.0	1	0	1
1,396.0	1	0	1
1,490.0	1	0	1
2,384.0	1	0	1
2,740.0	1	0	1
2,820.0	1	0	1
Total	16	13	29

Simple Statistics for Monetary Values of All Outputs Harvested

	Project's farmers	Non-project farmers	Total farmers
Mean value (USD)	1,205.5	130.4	
Standard deviation	821.6	190.7	
Minimum value (USD)	0.0	0.0	
Maximum value (USD)	2,820.0	476.0	
Total famers	16	13	29

*All the 29 farmers farm in the forest. A total of 16 farmers farmed on the project's land and 13 farmers illegally farmed elsewhere in the forest reserve. Two farmers did not farm in the forest reserve. Note: The table is in two parts, the second (lower) part presents the mean, standard deviation, and minimum and maximum monetary values of the outputs harvested by the 29 farmers. ** Yes = farmer farms on the project's land. **No = farmer farms in the forest but not on the project's land.

The 16 farmers planted their crops on the project's land and the other 15 farmers cultivated their non-project farmlands. Assessment of the harvested outputs from both sets of farmers indicated that the project's farmers harvested more produce than those who farmed on the non-project land. Although 81% of the project's farmers harvested between USD 500 and USD 3000 worth of produce within the first six months of cultivation, none of the non-project farmers harvested more than USD 500 worth of produce (Figure 5.6 and Table 5.3). The reason was that, first, the existing farmlands of the non-project farmers were infertile. Second, although these farmers had other illegal farms in the forest, they feared arrest by forest guards. Consequently, they could not spend enough time maintaining their crops and weeds, and therein pests and diseases took over their farms. According to the farmers, weeds were competing with the crops for nutrients. Pests were feeding on the crops, causing damage and destruction to crops such as maize, tomatoes, and beans, and diseases were infecting the crops due to poor farm maintenance. This delayed the maturity and affected the health of the crops. As a result, 54% of the non-project farmers could not harvest anything at the time all the other farmers were harvesting their crops. Insecure land tenure thus affects farm productivity (Kansanga & Luginaah, 2019).

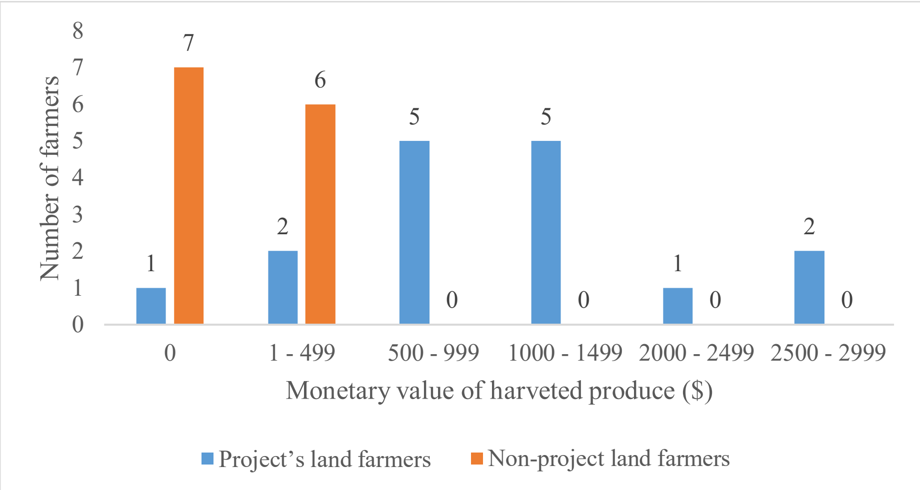


Figure 5.6 Monetary Values of Outputs Harvested on the Project's Land and Non-Project Land.

Note: 29 farmers cultivated in the forest, 16 on the project's land, and 13 illegally elsewhere in the reserve. Two participating farmers did not farm in the reserve.

Aside from land tenure security, soil fertility determines the quantity of produce a farmer harvests (Haggblade et al., 2010; Place et al., 2003; Sanchez, 2002). A total of

44% of the project's farmers harvested 85% to 100% of their produce from the project's land (Table 5.4), although their other farm plots were bigger than the plots they obtained from the project. The other farmers harvested up to half of their produce from the project's land. These results confirm the rationale behind the farmers' participation in the reforestation project. Other studies in Ghana and some developing countries have stated similar reasons for farmers' participation in forest management (Acheampong et al., 2018; Adhikari et al., 2014; Coulibaly-Lingani et al., 2011). The first priority of farmers is a secure livelihood, and they participate in interventions that place high importance on their livelihoods.

Table 5.4 Proportion of Produce Harvested from the Project's Land.

Percentage of harvested produce from project land	Farms in the forest and on the project's land (number of farmers)					
	Yes*	%	No*	%	Total	%
0	1	6.3	13	100.0	14	48.4
8.00	2	12.5	0	0.0	2	7.0
14.00	1	6.3	0	0.0	1	3.4
36.00	2	12.5	0	0.0	2	7.0
40.00	1	6.3	0	0.0	1	3.4
44.00	1	6.3	0	0.0	1	3.4
45.00	1	6.3	0	0.0	1	3.4
86.00	1	6.3	0	0.0	1	3.4
96.00	1	6.3	0	0.0	1	3.4
97.00	1	6.3	0	0.0	1	3.4
100.00	4	25.0	0	0.0	4	13.8
Total	16	100.0	13	100.0	29	100.0

* Yes = farmer farms on the project's land. *No = farmer farms in the forest but not on the project's land.

One indicator of a farmer's improved livelihood is being food secure (Andersson Djurfeldt, 2015; Bailey & Buck, 2016; Davies, 1996). Selling excess produce for income contributes to improved livelihoods. Four-fifths (81%) of the farmers sold between 80% and 99% of their harvested produce. All the sales of 25% of these farmers were from the project's land, whereas 19% had between 85% and 96% of their market produce from the project's land. Few farmers sold less of their produce harvested from the project's land (Figure 5.7). The outcome of the project contributed to the financial assets of the farmers.

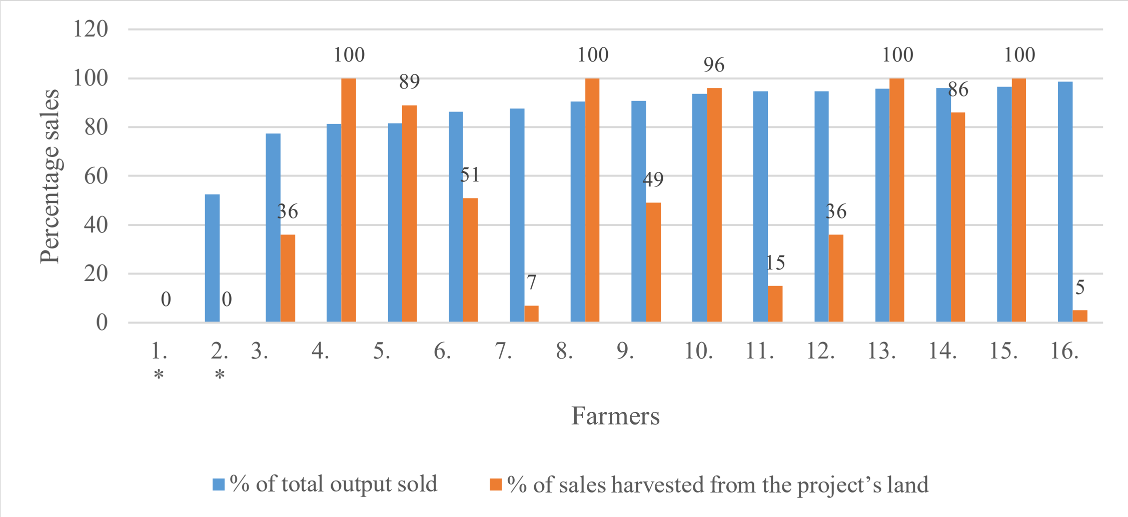


Figure 5.7 Output Sold and Proportion Harvested from the Project's Land.

*Farmers 1 and 2 grew banana and plantain on the land they obtained. These crops had not matured at the time this survey was taken, and hence this is the reason for 0% sale from the project's land. How to interpret the graph: Farmer 3 sold 77.4% of the produce harvested from all his/her farmlands, and this included 36% from the project's land. Farmer 4 sold 81.2% of produce harvested from all his/her farmlands, and this included 100% from the project's land, etc. The data labels indicate the percentages of the harvests from the project land that were sold.

The project's farmers sold more than half of their harvested produce because they had enough to meet their domestic needs. These farmers utilised the project's land (additional natural capital) to obtain more financial assets while depending on their other land for food security. Over half (56%) of the project's farmers derived 90% to 100% of their food consumption from the project's land. Overall, the implementation of the reforestation project enhanced the livelihoods of the farmers through access to fertile land, additional income through sales of produce, and providing food security.

5.3.6 The Contribution of the Reforestation Project to the Achievement of the SDGs

The reforestation project using the landscape approach contributed to the SDGs 1, 2, and 15. The government of Ghana has been investing in restoration of degraded forests but with little success [59] because the farmers who contribute to deforestation are usually excluded from reforestation projects and forest management decisions. Our reforestation project contributed to SDG 15 in two ways. First, we engaged the farmers, thereby preventing them from clearing other areas of the forest, preserving life on land. Second, we (with the farmers) planted a degraded portion of the forest, and this activity will continue, gradually restoring the forest and its biodiversity. Farming is the predominant employment in forest-fringe communities of Ghana, but scarcity of fertile farmlands makes some farmers degrade forest reserves (Acheampong et al., 2019; Damnyag et al., 2013; Donkor et al., 2011). The government could adopt this economically efficient farmer-centred landscape approach to restore degraded forest reserves in Ghana. This could gradually create a pathway to a forest transition and regeneration of ecosystem services while benefiting the participating farmers.

Engaging farmers in forest restoration after they have contributed to its degradation leads to long-term land rights for the farmers and gradual poverty reduction—key foci of SDGs 1 and 2. Most farmers in forest fringes of Ghana are poor and landless, living on less than USD 1.25 a day (Dzanku, 2015; Sobeng et al., 2018; United Nations General Assembly, 2015). Meanwhile, the project's farmers had a minimum of USD 2.8 income a day from the sale of the farm produce in the first 6 months of the project's implementation. This value excludes the produce harvested for consumption. Having free fertile lands to farm could break the extreme poverty cycle of these farmers and increase their natural and financial assets. Access to fertile farmland could boost agricultural production and eliminate hunger in farm households (Haggblade et al., 2010; Place et al., 2003; Sanchez, 2002). Excess harvest could be sold and the income used for other household expenses.

The reforestation project has demonstrated the effectiveness of applying a human-centred landscape approach to environmental conservation and livelihood improvement. All the participating farmers will have secure lands to farm through future cycles of forest harvesting and reforestation for the indefinite future, a big benefit especially for the landless farmers. All except two farmers harvested produce to sell in markets as well as for household consumption. The landscape approach, therefore, is an all-inclusive and flexible mechanism that could be adopted alongside other strategies to achieve the SDGs.

5.3.7 The Reforestation Project and Other Restoration Actions: The Nexus

Tropical forest restoration occurs through either natural regeneration or establishment of native or exotic tree plantations (Lamb et al., 2005; Lejju et al., 2001; Webb & Sah, 2003). Tree species diversity is one objective of forest restoration projects, and plantations of native tree species mostly show greater species diversity than plantations of exotics (Bremer & Farley, 2010; Erskine et al., 2006; Healey & Gara, 2003). We started our reforestation project with exotic tree species because, first, this was the first time most of the farmers were involved in a reforestation project, and maintenance of most exotic species such as teak (*Tectona grandis*) is easier than native tree species. Second, some exotic tree species promote regeneration of native species and can withstand harsh weather conditions in their early stages of planting, at which time they need maximum care and maintenance [68]. We made provisions for natural regeneration of native species through 3 meter spacing for the planted trees, although the project team and the farmers agreed to interplant the existing plantation with some known native tree species.

Our reforestation project is similar to the Taungya system, an agroforestry system whereby tree plantation establishment is mixed with food crops cultivation as a livelihood mechanism for participating communities (Ehiagbonare, 2006; Nair, 1985; Vieira et al., 2009). The Taungya system started in Ghana in the 1930s, collapsed in 1987 due to various shortcomings including top-down decision making and abuse of power, but was reintroduced as the Modified Taungya system (MTS) in 2002 (Agyeman et al., 2003; Forestry Commission of Ghana, 2008b; Milton, 1994). The MTS continued to witness almost the same challenges as the old system—top-down decision-making, neglecting the concerns of the participating farmers in relation to incentives for planting and maintenance, and poor supervision (Acheampong et al., 2016). The MTS ceased to function in 2009, and since then the Forestry Commission of Ghana has been collaborating with private enterprises in the restoration of Ghana’s degraded forests (Forestry Commission of Ghana, 2016a, 2017b). Our reforestation project has achieved some successes because the weaknesses of the MTS were considered in implementing the project. Participatory decision-making processes with the farmers, resolving issues through consensus and negotiations, respecting the rights and responsibilities of all stakeholders, and incentivizing the farmers for planting and other activities related to the project were of much concern to the project team, and all these are key principles of the landscape approach.

Forest restoration projects in most developing countries combine forest recovery objectives with livelihood improvement of forest-dependent communities. There are mixed levels of evidence of successes and failures. For instance, in the Edo State of Nigeria, natural regeneration of endemic tree species was more successful in fallowed deforested areas than deforested areas under agroforestry practice due to continuous cultivation (Ehiagbonare, 2006). Contrarily, in eastern Panama, inter-planting young trees with food crops was found to be an important silvicultural practice that facilitated forest restoration (Paul & Weber, 2016). However, the assumption for most tropical forest restoration projects is that once the tree canopy closes, the remaining flora and fauna will regenerate naturally (Hilderbrand et al., 2005), although there are some exceptions (Aide et al., 2000; Kanowski et al., 2005; Marín-Spiotta et al., 2007). The project team and the farmers however decided to interplant the existing plantation with various native tree species before canopy closure, one step ahead of natural regeneration. This is made possible because of the trust built between the project team and the participating farmers, as well as the benefits accrued to the farmers through the project, which are also evident elsewhere (Paul & Weber, 2016).

5.4 Conclusions

The Ongwam II forest reserve has been managed by the state since its establishment in the 1930s, yet illegal logging, fire, and illegal farming have left more than half of the reserve with few trees. We found that some farmers in two fringe communities of the reserve were willing to participate in restoring the degraded portions of the forest to obtain fertile land to farm. We held a stakeholder meeting with forestry officials and the farmers in order to build consensus on the processes for restoring the degraded forest reserve and improving the livelihoods of the farmers. Ten principles of the landscape approach were adopted to assess the extent to which they could be applied in the forest restoration process. The human-centred attributes of the principles resulted in their effective application to reforest the degraded reserve. The farmers, supervised by the project team, were able to plant teak seedlings on 10 ha of the degraded reserve within six months of the project’s initiation. The progressive implementation of this project in the next 5 to 10 years will result in significant portions of the degraded forest being restored. A meeting held with the farmers in late 2019 brought about a decision to interplant the existing teak plantation with native tree species. The participants (foresters, the project team, and the farmers) chose to plant mahogany (*Khaya anthotheca*), wawa (*Triplochiton scleroxylon*), ofram (*Terminalia superba*), and sapele (*Entandrophragma cylindricum*), amongst other species. These valuable species in addition to others will be planted in 2020 to restore the forest and its biodiversity to a condition nearer to its original state. We will also introduce other non-timber forest products with potential to bring the long-term benefit for the farmers.

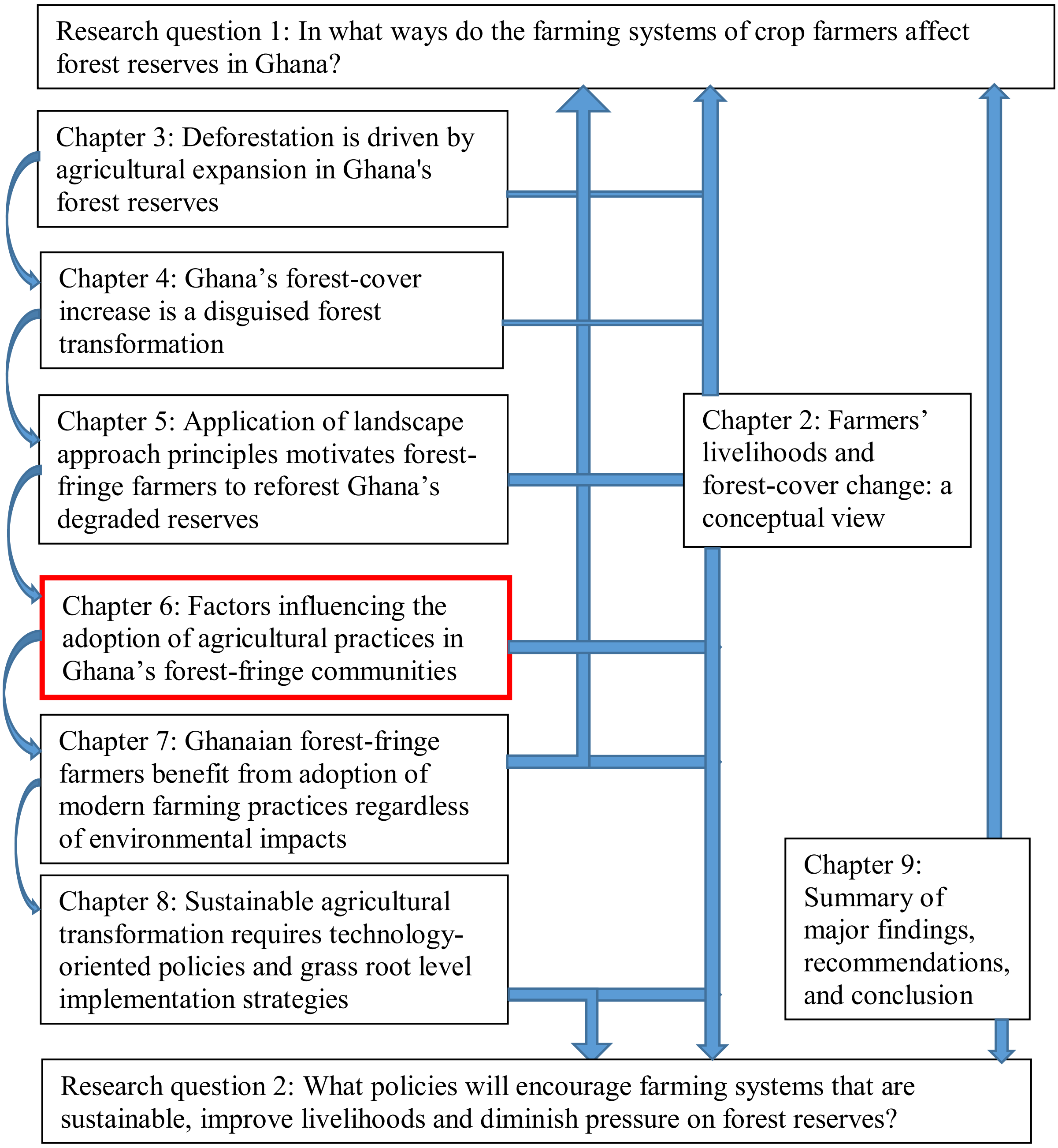
The farmers that cultivated on the project land benefited from participating in the forest restoration project more than the farmers that cultivated on their non-project land. In the first 6 months of the project's implementation, the farmers improved their livelihoods financially through the sale of the excess crops they harvested from the project's land. The farmers became food secure because they had surpluses to sell for extra income. Although the farmers are assisting in reforesting the reserve in the following years, their poverty levels will gradually reduce. Nutritional levels of the farmers' households will improve because they will have extra income to purchase other foods to supplement those that they harvest from their farms. This will contribute to the achievement of SDGs 1 (eradication of extreme poverty) and 2 (ending hunger and achieving food security). The application of the landscape approach in several similar reforestation projects in Ghana could lead to forest transition and a gradual reduction in rural poverty.

Predicting the state of multifunctional forest landscapes in the future will not always be possible. It is, however, possible to maintain the building blocks—the species, ecosystems, knowledge, cultures and institutions—needed to retain resilience and maximise future options for the landscape (Walker & Salt, 2006). Collaboration among all stakeholders is key to sustainable conservation and management of forest landscapes. Excluding any stakeholder, especially farmers in forest-fringe communities, could lead to conservation failures. Building the capacity of these farmers to champion a conservation agenda is key to sustainable management and restoration of forest landscapes.

The landscape approach principles were originally conceived to address problems at larger scales and with more stakeholder conflicts. We have used them successfully at a micro-scale. We now have a community of farmers, key members of the local forestry administration, and a research assistant from a local not-for-profit Non-Governmental Organization (NGO) (Ecomafghana) who have experience in the use of the principles and have built up a level of trust and experience, and who see the value of these principles. Landscape approaches have struggled to achieve traction in other parts of the world, but we postulate that beginning at a small scale to establish the credibility of the approach may be an essential first step in moving to broader application of the principles. We hope to use this community of practitioners to lead the development of more ambitious, larger scale landscape initiatives extending beyond the boundaries of the Forest Reserve to address the urgent issue of land competition in the broader landscape.

What Next?

Chapter five demonstrated that farmers in forest-fringe communities are willing to participate in forest restoration programs so far as their need for fertile land for farming is met. There are however other farmers who do not have this opportunity of accessing fertile lands through forest restoration projects. These farmers, as reported in chapter three, mostly rely on fragmented portions of the forests as land banks for cultivation when their existing farmlands become infertile. Agricultural intensification has been recommended as a strategy to minimize or better still prevent farmers' encroachment of forest reserves. Chapter six examines the factors that influence farmers in the forest-fringe communities of Ghana to adopt agricultural intensification technologies.



Chapter Six: Factors Influencing the Adoption of Agricultural Practices in Ghana's Forest-Fringe Communities

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Article

Factors Influencing the Adoption of Agricultural Practices in Ghana's Forest-Fringe Communities

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Abstract: Two-thirds of rural Ghanaians are farmers, and farming is almost the only income source for Ghana's forest-fringe communities. Some farmers adopt some agricultural practices to augment their operations while others do not. We examined the factors that influence farmers' adoption and intensity of adoption of agricultural practices, namely, chemical fertilizers, pesticides, herbicides, improved seeds, animal manure, and crop rotation. We surveyed the agricultural systems and livelihoods of 291 smallholder households in forest-fringe communities and developed a multivariate model (canonical correlation analysis) to test the degree to which social, economic, and institutional factors correlate with adoption and intensity of adoption of the above practices. We found that 35.4% of the farmers do not adopt any of the practices because they perceive them to be expensive, not useful, and difficult to adopt. The rest (64.6%) adopt at least one of the practices to control weeds, pests and diseases, and consequently increase crop yields. Our results indicate that farmers that perceive the aforementioned practices to be more beneficial, cultivate multiple plots, and have access to extension services adopt more of the practices. Farmer age and distance to source of inputs negatively correlate with adoption and intensity of adoption of agricultural practices. Almost two-thirds each of adopters and non-adopters do not have access to agricultural extension services and this could pose threats to the sustainability of the forest reserves within and around which the farmers cultivate. Educating farmers on agricultural practices that are forest-friendly is critical in the forest-fringe communities of Ghana. The correct application of practices could double outputs and minimize threats to forests and biodiversity through land-sparing.

Keywords: farming systems; agricultural education; farm intensification; forest-fringe communities; rural Ghana

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Abstract

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Keywords: Farming systems; agricultural education; farm intensification; forest-fringe communities; rural Ghana.

6.1 Introduction

Agriculture employs over 70% of Ghana's rural workforce and almost all residents of forest-fringe communities are farmers (Ghana Statistical Service, 2013a). Many of these farmers have their farms within and at the fringes of forest reserves officially protected and managed by the Forestry Commission of Ghana for conservation and/or production (RMSC, 2016). Farming practices such as the use of agricultural inputs influence the economic welfare of farmers (Takeshita & Noritake, 2001; Young et al., 2017). Farmers adopt practices to control weeds, pests and diseases, and improve crops yields and outputs (Gianessi, 2013; Norsworthy et al., 2012). However, when these practices (e.g. application of herbicides and pesticides) are adopted within forest frontiers, they may adversely affect tree species that are naturally regenerating, beneficial insects, and other living organisms that contribute to the richness of the forests' biodiversity (Kabir & Rainis, 2015; Lekei et al., 2014; Skevas et al., 2013). Agricultural practices such as legume-crop rotation and intercropping, and the application of organic manure, help enrich the soil and increase crops yields with minimal negative agro-ecological impact

(Agula et al., 2018; FAO, 1989; Fung et al., 2019). Farmers' adoption of agricultural practices is however contingent on a range of factors such as land tenure, access to inputs and extension services, and the farmers' perceptions of such practices (Donkor et al., 2016; Mishra et al., 2018; Nkegbe & Shankar, 2014; Tsinigo & Behrman, 2017).

Farming practices such as slash-and-burn cultivation and incorrect application of agricultural inputs at forest frontiers are one of the major causes of deforestation and forest degradation in Ghana (Acheampong et al., 2019; Adomako & Ampadu, 2015; Sanchez & Palm, 2005). Slash-and-burn with continuous mono-cropping has led to degraded and infertile soils - a major constraint to increased agricultural productivity (Manda et al., 2016; Ngwira et al., 2012; Sanchez & Palm, 2005). The use of fertilizers, herbicides and pesticides has improved agricultural productivity but with some negative environmental impacts including soil compaction, salinization, and acidification, and damage to indigenous flora and fauna (Gianessi, 2013; Kabir & Rainis, 2015; Lekei et al., 2014; Norsworthy et al., 2012). Adoption of forest-friendly agricultural practices at forest frontiers in Ghana could play an important role in improving agricultural productivity and forest protection.

Farming practices are intrinsically linked both to the scale of agricultural activities and the goal of farming, whether subsistence or commercial. For instance, rice farmers in Northern Ghana who implement row-planting in addition to the use of improved seeds and agro-inputs tend to produce higher yields for markets (e.g. Agula et al., Agula, Akudugu, Dittoh, et al., 2018; Donkor et al., 2016; Donkor et al., 2018). Regardless of farm scale, research has demonstrated the importance of various agricultural intensification techniques to increase yields, restore soil quality, and enhance the resilience of smallholder farming systems. These techniques include legume-crop rotation and intercropping, conservation tillage, use of improved crop varieties and animal manure, soil and stone bands for soil and water conservation, and agroforestry for tree-friendly farming (Mutyasira, Hoag, & Pendell, 2018; Teklewold et al., 2013). Some of these practices apply to specific contexts but they have been shown to be effective in improving yields and increasing outputs with minimal environmental disturbance when properly applied (Manda et al., 2016; Mutyasira, Hoag, & Pendell, 2018; Teklewold et al., 2013). Here, we examine the factors influencing farmers' adoption of some agricultural practices in order to recommend approaches for sustainable agriculture in African forest-fringe landscapes.

6.2 Adoption of Agricultural Practices: A Conceptual Review

Here, we examine agricultural inputs and agricultural practice under the general term 'practices'. The inputs of interest are chemical fertilizers, pesticides, herbicides, improved seeds, and animal manure. Crop rotation is the practice identified with the aforementioned inputs.

In Ghana, researchers have documented the extent of farmers' adoption of various agricultural practices and their effects on soil fertility, agricultural productivity, food security and household incomes (Adowla et al., 2017; Adowla et al., 2019; Adomako & Ampadu, 2015; Agula et al., 2018; Ehiakpor et al., 2021; Issahaku & Abdulai, 2020; Kotu et al., 2017; Mahama et al., 2020; Zakaria et al., 2020). Some of these studies have demonstrated that the adoption of agricultural practices is influenced by farm size, the effectiveness and frequencies of agricultural extension services, farmer education, input availability, and distance to sources of inputs (Donkor et al., 2016; Ehiakpor et al., 2021; Kotu et al., 2017; Tsinigo & Behrman, 2017). For instance, Kotu et al. (2017) observed that most farmers are unwilling to travel long distances to purchase agricultural inputs, e.g., chemical fertilizers; hence, they continue with slash-and-burn farming. Others even do not have access to such inputs and as a result do not adopt innovative technologies (Adowla et al., 2017; Adowla et al., 2019). Issahaku and Abdulai (2020) and Zakaria et al. (2020) observed that education of household head, access to extension and weather information, and membership of farmer-based organizations influence farmers' likelihood of adopting climate-smart agricultural practices. Zakaria et al. (2020) further stated that the intensity of adoption of climate-smart practices depends on farmers' participation in capacity building programs, family labour, and access to agricultural insurance. Ehiakpor et al. (2021) identified that the intensity of adoption of sustainable practices is influenced by farmers' access to agricultural credit, participation in field demonstrations, and farm size. Similarly, Mahama et al. (2020) found that the intensity of adoption of sustainable soybean production technologies in northern Ghana is determined by age, education, extension visits, mass media, and perception of adoption. Generally, farm characteristics, socio-economic, and institutional factors determine the agricultural practices a farmer adopts, while the intensity of adoption in a given place also reflects a farmer's motivation and capacity (Macgregor, 2009).

It is not only in Ghana that farmers adopt and intensify their adoption of new or existing practices for various reasons. For instance, smallholder farmers in Zambia and Kenya who own their farmlands tend to practice agroforestry and mixed cropping to sustain production, while conversely farmers with insecure land tenure tend to use chemical fertilizers to sustain production (Nkomoki et al., 2018; Nyaga et al., 2015). Faße and Grote (2013) observed that experienced farmers in Tanzania employ crop diversification and agroforestry more than inexperienced farmers because the latter have little knowledge about farming techniques. Kassie et al. (2013) found that households with short-lease land tenure adopt legume intercropping and chemical fertilization to increase short-term productivity, with the intensity of their adoption correlating with farm size, distance to farms, and availability of household labour. According to Kassie et al. (2013), household size positively influences farmers' use of manure since collecting and transporting manure to farms is labour intensive .

However, the issue surrounding the Ghanaian studies reviewed above is that none of them considered the locations of farms to determine whether the practices adopted could conflict with the surrounding landscapes and the possible resolutions that could be offered. Research sites were generally arable lands used for subsistence and commercial farming, not designated as forest reserves, and where sometimes there are almost no forest. Farmers in forest-fringe communities in Ghana however cultivate within and around forest reserves that are officially protected (Acheampong et al., 2018; Akamani et al., 2015; Kotey et al., 1998). Evidence shows that these farmers often rely on the forests as land banks for agricultural production when their existing farmlands become infertile (Acheampong et al., 2018; Owubah et al., 2000).

According to Acheampong et al. (2019), agricultural expansion between 1986 and 2015 caused 78% of the deforestation in the forest reserves of the Ashanti region. The underlying factors were that, first, before the demarcation of the areas as forest reserves, human settlements and farms already existed within the forests (Kotey et al., 1998). The Forestry Commission of Ghana allowed the settlers and their farms to remain in the reserves with their boundaries delineated to prevent further encroachment into the reserves. Population growth and weak enforcement of forest protection laws led to the expansion of the farms into the reserves. Second, a majority of the inhabitants interplant their food crops with tree crops for cash and depend on natural soil fertility to increase output. According to these farmers, when the tree crops form a canopy, they encroach more of the forest in the search for fertile land to cultivate their food crops (Acheampong et al., 2019). Since the tree crops are the main source of income for the farmers, after about two years of cultivating the newly cleared land, they will interplant their food crops with tree crops.

This continuous conversion of protected forestlands to agriculture reduces forest cover and biodiversity, limits the provision of ecosystem services, and contributes to climate change (Acheampong et al., 2019; Celentano et al., 2017; de Blécourt et al., 2013; Ramdani & Hino, 2013). The adoption of certain high-yielding agricultural practices by farmers in forest-fringe communities may enhance agricultural sustainability and forest conservation. This is possible via a presumed ‘land-sparing’ effect whereby higher yields on existing plots diminish the need to convert surrounding forests (Phalan et al., 2011). We explore the factors influencing the adoption and intensity of adoption of the agricultural practices listed above at forest frontiers of Ghana and offer possible recommendations for agriculture and forest sustainability.

6.3 Materials and Methods

We surveyed 291 farmers in forest-fringe communities of the Ashanti region of Ghana to obtain data on their farming operations. We used the farmers’ cropping patterns and inputs to identify the agricultural practices they adopt. We used the farmers’ perceptions to identify the rationale for adoption and non-adoption of the practices. We then examined the extent to which socio-economic, institutional, and farm factors influence farmers’ adoption of agricultural practices.

6.3.1 Study Area

To reduce repetition, see section 3.2.1 for the description of the study area. Recent research shows that farming is a major cause of deforestation and forest degradation in the region (Acheampong et al., 2019). As described by Acheampong et al. (2019), the forest extent within the region’s forest reserves declined by 33.2% since 1986, with more than two-thirds of such degradation attributable to the expansion of annual crop farms and tree crop plantations. Of 291 farmers surveyed, about one-fifth hold farms within the forest reserves while half are within 5 km of reserve boundaries. All the farmers are slash-and-burn semi-subsistence cultivators. The prevalence of slash-and-burn has contributed to forest degradation within and around the forest reserves in the region.

6.3.2 Sample Size Selection and Data Collection

The forest reserves in the Ashanti region have the most forest-fringe communities in Ghana and over 70% of the residents in these communities are farmers (Ghana Statistical Service, 2013b; RMSC, 2016). We selected 10 of the 58 forest reserves in the region and sampled communities that are within 3 km from the 10 reserves. To avoid repetition, refer to section 3.2.3 for details of the sample size and selection process.

We carried out a household survey from March to June 2018 to collect data on farmers' perceptions for adopting or not adopting some agricultural practices using survey questionnaires. The practices we identified from our survey are the use of fertilizers, herbicides, pesticides, animal manure, improved seeds, and crop rotation. All the farmers practice slashing-and-burning before cultivation so we did not consider slash-and-burn as a potential practice to be adopted. Crop rotation was considered as a practice because it is an alternative means of adding inputs (e.g., natural nitrogen fertilizers) to the soil yet not all farmers practice it.

Data on farmers' age, education, household labour, labour hired, and distance to sources of inputs, access to extension services, farming system, land tenure, and plots per farmer were the socio-economic, institutional, and farm variables collected to determine the extent of their influence on the adoption of the agricultural practices identified (Table 6.1). We ensured that farmers surveyed in each community were randomly distributed across their respective communities. Only one farmer was surveyed in each house and household (some communities had compound houses with more than one farm household) to avoid pseudo-replication.

Table 6.1 Descriptive Statistics of Variables Investigated and the Statistical Values of the Quantitative Variables.

Factors of adoption	Variables measured/ identified	Categories	Mean value	Standard deviation	Mean difference	t-values	Description of variables
Socio-economic	Age	Adopters	46.98	14.83	-2.209	-3.628	Age of the famer (e.g. 58 years)
		Non-adopters	50.61	12.53			
	Education	Adopters	6.840	4.45	.890	.471	Level of education the farmers completed
		Non-adopters	6.37	4.06			
	Household size	Adopters	4.30	2.39	1.049	.293	Number of people in a farmer's household
		Non-adopters	4.01	2.06			
	Household labour	Adopters	1.74	1.24	-.020	-.003	Household members working with the farmer
		Non-adopters	1.75	1.13			
	Number of hired labour	Adopters	3.90	3.64	1.996	.839	Farm labourers the farmer hires per cropping season
		Non-adopters	3.06	2.97			
	Distance to source of inputs	Only adopters	11.13	17.51			Distance (in km) to main source of input
Institutional	Access to extension services						Extension officers' visit to community
Farm characteristics	Farming system						Mixed cropping, mono cropping, mixed and mono cropping
	Land tenure system						The landholding status of the farmer (e.g. own, lease)
	Number of farm plots	Adopters	1.66	.98	3.039	.315	Number of plots the farmer is currently cultivating
		Non-adopters	1.35	.76			
	Number of practices adopted	Only adopters	1.24	1.24			Complementary practices a farmer adopts at a time
Perceptions for adoption							Reasons why the farmers adopt the practices
Perceptions for non-adoption							Reasons why the farmers do not adopt any practice

Distance to source of inputs refers to the number of kilometres a farmer has to travel to purchase their preferred input. This distance is based on the most preferred location that the farmer purchases inputs. Extension officers visit farming communities to provide agricultural education. We asked farmers if an extension officer visited their community during the previous or the current cropping season. We did not ask the frequency of visits.

Farming system refers to how the farmers cultivate, whether they mix their crops on their farmlands (mixed cropping), grow only one crop on all their lands (mono cropping), or mix crops on one land and grow only one crop on another land (mixed and mono cropping). The farmers were asked about their perceptions for adopting the practices. For the purpose of quantitative analysis, all adopters were assigned the value of one (1) while non-adopters were assigned zero (0). Reasons for not adopting any practice were also obtained from the non-adopters. This was used for descriptive analysis only.

6.3.3 Data Analyses Techniques

The data on farming practices the farmers adopt and the perceptions for adoption and non-adoption were first descriptively analysed and related to the farming operations of the respondents. We used the multivariate technique, canonical correlation analysis (CCA), to assess the relationship between adoption and intensity of adoption of agricultural practices and a set of adoption factors, namely, age, education, household size, household labour, hired labour, access to extension services, number of farm plots, land tenure, distance to sources of input, and perception for adoption. We adopted this technique to limit the probability of a type 1 error (Thompson, 1991) by performing one statistical test on the same predictors for the two dependent variables (adoption and intensity of adoption) instead of running separate univariate models. We relied on Wilks' test of significance to assess the significance of the full model and the proportion of the variance explained by the variable sets (Sherry & Henson, 2005). We then tested the hierarchical arrangements of the canonical covariates for statistical significance through the dimension reduction analysis. This was done to determine whether only the first canonical covariate or both are worthy of interpretation. We adopted a cut-off correlation of .30 to determine the variables that contribute significantly to the relationship between the adoption variables and the factors of adoption (Tabachnick &

Fidell, 2019). We checked the data for normality, linearity, and absence of multi-collinearity for the purpose of the multivariate analysis, specifically the correlation analysis. The data were generally normally distributed and when they were not they were log transformed to approximate normality (Zar, 1999). Multi-collinearity was not problematic (Gujarati & Porter, 2009).

6.4 Results

We identified six main agricultural practices that some farmers in the forest-fringe communities of the Ashanti region complement with slash-and-burn. These are chemical fertilizers, pesticides, herbicides, improved seeds, animal manure, and crop rotation. While 64.6% of the farmers adopt at least one of the practices, 35.4% have some reservations that discourage them from adoption of any practice. Out of the 103 farmers that rely only on slash-and-burn, 44.7%, 28.2%, and 13.6% perceive that the above complementary practices are expensive, not useful, and difficult to work with, respectively. There are other secondary reservations as well (such as 'not allowed' = 7.8%, and 'no more supplies' = 5.8%). The majority of these 103 non-adopters (76.7%) do however practice inter-cropping to hedge against the failure of a given crop, and 72.4% of these mixed croppers perceive the aforementioned agricultural practices as not useful. Most of these mixed croppers admitted that they do not need to rely on inputs for increased production because the residues from their crops add nutrients to the soil – a statement that is technically true but short sighted, given that nutrients are progressively leached in the absence of fallowing.

Various land tenure systems exist in the forest-fringe communities. We have categorized them into three – private land (own land), leased land, and forest reserve, based on the responses the farmers gave concerning how they obtained the land. Private land is the land that the holder owned through gifting, share cropping to land sharing arrangements, inheritance, and outright purchase. Leased land is that which the farmer rents for a period of time and pays the rent by either cash or other crop sharing arrangements. Reserve land is a degraded land in the forest reserve that the foresters apportion to farmers in need of land but require the farmers to interplant their food crops with trees supplied by the foresters.

The majority (75.7%) of the non-adopters own their farmlands, while 10.7% and 13.6% farm on leased land and reserve land, respectively. Out of the 46 non-adopters who own their farmlands, 76.1% perceive the agricultural practices as expensive. These farmers reported that their farming operations do not yield enough income to purchase inputs. Data on incomes were however difficult to obtain from farmers. Finally, 78.6% of the non-adopters who perceive the practices to be difficult to apply own their farmlands. Probing further, we found that these farmers have not attempted to apply any of the practices before; hence, the farmers only perceive adoption to be overly-difficult to attempt, suggesting a crucial role for further agricultural extension.

According to the reserve-land farmers who secured their farmlands from forestry officials, one condition of their land acquisition was that they would apply no chemical agricultural input (e.g. herbicides, pesticides) because these inputs adversely affect the survival and growth of the young trees planted amidst food crops. Land tenure and associated farming systems therefore have effects on the likelihood of farmers adopting complementary agricultural practices. Other farmers however have some reasons for adopting various agricultural practices in the study area.

The mean distance from the communities to the nearest central markets where the farmers sell their produce and purchase agricultural inputs is 11 kilometres. Twelve of the 20 study communities have agro-chemical shops from which inhabitants can purchase agricultural inputs. Almost all (18) of the communities have information centers that relay various information, including that on agriculture, to their members. Eleven of the 20 communities had extension service visits at least before our survey. It is however worth mentioning that according to our study, adoption or non-adoption of complementary agricultural practices is not based on a community's nearness to central markets, availability of agro-chemical shops and information centers in community, operation of periodic markets in community, or any other characteristic of a community. This is because each community had a mix of adopters and non-adopters based on the farmers' perceptions and some other probable factors which are elaborated in the succeeding sections.

6.4.1 Adoption and intensity of adoption of complementary agricultural practices

Chemical fertilizer application is the main practice that 44.1% of the 188 adopters have applied, followed by the use of herbicides (23.9%) and the practice of legume-crop rotation (14.9%). Pesticides use (8.5%), the use of improved seeds (6.4%), and the application of organic manure (2.1%) are the other practices adopted (Table 6.2).

Table 6.2 Descriptive Statistics of the Farmers and their Farming Practices.

Categorical variables	Categories	Number of farmers	Percentage
Main practices adopted	Use of herbicides	45	15.5
	Legume-crop rotation	28	9.6
	Use of improved seeds	12	4.1
	Use of organic manure	4	1.4
	Use of inorganic fertilizers	83	28.5
	Use of pesticides	16	5.5
	None	103	35.4
Perceptions for adoption*	Controls pests	10	4.5
	Increases yield	91	40.6
	Makes farming easy	84	37.5
	Controls weeds	39	17.4
	**None	103	35.4
Land tenure system	Leased land	68	23.4
	Own land	190	65.3
	Forest reserve	33	11.3
Farming system	Mixed cropping	194	66.7
	Mono cropping	74	25.4
	Crop rotation	6	2.1
	Mixed and mono cropping	17	5.8
Access to extension services	No	187	64.3
	Yes	104	35.7
Total farmers (N)		291	100.0

*The number of farmers that adopt at least one agricultural practice is 188. The total for the categorized perceptions for adoption is 224 farmers because some farmers gave more than one response. Because of multiple responses, the percentages for perceptions for adoption do not add up to 100. **'None' refers to the farmers who do not adopt any of the practices but rely solely on slash-and-burn. The percentage for 'none' is out of the total farmers.

We conducted canonical correlation analysis to evaluate the multivariate-shared relationship between social, institutional and farm factors and adoption and intensity of adoption of agricultural practices. The analysis produced two canonical covariates with squared canonical correlations (R_c^2) of .716 and .094 for canonical variates 1 and 2, respectively. The test statistics of the multivariate model adopting Wilks' Lambda criterion (λ = .257, F(20,552.00) = 26.791, ρ < .001) indicate that the full model is statistically significant and that the model explains 74.3% (1-λ) of the variance shared between the two sets of variables. The dimension reduction analysis for canonical variates 1 to 2 (F(20,552.00) = 26.791, ρ < .001) and 2 to 2 (F(9,277.00) = 3.198, ρ < .005) indicate that both functions are statistically significant (Table 6.3). However, given the R_c^2 effect of each function (71.6% and 9.4%) of shared variance for canonical variates 1 to 2 and 2 to 2, respectively), the first canonical variate is more noteworthy of interpretation although the second function is still significant for interpretation.

Table 6.3 Results from the Multivariate Model Using Canonical Correlation Analysis.

Effect…. Within Cells Regression Multivariate Tests of Significance (S = 2, M = 3 , N = 137)					
Test Name	Value	Approximate F	Hypothesis DF	Error DF	Significance of F
Pillai's	.80988	18.84993	20.00	554.00	.000
Hoteling's	2.62201	36.05263	20.00	550.00	.000
Wilks'	.25749	26.79126	20.00	552.00	.000
Roy's	.71576				
Eigenvalues and Canonical Correlations					
Root No. (Can. Var)	Eigenvalue	%	Cumulative %	Canonical correlation	Squared correlation
1	2.51811	96.03725	96.03725	.84602	.71576
2	.10390	3.96275	100.00000	.30680	.09412
Dimension Reduction Analysis					
Roots	Wilks λ	F	Hypothesis DF	Error DF	Significance of F
1 to 2	.25749	26.79126	20.00	552.00	.000
2 to 2	.90588	3.19792	9.00	277.00	.001

The coefficients and proportions of variance explained in the first pair of canonical variates show that both adoption and intensity of adoption of complementary agricultural practices correlate with the canonical variate (Table 6.4). The first pair of canonical variates indicate that farmers that have fewer number of farm plots (-.31), have to travel long distances to purchase inputs (-.71), and that have negative perceptions about complementary agricultural practices (-.98) do not adopt any complementary agricultural practices (.855). On the other hand, possession of more farm plots (-.31), short distances to sources of inputs (-.71), and positive perception about complementary agricultural practices (-.98) influence adopters to increase the number of practices they adopt (-.899). The second pair of the canonical variates indicates that adopters (.519) increase the number of practices they adopt (.438) when they have access to agricultural extension services (.713) and cultivate more than one plot (.32) but do not adopt or decrease intensity of adoption as they age (-.422) and also with long distance to sources of inputs (-.356). The farmers that adopt one, two, three, four, and five practices at a time represent 43.6%, 33.0%, 13.3%, 8.0%, and 2.1%, respectively of the 188 adopters. No farmer adopts all the six practices.

Table 6.4 Canonical Solutions for Adoption and Intensity of Adoption of Agricultural Practices for Canonical Variates 1 and 2.

	Canonical variate 1			Canonical variate 2			
Variable	Coef	r_s	r_s^2 (%)	Coef	r_s	r_s^2 (%)	h2 (%)
Adoption of complementary agricultural practices	.521	.855	73.11	1.069	.519	26.89	100.00
Number of practices adopted	-.617	-.899	80.80	1.017	.438	19.20	100.00
R_c^2			71.6			9.4	
Age of farmer	.034	.167	2.80	-.451	-.422	17.81	20.62
Education	.041	-.002	0.00	.162	.113	1.27	1.27
Household size	.025	-.070	0.49	.020	-.030	0.09	0.59
Household labour	-.059	-.058	0.34	-.082	-.164	2.70	3.04
Labour hired	-.083	-.238	5.67	.069	.072	0.52	6.19
Agricultural extension visits	.098	.078	0.60	.658	.713	50.77	51.37
Number of farm plots	-.126	-.307	9.44	.312	.316	10.01	19.45
Land tenure	.042	.238	5.68	.103	-.179	3.21	8.88
Distance to input	.063	-.713	50.78	-.635	-.356	12.67	63.45
Perception for adoption	-.983	-.978	95.64	.351	-.006	0.00	95.65

Note: Structure coefficients (r_s) greater than I.30I are underlined. Communality coefficients (h^2) greater than 45% are underlined. Coef = standardized canonical function coefficient; r_s = structure coefficient; r_s^2 = squared structure coefficient; h^2 = communality coefficient.

The 188 adopting farmers had various perceived factors that motivate them to adopt the complementary agricultural practices. We have categorized all the varied reasons for adoption into four main perceptions based on the main themes that emanated from farmers' responses to the survey (Table 6.5). Despite the diverse reasons, the highest priority motive for the farmers to adopt the practices is to increase yield. Similar to the non-adopters, the majority of the farmers that adopt the agricultural practices mainly to increase yield are mixed croppers (60%), followed by mono croppers (33.3%). Also, the majority of these farmers own their farmlands followed by those who cultivate on leased plots. The obvious reason for these similarities is that the main land tenure systems in the study area are owner-occupied land and leased land while the main farming systems are mixed cropping and mono cropping.

Table 6.5 Categorized Perceptions for Adoption Based on Farmers' Responses.

Motivation	Responses from farmers indicating the categories	Number of farmers*	%
Controls pests	Control pests; help control pests and increase yield; help prepare my farm and drive pests away, etc.	10	4.5
Increases yield	Clear the weeds and pest and also increase yield; get more yield; help increase yield and prepare land; I do this to get more yield; I need more produce, etc.	91	40.6
Makes farming easy	Good for my work; help in my farm and increase yield; help in my farm and to control weeds and pest; prepare my farms for cultivation; to work faster and easier, etc.	84	37.5
Controls weed	Easy destruction of the weeds; help do away with weeds to prepare the land; I do not use labourers to weed the farm. I plough the land first and when the weeds start growing, the labourers spray it; it helps to increase the size of the land when there is no hired labour available to weed	39	17.4
Total farmers that adopt at least one agricultural practice		188	

*The number of farmers that adopt at least one agricultural practice is 188. The total for the categorized perception for adoption is 224 farmers because some farmers gave more than one response. Because of multiple responses, the percentages for perceptions for adoption do not add up to 100.

As aforementioned, the first canonical variate demonstrates that positive perceptions (-.98) emanating from the need to improve yield and control weeds, pests, and diseases (Table 6.5) are the main motivational factors that increase the number of practices a farmer adopts (-.90). According to the farmers, application of these practices makes their farming operations easier. Some adopters stated that adopting more of the practices results in harvesting more outputs on a relatively smaller plot compared to farming with no complementary inputs. However, a comparative analysis between the adopters and non-adopters revealed that the adopters farm on larger plots. For instance, while 54.8% of the adopters have their total farm sizes larger than 2 ha and the rest with plots sizes smaller than 2 ha, 40.8% of the non-adopters have same. The adopters however harvest almost three times the outputs of the non-adopters. Data collected from maize growers for instance indicated that while adopters of complementary agricultural practices harvest averagely 19 bags of maize per hectare, non-adopters harvest averagely eight bags.

Both canonical variates show that multiple-plot farmers (-.31 and .32 for functions 1 and 2, respectively) tend to intensify their agriculture through adopting more practices at a time (-.90 and .44 for functions 1 and 2, respectively). Cereals (maize, rice) farmers constitute 40.4% of the multi-plot adopters followed by tree crops growers (28.2%) and tubers cultivators (18.1%). According to some of the multi-plot farmers, they are able to control weeds, pests and diseases and increase crops yields at the same time using complementary agricultural practices. Cross-referencing the number of farm plots cultivated with the main practice adopted indicated fertilizer application dominating all the categories of farmers except those who cultivate three plots where herbicides usage is the main practice followed by legume crop rotation (Table 6.6).

Table 6.6 Number of Farm Plots the Farmers Cultivate and Main Agricultural Practice Adopted.

Number of farm plots	Categories	Main agricultural practice adopted: Herbicides	Legume-crop rotation	Improved seeds	Organic manure	Fertilizer	Pesticides	Total farmers
1	Count	30	11	8	2	59	9	119
	% of Total	16.0%	5.9%	4.3%	1.1%	31.4%	4.8%	63.3%
2	Count	4	7	1	0	11	3	26
	% of Total	2.1%	3.7%	0.5%	0.0%	5.9%	1.6%	13.8%
3	Count	10	7	3	1	6	3	30
	% of Total	5.3%	3.7%	1.6%	0.5%	3.2%	1.6%	16.0%
4	Count	1	3	0	1	7	1	13
	% of Total	0.5%	1.6%	0.0%	0.5%	3.7%	0.5%	6.9%
Total farmers	Count	45	28	12	4	83	16	188
	% of Total	23.9%	14.9%	6.4%	2.1%	44.1%	8.5%	100.0%

According to the second canonical variate, access to agricultural extension services has a strong positive correlation (.71) with both adoption (.52) and number of practices adopted (.44). While 64.6% of the farmers adopt at least one of the practices, only 35.6% had access to extension services at the time of the survey. These adopting farmers could not explain why extension agents generally do not visit their communities. The same farmers stated that they instead rely on their own knowledge and that of other adopters to apply the agricultural practices they have adopted.

While perceptions for adoption, number of farm plots cultivated, and access to agricultural extension services increase the intensity of adoption, two other factors are on the contrary – age of a farmer, and distance to sources of agricultural inputs. The second canonical variate demonstrates that the age of a farmer (-.42) negatively correlate with adoption and number of practices a farmer adopts. Further enquiry into the ages of the adopters revealed that 35.6% are over 50 years old. Out of this, 52.2% adopt only one practice while 28.4% adopt two practices at a time. Ideally, these farmers (>51 years) should be using more agricultural inputs to boost productivity because age might reduce their physical capacity. Yet our results indicate that the more farmers age, the lesser the number of complementary practices they adopt.

Agricultural inputs play vital roles in farming. However, the distance a farmer has to travel to purchase these inputs (-.36) reduces adoption and for the farmers adopting, the intensity of their usage. We identify that distance to sources of inputs (-.71) in the first canonical covariate positively correlates with the number of practices adopted (-.90). This interpretation is however questionable considering the small standardized coefficient of distance to input (.06) perhaps resulting from a multi-collinearity issue. Nevertheless interpretation is still valid for the second canonical covariate. The majority of the adopters travel less than 20 km to purchase agricultural inputs. For instance, all the farmers that adopt five practices purchase their inputs within 5 km of their residence. A third (66.7%) of those that adopt four practices, 72% of those that adopt three practices, 67.7% of adopters of two practices, and 70.7% of one practice adopters travel within 20 km to purchase their inputs. This implies that shorter distance to sources of inputs correlates positively with increased adoption of agricultural practices. Eight of the fringe communities have access to agrochemical shops that supply inputs to the farmers. According to the adopters in these communities, purchasing inputs from shops in their communities is easier and preferable to shops outside of their communities. Nevertheless, not all farmers having agrochemical shops in their communities adopt the practices due to the cost of the practices (mainly input prices). The farmers admitted that incomes from sale of produce are not enough to cater for both household expenditure and agricultural inputs although significant proportions of their produce are sold (Table 6.7).

Table 6.7 Percentage of Harvested Produce of Major Crops Cultivated by Non-Adopters.

Proportion of harvested produce consumed	Percentage farmers
Consumed all	16.0
Consumed below 50%	77.3
Consumed 50% and beyond	6.7
Total farmers (food crops growers)	75
Tree crop growers	28
Total farmers (all non-adopters)	103

Note: Some of the non-adopters have tree crops (cocoa, cashew, orange) as their major crops. These farmers were excluded from the calculations since their crops are not for direct domestic consumption and were processed in factories. The calculations were based on 'Total farmers (food crops growers)'.

6.5 Discussion

The majority of the farmers in the study area adopt various intensification techniques, a result observed in other studies (Deressa et al., 2009; Mishra et al., 2018; Mutyasira et al., 2018). Non-adopters in the study harvest averagely about half the yields of the adopters. The cost of the practices as well as other institutional factors (e.g. lack of access to extension services or lack of supply from the government) is the main constraining factor for the non-adopters (Mishra et al., 2018). According to these farmers, they do not have any other source of income, aside from crop sales, and they only sell crops that are in excess of their subsistence needs. Although significant proportions of the harvested produce are sold (Table 6.7), some of the non-adopters stated that the incomes from sales are not enough to meet household expenditure and purchase agricultural inputs.

Non-adoption of complementary agricultural practices is not unique in farming communities in Ghana (Acheampong et al., 2018), but it is a critical issue in forest-fringe communities. Although some practices such as the use of herbicides and pesticides pose threats to forest health, their correct and moderate application in addition to organic manure, crop rotation, inorganic fertilizers, and improved seeds could minimize their impacts on the forest environment while improving farm productivity and subsequent livelihood improvement. This is based on two presumptions. First, a land-sparing scenario where we presume that farmers who meet their subsistence needs on a smaller land through intensification will not desperately encroach the forest for increased agricultural production (Phalan et al., 2011). This can be more achievable through motivations given to the farmers by the Forest Services Division of Ghana for not encroaching the forest. Evidence shows that farmers in forest-fringe Ghana are willing to forgo exploitation of forest resources if they are compensated (Amadu et al., 2020). Our suggestion is not in a form of compensation but motivational packages for practicing forest-friendly agriculture. Second, strengthening forest protection strategies so that profit-maximizing farmers may not be able to expand their farms into the adjoining forests after adopting the yield-enhancing practices. Access to non-farm jobs through investments in small-scale enterprises and flexible agricultural loans (such as low interest rates) to farmers may also reduce the total reliance on farming for survival and enhance farmers' capacity to intensify agriculture, with similar land-sparing effects. Improved access to non-farm incomes and agricultural loans in Ethiopia for instance has enhanced farmers' access to technical, mechanical and capital inputs to sustain agricultural production, culminating in significant economic returns and food security (Mutyasira2009; Mutyasira, Hoag, Pendell, et al., 2018).

6.5.1 Promoting Complementary Agricultural Practices is Critical for Improved Productivity

Although 64.6% of the farmers are adopters of complementary agricultural practices, 64.3% of all the farmers do not have access to extension services. A third of both adopters and non-adopters lack access to extension services. Meanwhile, our results indicates that access to agricultural extension services (.71) has strong correlation with both adoption (.52) and intensity of adoption of agricultural practices (.44) (Table 6.4). Agricultural extension agents in Ghana educate farmers on best farming practices such as how to use modern inputs, sustain soil fertility, control pests and diseases, and increase crops yields. However, the extension agents are not able to reach all farming communities due to limited resources and poor road infrastructure in remote areas

(Acheampong et al, 2018) coupled with the limited number of extension officers with the current extension agent to farmer ratio of about 1:1300 (that is, if all extension officers are deployed) instead of the ideal 1:500 (Anang et al., 2020). According to some adopters with no access to extension services, they obtain knowledge through farmer-to-farmer diffusion, a process that yields quality results if the giver has the correct information (Carsky et al., 2003; Sanchez, 2002). While correct application of agricultural practices through effective extension services could double or even triple outputs, wrong application of inputs can cause damage to crops, human health, and biodiversity (AGRA, 2011; Mishra et al., 2018; Mutyasira, Hoag, & Pendell, 2018; Sanchez, Pedro A. Sanchez, 2009). Without access to adequate knowledge and improved technology, farmers are likely to continue with farming practices that results in little or no improvement in productivity.

Some studies (e.g. Abdulai & Binder, 2006; Donkor et al, 2016) indicate that the age of farmers positively influence their intensification of agriculture. This is contrary to what was revealed in our regression results. The older farmers in the study area prefer to use less inputs in their farming operations (Table 3). This is not unusual. Older farmers are found to be less trusting of new technologies and/ or management practices. They are often resistant to change and prefer to continue with what is well tried and tested (Karidjo et al., 2018; Simtowe & Mausch, 2019; Sodjinou et al., 2015). The majority of the older farmers (Above 50 years old: 71.6% of adopters and 83.7% of non-adopters) own their farmlands. The majority of these older farmer land owners (75.0% of adopters and 87.8% of non-adopters) operate on one plot. According to both of our canonical variates (Table 3), the likelihood of these one-plot farmers adopting more practices is less than average (Nkegbe & Shankar, 2014), let alone for non-adopters to start practicing any agricultural innovation. However, effective diffusion of information about the benefits of yield-enhancing practices may influence older farmers to appreciate the need to complement their activities with inputs as they age (Abdulai & Binder, 2006; Donkor et al., 2016).

Age is not the only factor that reduces the intensity of farmers' adoption of agricultural intensification. Long distance to sources of inputs is another factor that discourages farmers to intensify agriculture (Donkor et al., 2018; Kotu et al., 2017; Tsinigo & Behrman, 2017). Positive perception and motivation towards adoption of inputs through effective extension services may attract suppliers to use mobile supply services in the farming communities. Improvement in rural road networks will reduce transportation cost and enhance access to, and distribution of agricultural inputs. Improved roads lead to the use of more inputs resulting in higher yields, better market integration by enabling smallholders to transport a larger proportion of their harvested produce to the market, and commercialization of farms without necessarily expanding farm size (Acheampong et al., 2018; Hazell, 2013). Forming farmer-based organizations will also be an effective means to access agricultural inputs in bulk for distribution among the members. This will reduce the retail and transportation costs incurred by individual farmers to access agricultural inputs. Farmer-based organizations are not only helpful in procuring bulk inputs, they also aid in securing good prices for agricultural produce marketed by members and accessing agricultural financial credits. Farmer-based organizations are known to play important roles in the farming operations of members (Francesconi & Wouterse, 2015; Gramzow et al., 2018; Sinyolo & Mudhara, 2018; Sirdey & Lallau, 2020; Trebbin, 2014).

The application of inputs is not the only agricultural practice that improves farm productivity. Legume-crop rotation is a less expensive alternative and is effective with both economic and environmental benefits. Legumes improve the soil through nitrogen fixation that boosts the yields of crops, reduces diseases, weed and insect population, and increases soil-carbon content (Andersson et al., 2014; Douthwaite et al., 2002; Place et al., 2003). Retaining the residues of legumes on the land enriches the soil (Manda et al., 2016). These attributes of legumes increase crop yields especially maize (Carsky et al., 2003; Manda et al., 2016; Teklewold et al., 2013). Legume-crop rotation is the third most adopted practice and 51.9% of the farmers in the study area grow maize. Educating farmers about the benefits of legume-maize rotation should enhance adoption of the practice.

6.5.2 Adopting Complementary Agricultural Practices around Forests is a Contested Issue

Out of the 103 non-adopters, 65.1% of them expand their farms to increase food crop production and 28.4% and 14.9% of these farmers have their plots within the reserve and less than 1 km from the reserves, respectively. The likelihood that these farmers will encroach the adjoining forests for fertile land is high (Asase & Tetteh, 2010; Gibbs et al., 2010; Owubah et al., 2000). Non-adoption of complementary practices (especially soil enrichment techniques) by farmers who farm within and at the fringes of forest reserves is a threat to the sustainability of the reserves. Application of soil-enrichment techniques at Ghana's forest frontiers together with reinforcing activities towards forest protection is one of the remedies to reduce forest encroachment and degradation. Adoption of inputs such as pesticides and herbicides especially in forest reserves could have negative impacts on the forest ecosystem and biological diversity. The farmers however need these inputs to enhance their farming operations to improve upon their livelihoods without necessarily expanding their farms. The priority of the farmers is yield improvement but this should not be at the expense of forest health. Forest and biodiversity conservation is crucial for improved provision of ecosystem services and reduction in climate change effects (Alamgir et al., 2016; Celentano et al., 2017; de Blécourt et al., 2013; Estoque et al., 2018; Ramdani & Hino, 2013). The work of extension agents through extensive education could help reduce the negative impact of agricultural inputs on the forest environment.

Our findings indicate that education, by means of agricultural extension services, is the main method through which a farmer gets knowledge about agricultural inputs. However, extension services are poor in the study area and Ghana as a whole due to inadequate resources (e.g. funds, motorbikes) and poor rural road networks that make it difficult for extension agents to travel to the remote places. Various agricultural development policies in Ghana have documented the above as the challenges facing extension services delivery in Ghana (MoFA, 2010, 2018; NDPC, 2014). This leaves farmers with no other option than to practice what they think is correct for them.

The Forest Services Division of Ghana has forest rangers in each forest district to patrol the various forest reserves. With the limited resources available for extension services, a possible option could be a joint force between the Forest Services Division and the District Agricultural Development Unit of Ghana to have a combined training program on forest-friendly agricultural practices for both extension agents and forest rangers. Collaboration between forestry and extension officers to educate farmers on agricultural practices that increase yields and outputs will, first, help sustain the forest reserves around and within which the input adopters cultivate. Second, the education may influence the non-adopters to start using forest-friendly complementary practices when they have the capacity to do so instead of expanding farms into adjoining forest areas to increase production and subsequently cause forest degradation.

The intervention should not end with the combined education strategy. Agricultural inputs subsidies and small loans with flexible payments and low interest rates could be made available to needy farmers who are willing to intensify their agriculture. Food security, rural poverty reduction, and forest sustainability are three key foci of the Sustainable Development Goals (SDGs) (United Nations General Assembly, 2015). Without subsidizing agricultural inputs and making agricultural loans available to smallholders, subsistence cultivation with low outputs will continue. Smallholders will continue to produce for household consumption and the surplus sold can only support household expenses with no extra income for farm innovation. Poor farmers seeking fertile land for food crops cultivation will have no choice than to encroach the forest reserves.

6.6 Conclusion

Complementary agricultural practices are important elements in farming due to the overall benefits that can be earned when properly applied. Farmers who adopt these practices enrich the fertility of their farmlands while reaping the benefits of higher yields. Perhaps of more importance for semi-subsistence farmers in Ghana and other developing countries is the adoption of soil enrichment technologies by farmers in forest frontiers. These farmers mostly rely on forests as fertile land banks for agricultural production. Adopting complementary agricultural practices could reduce the pressure on forest conversion for agriculture while at the same time enriching the farmers' lands for increased agricultural production. The agricultural practices identified in this study have both economic and environmental benefits. One way to optimize these benefits is to educate farmers on the best way to adopt the practices to ensure agricultural and environmental sustainability.

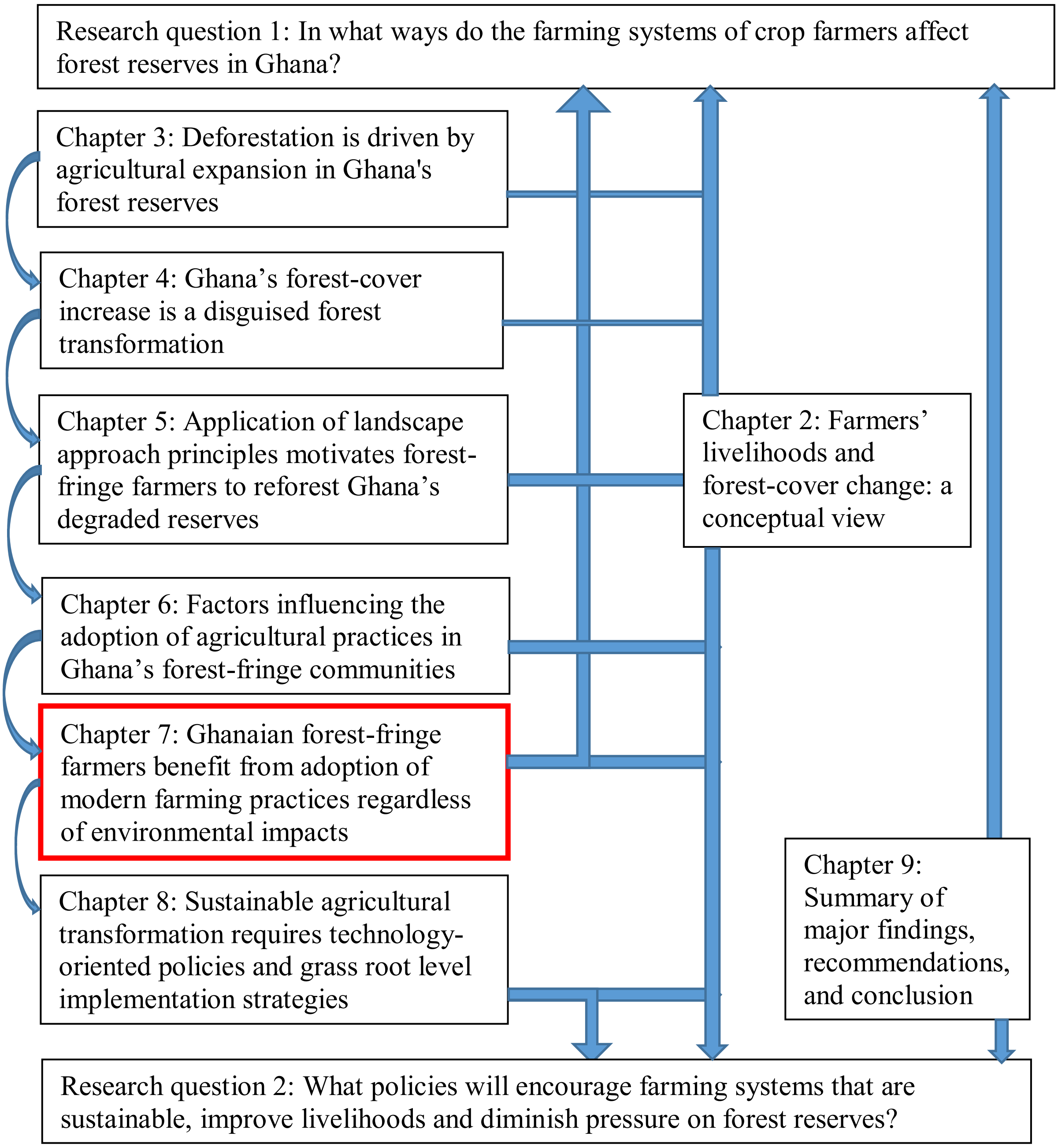
Our survey of 291 farmers in the Ashanti region of Ghana showed that 64.6% of the farmers adopt one or more complementary agricultural practices to control weeds, pest and diseases and enhance soil fertility with the ultimate goal of increasing farm outputs. We acknowledge that the adoption of practices such as herbicides and pesticides use are sometimes detrimental to the forest when not properly applied. However, their moderate use together with the use of fertilizers, organic manure, and crop rotation enrich the soil for increased production. This may reduce the need to expand farms to increase production and thereby encroach the forest. Some 35.4% of the farmers have some perceptions (e.g. costly, not useful, and difficult to use) about these practices that in effect demotivate them to adopt. Effective farmer-extension education towards the adoption of agricultural-enhancing practices is critical to change the perceptions of the non-adopters, motivate them to adopt these practices, and consequently restore the fertility of existing farmlands to increase agricultural outputs. Overall, this may help improve food security and livelihoods of the farmers with minimal effect on the environment. Further research is however required to investigate and understand the effect of each of the practices on the economic welfare of the farmers and the sustainability of the forest landscape.

The complimentary agricultural practices under study have been part of Ghana government's agricultural modernization policies since 1997 (NDPC, 1997, 2003, 2005, 2010, 2014). The adoption of improved seeds and planting materials for crops survival and the application of inorganic fertilizers for increased outputs in particular have been pursued by the government of Ghana for decades. The promotion of these practices together with other improved agricultural technologies have mainly been through extension services delivery although not highly effective due to resource scarcity and other challenges. Promoting the adoption of the studied complementary agricultural practices is therefore in line with Ghana's agenda of transforming its agricultural sector in a sustainable manner.

We acknowledge that our research is limited to the assessment of the factors of adoption treating all the identified practices as a combined component and that we failed to investigate the extent to which the factors affect each of the identified practices. We chose this method to provide a broader overview of factors of adoption and intensity of adoption in order to make generalized recommendations for agricultural development and forest sustainability. Since the adoption of complementary agricultural practices around forest reserves is a critical and contested issue, further research is required to investigate the factors affecting the adoption of each of the practices, the social, economic, and environmental costs and benefits associated with each of the practices, and the effects of adoption on outputs and income of the farmers. These will provide a more concrete rationale for the adoption of forest-friendly agricultural practices within forest-fringe communities while not compromising the conservation of the forest reserves.

What Next?

While some farmers adopt complementary agricultural practices to increase crops yields and outputs, others continue with traditional slash-and-burn farming because they perceive the agricultural-enhancing inputs to be expensive, not useful, and difficult to adopt. Chapter seven however argues that the adoption of agricultural intensification technologies could be more beneficial to the farmers and the farmed environment when properly applied. We report this through data sourced from environmental stakeholders and researchers on the costs and benefits of the complementary agricultural practices identified in chapter six.



Chapter Seven: Ghanaian Forest-Fringe Farmers Benefit from Adoption of Modern Farming Practices Regardless of Environmental Impacts

Abstract

Farming has led to significant loss of habitat and biodiversity in Ghana. Most farmers adopt organic and inorganic inputs to boost production with, at best, only secondary consideration of related environmental impacts. In some parts of Ghana, modern high-input farming is rapidly overtaking traditional, semi-subsistence agricultural practices. We examined the perceptions of five groups of stakeholders in regard to the social, economic, and environmental impacts of three farming systems (modern, mixed-input, and traditional farming), with emphasis on agricultural inputs and sustainable productivity. Our findings indicate that the perceived negative effects of modern farming (i.e., high use of inorganic inputs) are higher than the benefits. Farmers are however motivated to practice modern farming because of the perceived higher returns they obtain from their investments, regardless of environmental impacts. Mixed-input farming is not significantly different from modern farming in this respect because the mix of organic and inorganic inputs does not address the negative environmental and social impacts of agro-chemical applications. Traditional farmers do not use any inorganic inputs but instead rely on swidden 'slash-and-burn' practices, resulting in declining productivity and soil fertility over time, particularly as traditional practices become compromised by suboptimal fallowing due to growing demographic and commercial pressures. Farmers are then forced to encroach into nearby forests to merely maintain agricultural productivity. Reducing the use of inorganic inputs and promoting the adoption of organic inputs could minimize the negative impacts of agro-chemicals on the forest environment without necessarily compromising productivity. The adoption of organic inputs by traditional farmers in Ghana can improve crop yields as well as increase income and food security while slowing further forest encroachment through land sparing.

Keywords: Agricultural intensification, inputs adoption, farming practices, forest frontiers, rural Ghana, multi-criteria analysis.

7.1 Introduction

Agriculture has altered the Earth's surface more than any other human activity. Habitat loss resulting from agricultural expansion is perhaps the greatest single threat to global biodiversity (Foley et al., 2005). Over recent decades at least, the majority of new croplands have been established over tropical forests (Meyfroidt et al., 2014). Demand for food to sustain an increasingly affluent and populous Earth is putting pressure on the remaining uncultivated lands, especially forests, for agricultural production (FAO et al., 2015). Three-quarters of the rural poor in Africa rely on agriculture for their livelihoods but they generally practice unproductive traditional farming (Rudi et al., 2012). This is typical in Ghana, where over 70% of rural residents are farmers (Ghana Statistical Service, 2013a) and widely practice swidden slash-and-burn agriculture. Farming practices vary, however, and each practice has a corresponding diversity of social, economic, and environmental issues, such as forest conversion. Here, we examine the perceptions of five Ghanaian stakeholder groups about three agricultural systems in order to appraise the challenges of, and opportunities for, greater environmental conservation and agricultural productivity.

A number of studies have identified various agricultural practices in Ghana as well as the factors influencing the adoption of these practices. Kotu et al. (2017) found that farmers in northern Ghana adopt inorganic inputs (i.e., chemical fertilizers, herbicides, pesticides, improved seeds) and organic inputs or practices (e.g., intercropping, crop rotation, manure spreading) to increase production. The rationales for adoption are mainly economic (Donkor et al., 2016; Kassie et al., 2013; Tsinigo & Behrman, 2017). However, agricultural practices also have social and environmental implications, such as poverty reduction, food security, health problems, forest conservation, and contamination of water bodies (Dicks et al., 2019; Ikerd, 1990). The social, economic, and environmental effects of the practices adopted at forest frontiers are a subject of concern, the reason being that forest resources provide significant ecosystem services for global benefit.

Ghana has 256 forest reserves and several communities exist within and at the fringes of most of these (RMSC, 2016). Farming practices, such as the use of inorganic herbicides and pesticides, have been found to endanger biodiversity so they may not be suitable in or close to forests (Hayes et al., 2011; Norsworthy et al., 2012). Swidden farming practice may be suitable for farmers who cannot afford inorganic inputs, but pests and diseases impact farm productivity while the use of fire to clear fallows threatens neighbouring farms and forests (Styger et al., 2007). Such farmers may also be tempted to encroach on adjacent forests to access new, fertile lands, since existing croplands decline in fertility in the absence of other soil enrichment (Acheampong et al., 2018) or as fallows shorten under demographic or commercial pressures (Boserup, 1993). Agricultural and forest sustainability are contingent upon balancing the full range of social, economic, and environmental impacts of farming practices at forest frontiers of Ghana (Adjei-Nsiah, 2012; Ansong Omari et al., 2018; Tambo & Wünscher, 2015).

However, different stakeholders of sustainable rural resource management are likely to have different perceptions of, and attitudes towards, the effects of various farming practices due to the relative priority they afford various social, economic, or environmental concerns. Further, some farmers are inclined to mix or partially adopt certain practices, and may correspondingly exhibit diverse attitudes. Farmers in forest-fringe communities of the Ashanti region of Ghana, for instance, have adopted a range of agricultural practices to complement slash-and-burn farming, including fertilizer, herbicide, and pesticide applications (Acheampong et al., 2021). Through a survey of different stakeholders, including but not limited to farmers, we examine the social, economic, and environmental effects of different agricultural practices that farmers in the Ashanti region have adopted to sustain agricultural productivity.

7.2 Multi-Criteria Analysis for Agricultural Sustainability: A Brief Review

This study employs multi-criteria analysis (MCA) to assess the perceptions of different stakeholders on the costs and benefits of varied agricultural practices. MCA assists analysts and stakeholders to evaluate, prioritize, and/or select amongst alternative resolutions given conflicting interests, factors, or scenarios (Alencar & Almeida, 2010; Jeon et al., 2010). Multi-criteria analysis comprises varied techniques capable of processing data from a number of systems to generate an overall score indicating an 'optimal', or at least optimally compromised, decision or preference for a given resolution (Talukder et al., 2018).

Multi-criteria analysis as applied to agricultural sustainability may be applied in various ways based on sustainability principles. Some researchers use MCA to derive conceptual frameworks encompassing the range of values and perspectives of different stakeholders (Gibson, 2006). Others use MCA to define sustainability criteria in order to operationalise sustainability (Gibson, 2006; Pope et al., 2004). A particular utility of MCA along these lines is its ability to explicitly profile the so-called triple bottom line (TBL) by placing equal importance on the environmental, economic, and social pillars of sustainability decision-making process (Convertino et al., 2013; Gibson, 2006; Pope et al., 2004).

MCAs have also been used to access stakeholder knowledge of soil and land management to thus prioritize soil functions for sustainable production (Bampa et al., 2019; Bouma et al., 2012). Pashaei Kamali et al. (2017) adopted MCA to assess the validity of local expert opinions in scoring sustainability performance of agricultural systems. Comparing the sustainability scores of experts against published studies, Pashaei Kamali et al. (2017) concluded that expert opinions are a potential alternative to published empirical methods in the literature. Parra-López et al. (2007) similarly concluded through the use of MCA that local expert knowledge could inform decision-making processes where conventional empirical data is unavailable, partial, or costly. In all the MCA studies surveyed concerning agricultural management, none considered agricultural practices in relation to forest landscapes and forest management. This omission reflects the fact that none of the studies reviewed was realised in agricultural frontiers that abut against vulnerable forests.

This study of agricultural practices adopts MCA in light of two particular attributes. First, measuring the effects of agricultural practices on society and the environment in the field requires large quantities of empirical data on people's health, satisfaction towards some practices, poverty and food security levels, as well as soil fertility, crops yields, duration of growing cycles, and the costs and logistics of applying agricultural inputs. These data are usually very expensive to collect at large scales and require specialised expertise to process. Multi-criteria analysis is an alternative, reliable, and relatively inexpensive means of evaluating the effects of agricultural practices on the basis of stakeholders' qualitative estimates (Parra-López et al., 2007; Pashaei Kamali et al., 2017). Second, different stakeholders in rural resource management have different understanding of, and concern for, various environmental and social issues related to farming. For instance, farmers are interested in economic gains while foresters are concerned with forest conservation. Attempting to avoid environmental degradation due to farming without economically undermining farmers requires an analytical tool capable of resolving trade-offs amongst the array of relevant stakeholders. Multi-criteria analysis may assist in negotiating conflicting attitudes amongst stakeholders in regard to environmental management, highlighting relatively promising approaches to sustainable resource management at forest frontiers (Alary et al., 2008; Romero & Rehman, 2003).

7.3 Materials and Methods

We examined the environmental, economic, and social concerns of agricultural inputs and practices for three distinct farming systems in Ghana varied in terms of their alignment with Green Revolution technologies, namely modern, mixed-input, and traditional farming systems. Perceived costs and benefits of these systems were assessed according to appraisals by five stakeholder groups (farmers, foresters, agricultural extension officers, crop/natural resource researchers, and environmental NGOs) using V.I.S.A multi-criteria analysis model. The succeeding sections present the details.

7.3.1 Study Area and Sample Selection

The Ashanti region occupies about 10% of Ghana's extent and is located between longitudes 0.15°W and 2.25°W and latitudes 5.54°N and 7.46°N (Ghana Statistical Service, 2013b). The region contains 58 of the 256 forest reserves in Ghana (See section 3.2.1 for the description of the study area). We chose this region for this study because of its high deforestation rate and the associated transition from forest vegetation to savannah woodlands, especially the northern part of the region (RMSC, 2016). Along these lines, Acheampong et al. (2019) finds that agricultural practices in the region degraded over 70% of its original forest cover. Forest reserves were gazette in the region since the 1920s onwards, prior to which there was no official concern over sustainable forest management because forest-dependent residents were few and collected mainly Non-Timber Forest Products (NTFPs) for subsistence use (Kotey et al., 1998). Forest-fringe communities have since greatly increased in number, resulting in increased agricultural pressure on forest lands and raising concern over effective forest conservation (RMSC, 2016).

We surveyed five stakeholder groups for this study: farmers, foresters, agricultural extension officers, crop/natural resource researchers, and environmental NGOs. Six foresters in the positions of Assistant District Manager, Plantations Manager, and Deputy Area Manager in Ghana were surveyed as representatives of foresters' perspectives. Five agricultural extension officers of the Ministry of Food and Agriculture (MoFA), six crop/natural resource researchers of the Council for Scientific and Industrial Research's Crops Research Institute of Ghana (CSIR-CRI) and the University for Development Studies (UDS), and five Directors of regional environmental NGOs, all based in the Ashanti region, were similarly surveyed as representatives of their respective sectors. Regarding farmers, we surveyed one farmer from each of 10 select communities in the region adjoining forest reserves degraded by agriculture (according to regional foresters). Surveyed farmers were those identified by their communities as highly experienced. The 10 communities were selected from the set of 20 regional forest-fringe communities studied by Acheampong et al. (2019) (see Figure 7.1). Overall, 32 key participants from five stakeholder groups were surveyed.

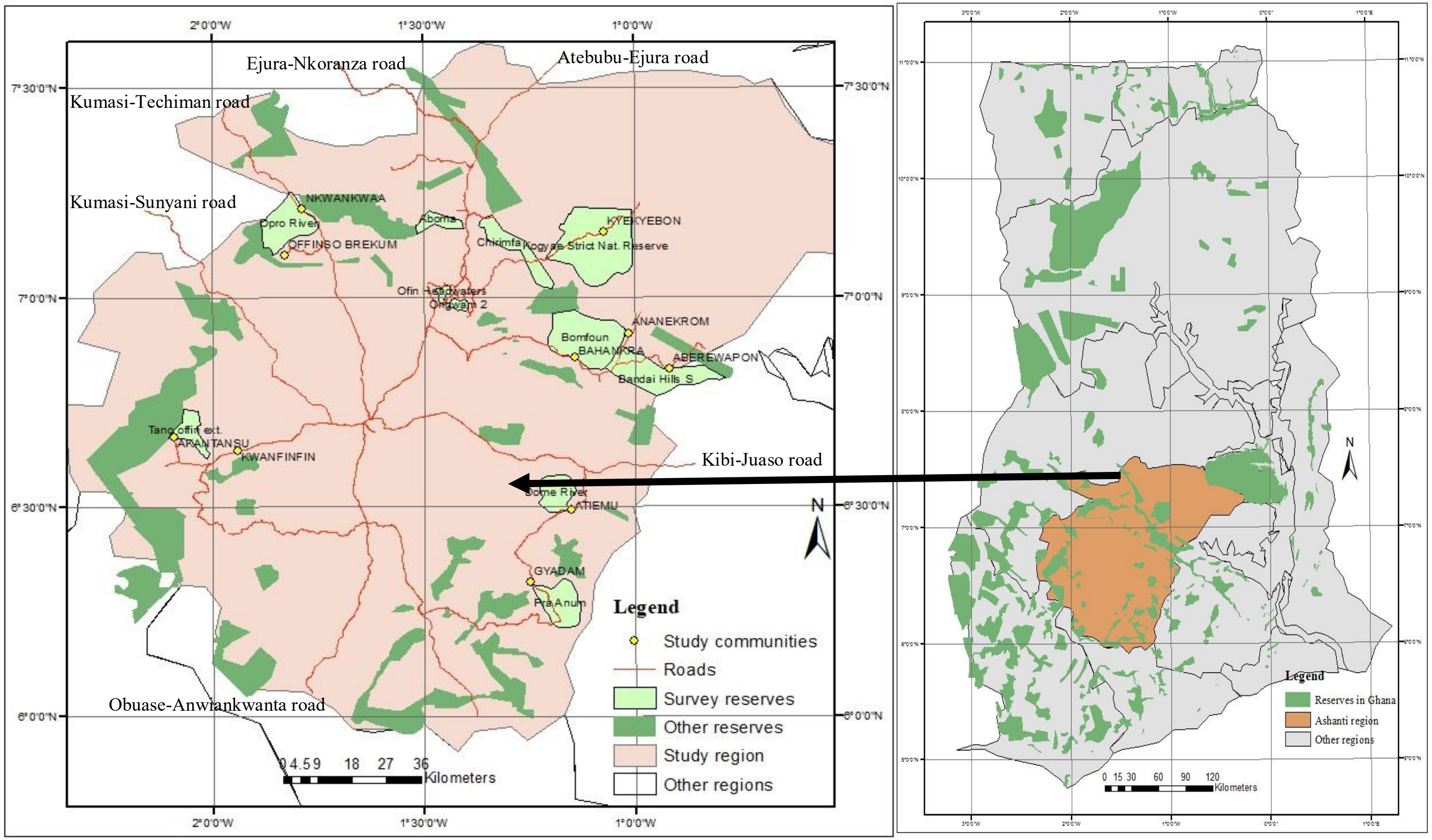


Figure 7.1 The Ashanti Region of Ghana and its Forest Reserves.

Source: Resource Management Support Center (RMSC), 2016

7.3.2 Data Collection and Analysis Techniques

In an earlier survey (Acheampong et al., 2021), we identified six main farming practices within the forest-fringe communities of the Ashanti region. These practices are the use of inorganic fertilizers, herbicides, and/or pesticides, the use of improved seeds, the application of organic animal manure, and annual crop rotation. We categorized these practices into three farming systems – modern, mixed-input, and traditional. The modern system exemplifies Green Revolution technologies as practiced elsewhere globally, entailing intensified, high, sustained agricultural productivity dependent on the regular input of inorganic agro-chemicals as well as improved seeds and, by extension, a negligible role for organic fertilisers, soil management, and pest control (Burton, 2004; Lowe et al., 1993). In contrast, traditional farmers rely on continuous slash-and-burn farming fallowing short-term (just between harvesting and the next cropping season) and without agro-chemical inputs. Traditional farmers will sell farm surpluses at market, but surpluses are relatively small as a proportion of total farm yield, much of which is dedicated to home consumption. Mixed-input farmers are, as the title implies, a hybrid of traditional and modern farmers. They use some inorganic inputs alongside organic manure and/ or crop rotation. Mixed-input farmers' partial use of relatively costly inorganic inputs reflects their greater commercial orientation compared to traditional farmers.

Table 7.1 Three Farming Systems and Corresponding Social, Economic, and Environmental Issues Assessed by the Stakeholder Groups in the Ashanti Region

	Modern farming	Mixed-input farming	Traditional farming
Indicative practices, inputs	Inorganic fertilizers, herbicides, and/or pesticides; Improved seeds	Organic manure (animal or plant-based), crop rotation (+ inorganic inputs)	Slash-and-burn practices
Social issues	Health risk to farmer, societal support of use, level of difficulty in application, food health	Health risk to farmer, societal support of use, level of difficulty in application, food health	Health risk to farmer, societal support of use, food health
Economic issues	Cost of inputs, cost of labour, frequency of application, effects on crop growth, yield, output, survival, resistance	Cost of inputs, cost of labour, frequency of application, effects on crop growth, yield, output, survival, resistance	Cost of labour, frequency of labour use, frequency of farm maintenance, effects on crop growth, yield, output, survival, resistance
Environmental issues	Effects on soil, water bodies, tree species, fauna, forest	Effects on soil, water bodies, tree species, fauna, forest	Effects on soil, tree species, fauna, forest

Using V.I.S.A. multi-criteria analysis (MCA) software, we adopted a non-econometric cost-benefit model to survey the views of the stakeholders on the negative and positive aspects of farming practices/inputs (Table 7.1). Input data for our cost-benefit model were derived from a five-point Likert scale questionnaire administered to each stakeholder. Here, the cost component for a given practice does not refer to monetary costs per se but rather to the negative effects or consequences of the practice. The qualitative, ordinal nature of the input data reflects the fact that the issues of interest in Table 7.1 were also qualitative in nature, e.g., societal support for fertilizer usage, health risks for crop rotation and manure spreading. The V.I.S.A MCA model, which is similar to other MCA models, weights costs and benefits using a “criterion” function (C), “scores for alternatives” function (S), and “criterion weighting” function (W) as follows (Hongoh et al., 2011; Linares & Romero, 2000; Pashaei Kamali et al., 2017):

$$MCAj = \sum_{ij} Wi * Sij$$

Where MCA_j is the overall outcome ‘score’ for practice j, W_i is the weight for criterion i, S_{ij} is the score for criterion i in practice j, and a criterion is a statement for which a stakeholder respondent provided a response on the Likert scale. The 'alternatives' in the model are the five stakeholder groups surveyed, which may offer alternative, or at least diverse, responses for a given criterion. The scores are the calculated values assigned to each statement/criterion by the respondents. V.I.S.A uses a scoring system of 0 to 100. We multiplied the average scores obtained from the statements/criteria by a scalar of 20 to agree with the 0-to-100 scoring system because our Likert scale had a range of one to five. We then calculated the total scores for each statement/criterion for each stakeholder category and calculated the average score for statement/criterion.

The weighting function within V.I.S.A is used to demonstrate the level of importance stakeholders afford to each criterion regardless of the score given to the criterion. Sometimes, the weighting function is used to influence decisions towards a certain interest. For instance, a stakeholder may score the economic benefit of animal manure and inorganic fertilizer usage same value of 80. The weighting for inorganic fertilizer may differ from animal manure based on the interest or recommendation of the stakeholder. The weights applied to the criteria will influence the outputs of the model.

We first applied equal weights to the criteria to examine preliminarily the model output based only on stakeholders' scores as given. This effectively ensured that the weighting function did not influence the views (scores) of the stakeholders. Subsequently, we weighted the criteria based on the relevant literature on sustainable farming practices, our personal experiences based on field surveys, and the suggestions and opinions of the stakeholders towards sustainable agriculture. Here, weights adopted a continuous scale of zero to one. Finally, the weighted criteria and the stakeholders' scores were combined to graphically produce outputs that we based on to recommend farming systems that will balance environmental sustainability and agricultural productivity.

7.4 Results

7.4.1 Brief Description of the three Farming Systems

The attributes of farmers of the farmer stakeholder group reflect those of the 291 farmers previously surveyed in the Ashanti region (Acheampong et al., 2021). In this earlier survey, 50.9% of farmers were modern, 14.0% were mixed-input, and 35.5% were traditional farmers. The majority of farmers for each of these three farm systems (63.5%, 67.5%, and 51.5% of modern, mixed-input, and traditional farmers, respectively) are below 50 years of age. About a third of farmers of each of the three systems have not been to any formal schooling while the rest, with few exceptions, completed at most grade 10. Over half of all the farmers have up to 20 years of farming experience while the rest have over 20 years of farming experience. More than two-thirds of the modern farmers cultivate a single farm plot, being 2 ha on average. Forty-five percent of mixed-input and 78.6% of traditional farmers cultivate multiple plots ranging 1-4 ha. Almost all farmers of the three systems manage plots within five km of the forest reserves (See Table 7.2). The three farm systems have both distinct and similar features. The distinct features relate to their farming operations.

Table 7.2 Characteristics of the Study Farmers Patronizing each Farming System

Ages of farmers					
Age groups	Category	Modern farmers	Mixed-input farmers	Traditional farmers	Total farmers
<= 20	% within types of farmers	0.0%	2.6%	1.0%	0.7%
21 - 30	% within types of farmers	14.2%	15.4%	4.9%	11.0%
31 - 40	% within types of farmers	25.7%	23.1%	17.5%	22.3%
41 - 50	% within types of farmers	23.6%	25.6%	30.1%	26.1%
51 - 60	% within types of farmers	19.6%	10.3%	28.2%	21.3%
61 - 70	% within types of farmers	10.1%	15.4%	13.6%	12.0%
71 - 80	% within types of farmers	5.4%	5.1%	5.8%	5.5%
81+	% within types of farmers	1.4%	2.6%	0.0%	1.0%
Total farmers	Count	148	39	103	291
	% within types of farmers	100.0%	100.0%	100.0%	100.0%

Educational (grades) attainments of farmers					
Educational attainments	Category	Modern farmers	Mixed-input farmers	Traditional farmers	Total farmers
0	% within types of farmers	25.0%	30.8%	24.3%	25.4%
3	% within types of farmers	0.0%	0.0%	1.0%	0.3%
4	% within types of farmers	2.0%	2.6%	4.9%	3.1%
5	% within types of farmers	0.0%	5.1%	1.9%	1.4%
6	% within types of farmers	6.1%	7.7%	8.7%	7.2%
7	% within types of farmers	2.7%	0.0%	4.9%	3.1%
8	% within types of farmers	1.4%	5.1%	4.9%	3.1%
9	% within types of farmers	29.7%	28.2%	22.3%	26.8%
10	% within types of farmers	23.0%	12.8%	26.2%	22.7%
11	% within types of farmers	0.7%	0.0%	0.0%	0.3%
12	% within types of farmers	6.8%	2.6%	1.0%	4.1%
15	% within types of farmers	2.7%	5.1%	1.0%	2.4%
Total farmers	Count	148	39	103	291
	% within types of farmers	100.0%	100.0%	100.0%	100.0%

Farming experience (years) of farmers					
Years of farming	Category	Modern farmers	Mixed-input farmers	Traditional farmers	Total farmers
1 - 10	% within types of farmers	29.7%	23.1%	27.2%	27.8%
11 - 20	% within types of farmers	26.4%	38.5%	27.2%	28.2%
21 - 30	% within types of farmers	18.2%	12.8%	28.2%	21.0%
31 - 40	% within types of farmers	14.9%	17.9%	11.7%	14.1%
41 - 50	% within types of farmers	5.4%	5.1%	3.9%	4.8%
51 - 60	% within types of farmers	4.7%	2.6%	2.9%	3.8%
61+	% within types of farmers	0.7%	0.0%	0.0%	0.3%
Total farmers	Count	148	39	103	291
	% within types of farmers	100.0%	100.0%	100.0%	100.0%

Number of farm plots cultivated					
Number of farm plots	Categories	Modern farmers	Mixed-input farmers	Traditional farmers	Total farmers
1	% within types of farmers	68.2%	43.6%	79.6%	68.7%
2	% within types of farmers	12.2%	20.5%	11.7%	13.1%
3	% within types of farmers	13.5%	25.6%	5.8%	12.4%
4	% within types of farmers	6.1%	10.3%	3.9%	5.8%
Total farmers	Count	148	39	103	291
	% within types of farmers	100.0%	100.0%	100.0%	100.0%

Average distances of farms from forest					
Average distance from forest	Categories	Modern farmers	Mixed-input farmers	Traditional farmers	Total farmers
<= .0	% within types of farmers	20.9%	23.1%	24.3%	22.3%
.1 - 1.0	% within types of farmers	12.8%	12.8%	18.4%	14.8%
1.1 - 2.0	% within types of farmers	15.5%	23.1%	11.7%	15.1%
2.1 - 3.0	% within types of farmers	3.4%	2.6%	1.9%	2.7%
3.1 - 4.0	% within types of farmers	8.1%	5.1%	14.6%	10.0%
4.1 - 5.0	% within types of farmers	8.8%	7.7%	9.7%	8.9%
5.1 - 6.0	% within types of farmers	0.7%	2.6%	2.9%	1.7%
6.1 - 7.0	% within types of farmers	7.4%	5.1%	7.8%	7.2%
7.1 - 8.0	% within types of farmers	12.8%	2.6%	5.8%	8.9%
8.1 - 9.0	% within types of farmers	0.7%	0.0%	0.0%	0.3%
9.1 - 10.0	% within types of farmers	4.7%	12.8%	3.9%	5.5%
11.1 - 12.0	% within types of farmers	0.7%	0.0%	0.0%	0.3%
12.1 - 13.0	% within types of farmers	0.0%	2.6%	0.0%	0.3%
13.1 - 14.0	% within types of farmers	0.7%	0.0%	0.0%	0.3%
15.1+	% within types of farmers	2.7%	0.0%	0.0%	1.4%
Total farmers	Count	148	39	103	291
	% within types of farmers	100.0%	100.0%	100.0%	100.0%

7.4.2 Costs and Benefits of Modern and Mixed-Input Farming Systems

All stakeholders viewed modern agriculture as more beneficial than detrimental generally before they responded to our survey, as inferred by the informal conversation prior to the actual survey. However, the MCA model based on the stakeholders' scores (Table 7.3) reveals that the overall cost of modern farming (51.9%) is slightly higher than the overall benefit (48.1%) (Figure 7.2). Negative environmental implications of modern farming (35.7%) in particular are almost double the positive environmental implications (23.1%) (Figure 7.2), though environmental implications generally were of only a middling importance compared to economic and social implications. Economic costs, resulting mainly from the procurement of chemical inputs, are highest amongst negative implications (42.9%), followed by negative environmental implications resulting mainly from the use of the chemical inputs (35.7%). The negative social implications of modern farming are ranked lower (21.4%) than negative environmental or economic implications. These negative social implications relate to contamination that farmers and communities experience from the application of inorganic inputs, society's general rejection of the use of chemicals for farming, and the lack of skills for applying such chemicals appropriately.

Table 7.3 Cost and benefit Scores Stakeholders Assigned to the Various Statements/ Criteria Representing Modern Farming System

components	Indicators	Measurement criteria	Stakeholders' scores for cost components				
			Foresters	Ext. agents	Env. NGOs	Researchers	Farmers
Social costs	Human health	Infection from chemicals use	93	84	92	83	53
	Societal rejection	Rejection of chemical use	90	36	44	27	30
	Application	High skills requirement	77	48	44	37	84
Economic costs	Inputs	Quantity/cost of pesticides and herbicides	77	72	92	80	90
		Quantity/cost of fertilizers	80	88	92	83	100
		Quantity/cost of improved seeds	80	72	76	87	76
		Farm labour hired	92	52	68	57	64
		Frequency of hired labour	67	55	52	60	70
Environmental costs	Pollution	Land pollution from chemicals	97	72	92	97	76
		Water pollution from chemicals	100	92	100	97	76
	Plant health	Negative effects of chemicals on crops	100	100	96	100	50
		Negative effects of chemicals on trees	100	68	96	90	46
	Living organisms	extinction from pesticides	100	100	100	97	47
			Stakeholders' scores for benefit components				
			Foresters	Ext. agents	Env. NGOs	Researchers	Farmers
Social benefits	Food health	Nutrition from improved seed	80	88	72	100	84
	Happiness	Reduced poverty and increased food security	87	76	76	90	89
		Society accepts improved seeds	80	92	88	80	100
Economic benefits	Output	Improved yield and increased quantity	83	92	92	90	96
	Profitability	Early maturity with associated high price	93	88	72	77	98
	Crop survival	High survival rate and resistance	97	88	88	97	100
Environmental benefits	Soil	Fertile soil through fertilization	90	92	92	90	98
	Forest	Less encroachment and stable forest	63	60	44	60	96

Farmers' motivations for adopting inorganic inputs within the modern farming system revolves around the economic returns from this system, which are proportionally higher (46.2%) than the corresponding economic costs (42.9%), albeit only marginally. The primary economic benefits in question include increased yields, increased resistance of crops to pests and diseases due to the use of improved seeds and pesticides, and greater farm profitability due to earlier crop maturation and more favourable marked prices.

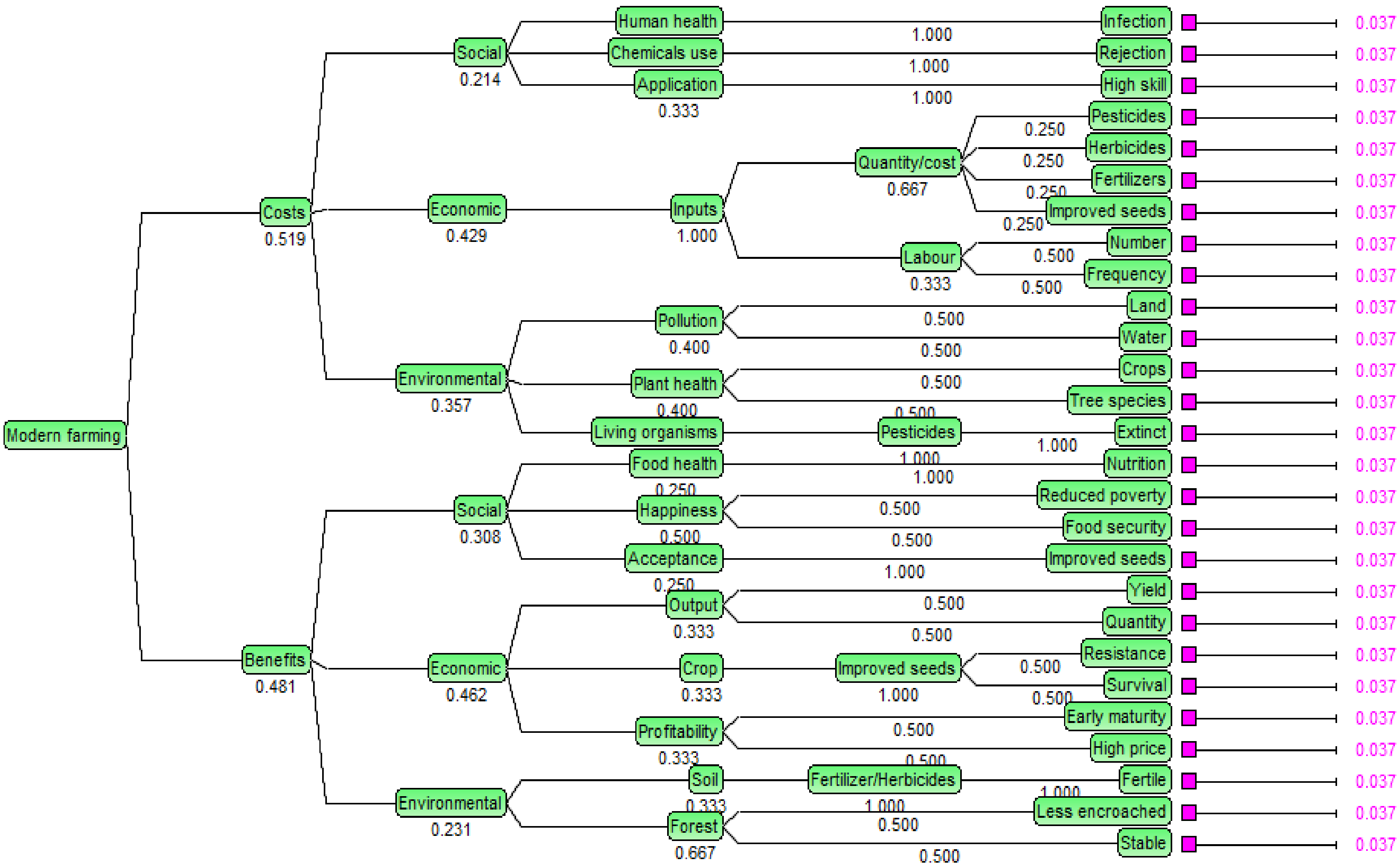


Figure 7.2 Costs and Benefits of the Modern Farming System Based on Stakeholders' Qualitative Scores

Overall cost-benefit balances differed predictably amongst the stakeholder groups. While foresters and representatives of environmental NGOs opined that the detrimental effects of modern farming outweigh the benefits, the farmers, agricultural extension officers, and crop/natural resource researchers held the opposite view (Figure 7.3 left panel and bottom graph). Although extension officers and crop/natural resource researchers are in favour of modern farming overall, they still held the same opinions as foresters and environmental NGOs regarding the damaging environmental effects of inorganic inputs (Figure 7.3 middle panel). According to the foresters, when inorganic inputs, especially herbicides and pesticides, are used within forest reserves, the environmental damage alone is higher than the overall benefit of the modern farming system. In the words of one forester: "The use of fertilizers enriches the soil to some extent, but the use of some herbicides hardens the soil and damages flora". Another forester stated that "pesticides protect food crops from pest infestation, but they destroy more other insects needed for pollination than those that infest food crops". Such comments and inter-stakeholder differences are highly suggestive that overall benefits of modern farming exceed overall costs for a given stakeholder only when that stakeholder may externalize such costs to other lands and/or landholders. Hence, the surprisingly small difference between overall cost and benefit scores for modern farming amongst all stakeholders combined (Figure 7.2).

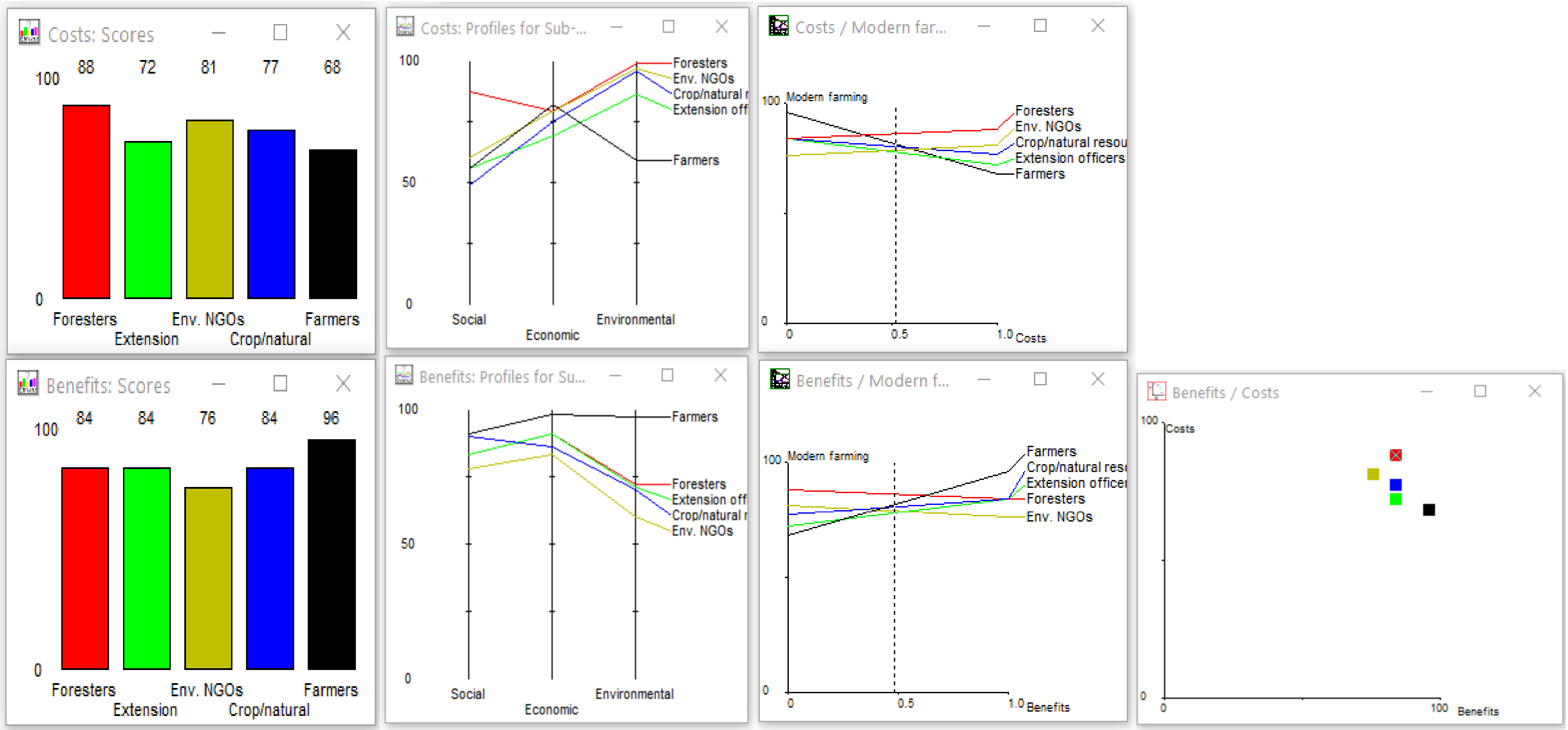


Figure 7.3 Stakeholders' Scores for Costs and Benefits of Modern Farming System.

Left panel presents the overall average cost and benefit scores from each stakeholder group. Middle panel presents the sum of the scores for social, economic, and environmental costs and benefits. Right panel presents stakeholder sensitivity levels. Bottom graph presents stakeholders' cost-benefit ratio.

Farmers, unlike the other stakeholders, perceive modern farming as more beneficial to them and to the environment. According to the farmers, the use of fertilizers, pesticides, herbicides, and improved seeds make farming not only less laborious but also more profitable. More surprisingly, and in stark contrast to other stakeholders, these farmers ranked environmental benefits attributable to modern agriculture almost as highly as economic benefits (Figure 7.3 middle panel). One farmer commented, "I do not cut down trees to expand my farm. I add more of these inputs to the same land to get more produce. I am rather helping to conserve the forest". Another farmer added, "There are two ways to get more farm produce. One is to expand the farm and the other is to apply more inputs. I have decided to use the inputs rather than to encroach the forest". The modern farmers perceive that since they do not clear the forest for cultivation, any negative environmental effects of their practices are insignificant.

The primary difference between the modern and the mixed-input farming systems is the use of organic inputs (manure and/ or mulch) and crop rotations by the latter, which meaningful alter associated costs and benefits (Figure 7.4 and Table 7.4). Hence, stakeholders' views of such attributes led them to score the benefits of mixed-input farming (52.8%) higher than the costs (47.2%) overall, in contrast to modern farming.

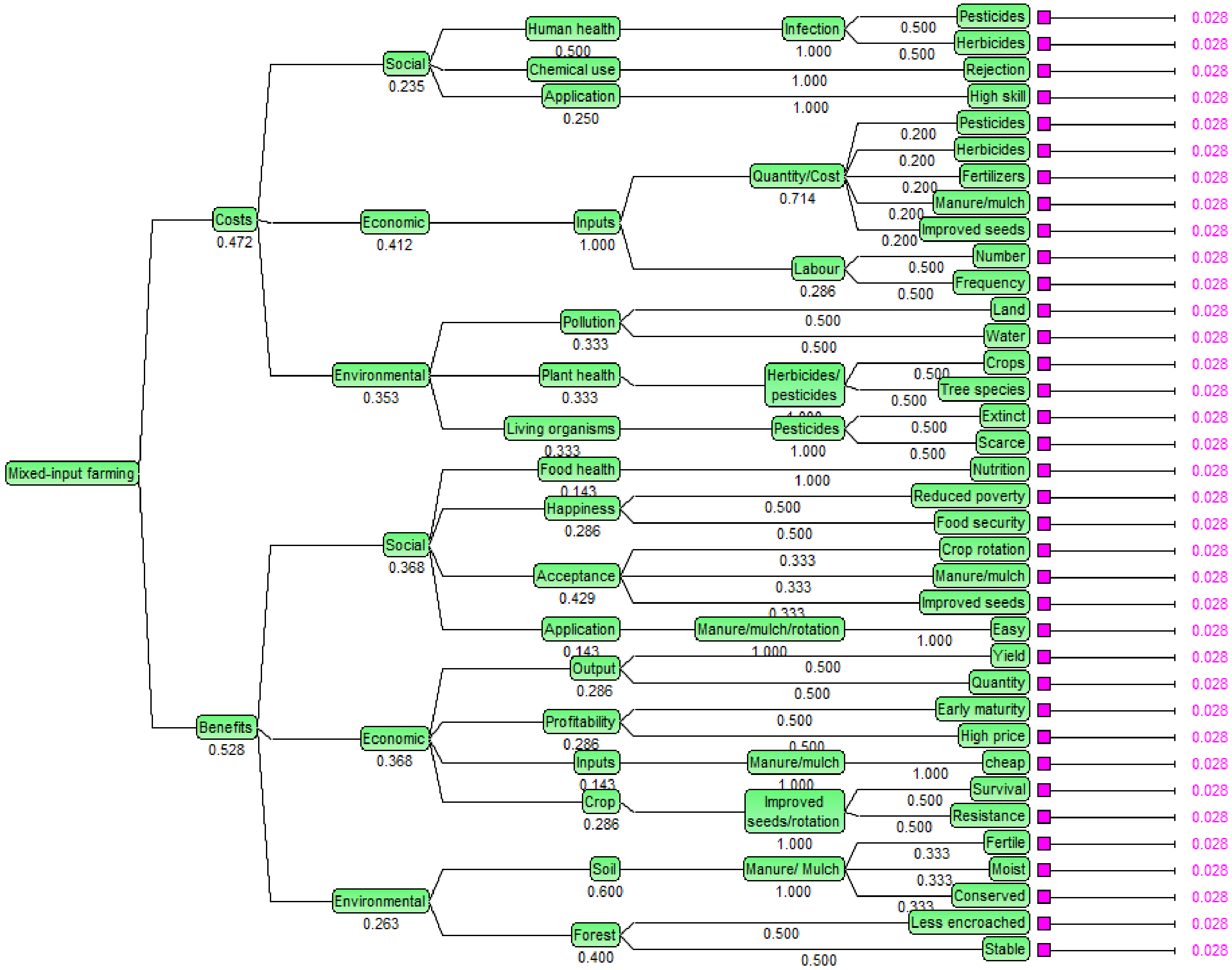


Figure 7.4 Costs and Benefits of Mixed-Input Farming Based on Stakeholders' Qualitative Scores

Table 7.4 Cost and Benefit Scores Stakeholders Assigned to the Various Statements/ Criteria Representing Mixed-Input Farming System

components	Indicators	Measurement criteria	Stakeholders' scores for cost components				
			Foresters	Ext. agents	Env. NGOs	Researchers	Farmers
Social costs	Human health	Infection from chemicals use	93	84	92	83	53
	Societal rejection	Rejection of chemical use	90	36	44	27	30
	Application	High skills requirement	77	44	44	37	84
Economic costs	Inputs	Quantity/cost of pesticides and herbicides	77	72	92	80	90
		Quantity/cost of fertilizers	80	88	92	83	100
		Quantity/cost of manure	20	20	27	28	20
		Quantity/cost of improved seeds	80	72	76	87	76
		Farm labour hired	92	52	60	57	64
		Frequency of hired labour	67	44	64	57	70
Environmental costs	Pollution	Land pollution from chemicals	100	72	92	97	76
		Water pollution from chemicals	100	92	100	97	76
	Plant health	Negative effects of chemicals on crops	100	100	92	100	50
		Negative effects of chemicals on trees	100	68	96	90	46
	Living organisms	extinction from pesticides	100	100	100	97	47
			Stakeholders' scores for benefit components				
			Foresters	Ext. agents	Env. NGOs	Researchers	Farmers
Social benefits	Food health	Nutrition from improved seed	80	88	72	100	84
	Happiness	Reduced poverty and increased food security	87	76	76	90	91
	Societal acceptance	Society accepts crop rotation, manure usage, and improved seeds	80	92	88	73	100
	Application	Easy to apply manure and crop rotation	67	80	64	70	74
Economic benefits	Output	Improved yield and increased quantity	83	88	88	90	96
	Profitability	Early maturity with associated high price	93	88	72	77	98
	Inputs	Manure/Mulch is cheap	77	76	80	67	75
	Crop survival	High survival rate and resistance	97	88	88	97	100
Environmental benefits	Soil	Fertile soil through fertilizer and manure	90	92	92	93	98
		Moist and conserved soil through manure	97	92	96	100	98
	Forest	Less encroachment and stable forest	63	60	44	60	96

Despite the higher overall benefit-to-cost ratio for the mixed-input farming system, our MCA model (Figure 7.4) describes overall negative economic and environmental effects as greater than economic and environmental benefits, due largely to the usage of inorganic inputs. This was due to some stakeholders, namely, foresters and environmental NGOs ranking the economic and environmental costs of mixed-input farming higher than the corresponding benefits due to its incorporation of such organic inputs (Figure 7.5).

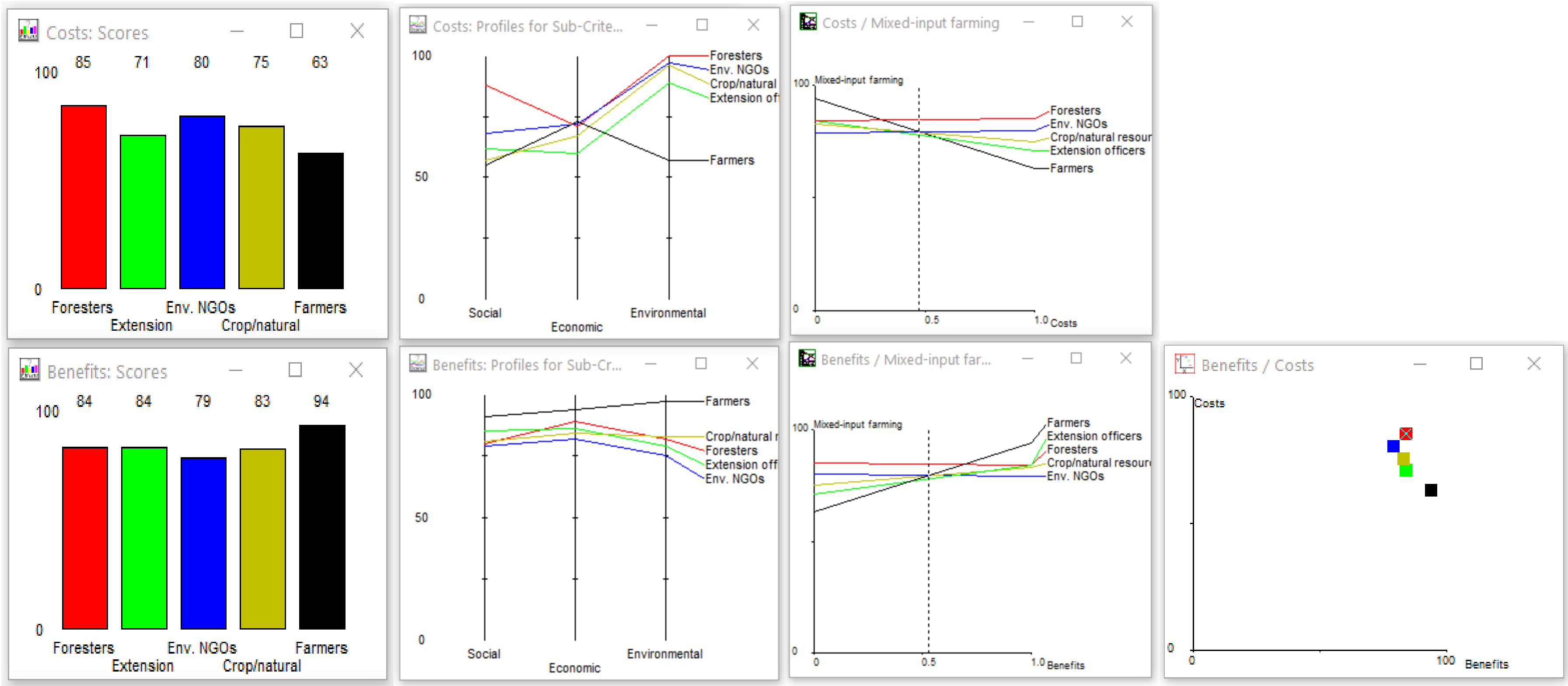


Figure 7.5 Stakeholders' Scores for Costs and Benefits of Mixed-Input Farming System.

Left panel presents the overall average cost and benefit scores from each stakeholder group. Middle panel presents the average scores for social, economic, and environmental costs and benefits. Right panel presents stakeholder sensitivity levels. Bottom graph presents stakeholders' cost-benefit ratio.

7.4.3 Costs and Benefits of Traditional Farming

In contrast to expectations of relatively high favour for organic agricultural production, due to a tendency to conflate organic and 'sustainable', stakeholders scored the traditional farming system as more costly than beneficial overall, with scores of 54.2% and 45.8% respectively (Figure 7.6). Accordingly, the traditional system registered an overall benefit-to-cost ratio lower than that for the modern farming system (Figure 7.2). The MCA model for the traditional faming system (Figure 7.6) and stakeholders' views on the same (Table 7.5) indicate that, compared to the modern system, this system is more unproductive but less costly overall for farmers, slightly less detrimental to the environment, and more favoured by society. Interestingly, despite its unprofitable nature, farmers and, to lesser degrees, foresters and agricultural extension officers all ascribed traditional farming more benefit than cost overall (Figure 7.7 left panel and bottom graph), primarily because the system does not entail agro-chemicals costly to landholder and harmful to forests and society. Farmers' net favour of the traditional system was however less acute than for the modern system (Figure 7.2), and the benefit-to-cost ratio amongst farmers most discrepant between these two systems. Again, such discrepancies amongst stakeholders seemingly reflect whether the costs or benefits of a given farm system are externalized by a given stakeholder.

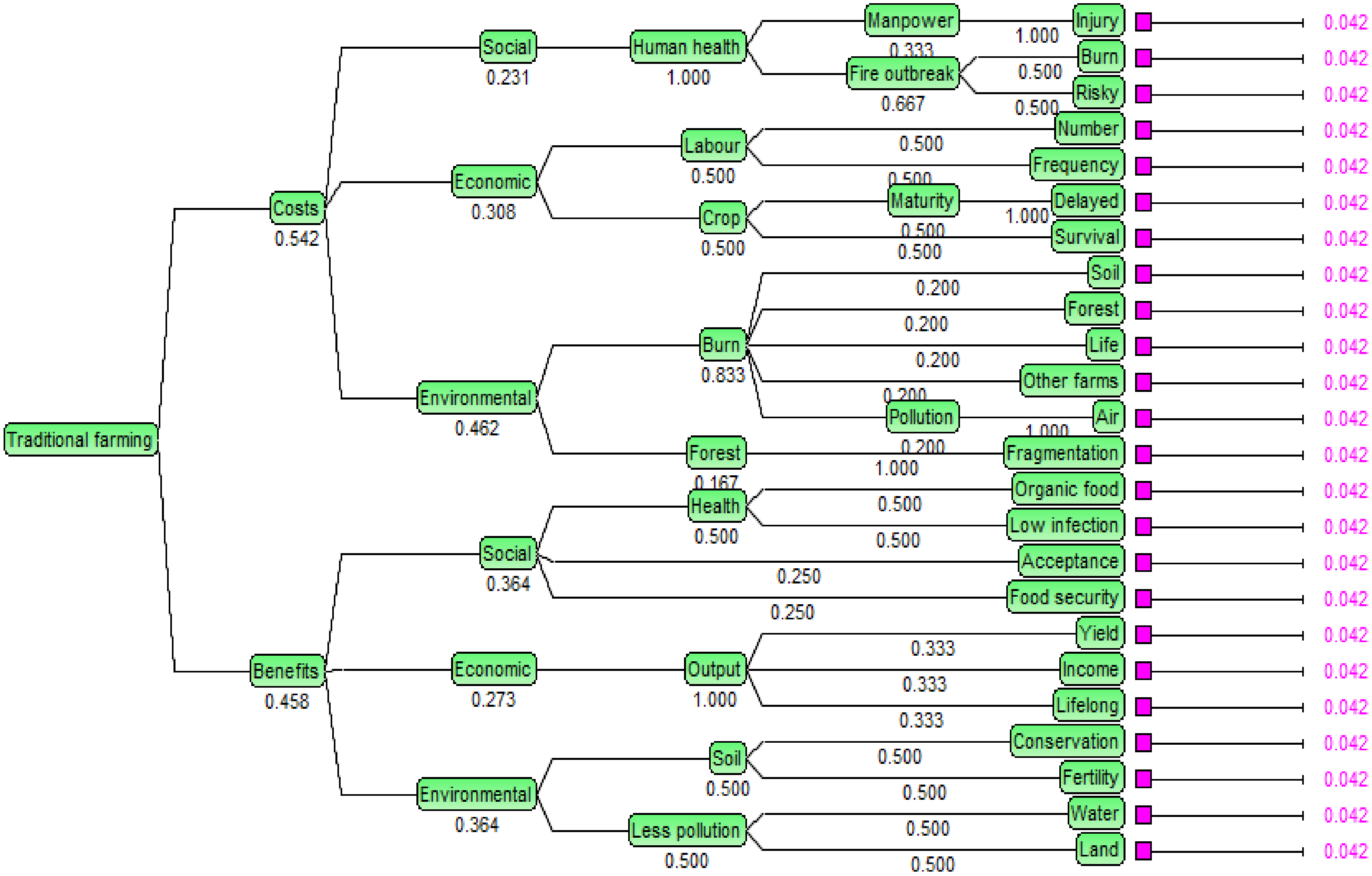


Figure 7.6 Costs and Benefits of Traditional Farming System Based on Stakeholders' Scores

Table 7.5 Cost and Benefit Scores Stakeholders Assigned to the Various Statements/ Criteria Representing Traditional Farming System

components	Indicators	Measurement criteria	Stakeholders' scores for cost components				
			Foresters	Ext. agents	Env. NGOs	Researchers	Farmers
Social costs	Human health	Injury from manual work	92	72	72	87	82
		Burns from fire	90	76	84	90	90
		Risk of fire outbreak	97	76	84	90	62
Economic costs	Labour	Farm labour hired	90	84	88	93	78
		Frequency of hired labour	87	80	88	87	80
	Crops	Delayed maturity of crops	63	48	64	60	88
		Low survival of crops	50	68	60	83	84
Environmental costs	Fire	Soil burns	97	92	88	90	46
		Forest burns	97	88	96	97	30
		Animal death through fire	97	92	88	90	72
		Fire outbreak into other farms	97	88	96	97	52
		Air pollution from fire	97	88	92	100	68
	Forest	Fragmentation	83	80	88	80	96
			Stakeholders' scores for benefit components				
			Foresters	Ext. agents	Env. NGOs	Researchers	Farmers
Social benefits	Food health	Nutrition from organic food	97	92	84	83	100
		Low infection	97	92	84	83	100
	Societal acceptance	Society accepts organic farming	83	84	72	77	78
		Food security	93	84	84	83	74
Economic benefits	Output	Improved yield and income	97	88	88	87	76
		Long shelf life for organics	97	70	60	80	50
Environmental benefits	Soil	Conservation	87	76	72	80	84
		Fertility	87	84	72	80	86
	Less pollution	Less water and land pollution	87	88	60	67	80

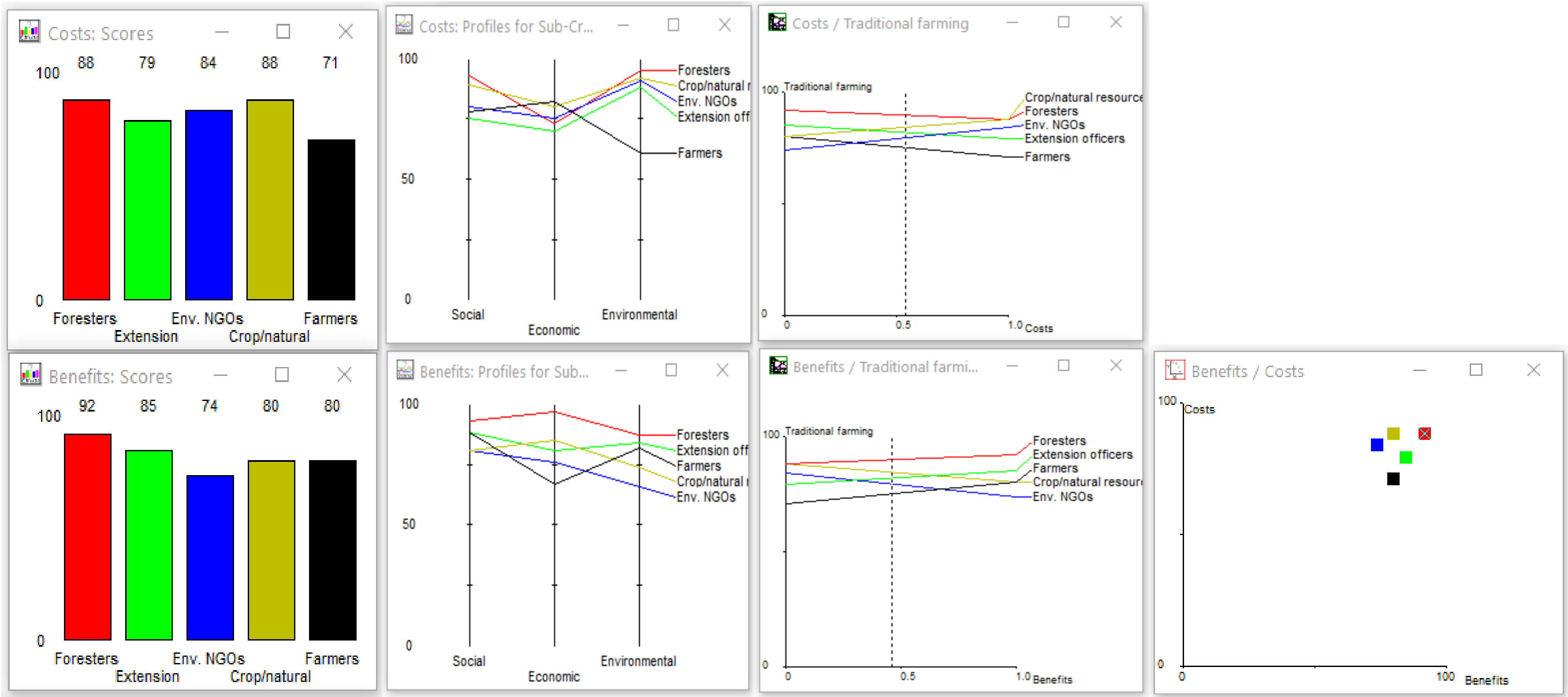


Figure 7.7 Stakeholders' Scores for Costs and Benefits of Traditional Farming System.

Left panel presents the overall average cost and benefit scores from each stakeholder group. Middle panel presents the sum of the scores for social, economic, and environmental costs and benefits. Right panel presents stakeholder sensitivity levels. Bottom graph presents stakeholders' cost-benefit ratio.

7.4.4 Improving Agriculture within Forest Landscapes

To examine the nature of the alternative traditional and mixed farming systems in terms of costs and benefits and, ultimately, sustainability, we applied weights to respondents' original statements. Weights sought to capture the importance the stakeholders afford to each of the statements and their suggestions towards sustainability based on the stakeholders' interest. Regarding the mixed farming system, our MCA model with weighted factors exhibited overall benefits that far exceeded costs, at a ratio of 5:1. This ratio in turn far exceeded the benefit-to-cost ratios for the modern and traditional farm systems described by unweighted factors above, being negative (ratios 0.84-0.92:1). In general, reducing the use of inorganic inputs and promoting the use of manure, improved seeds, and crop rotation will enhance mixed-input farming system whilst minimizing the environmental impacts of high inorganic input application rates (Figure 7.8). The economic benefits to the farmer will outweigh all costs and benefit components. While some damage to the forest environment will inevitably occur due to improved mixed-input farming, as perceived by the stakeholders (Figure 7.9), its magnitude would be less than that entailed by the modern and mixed-input farming systems, given their more extensive use of inorganic inputs.

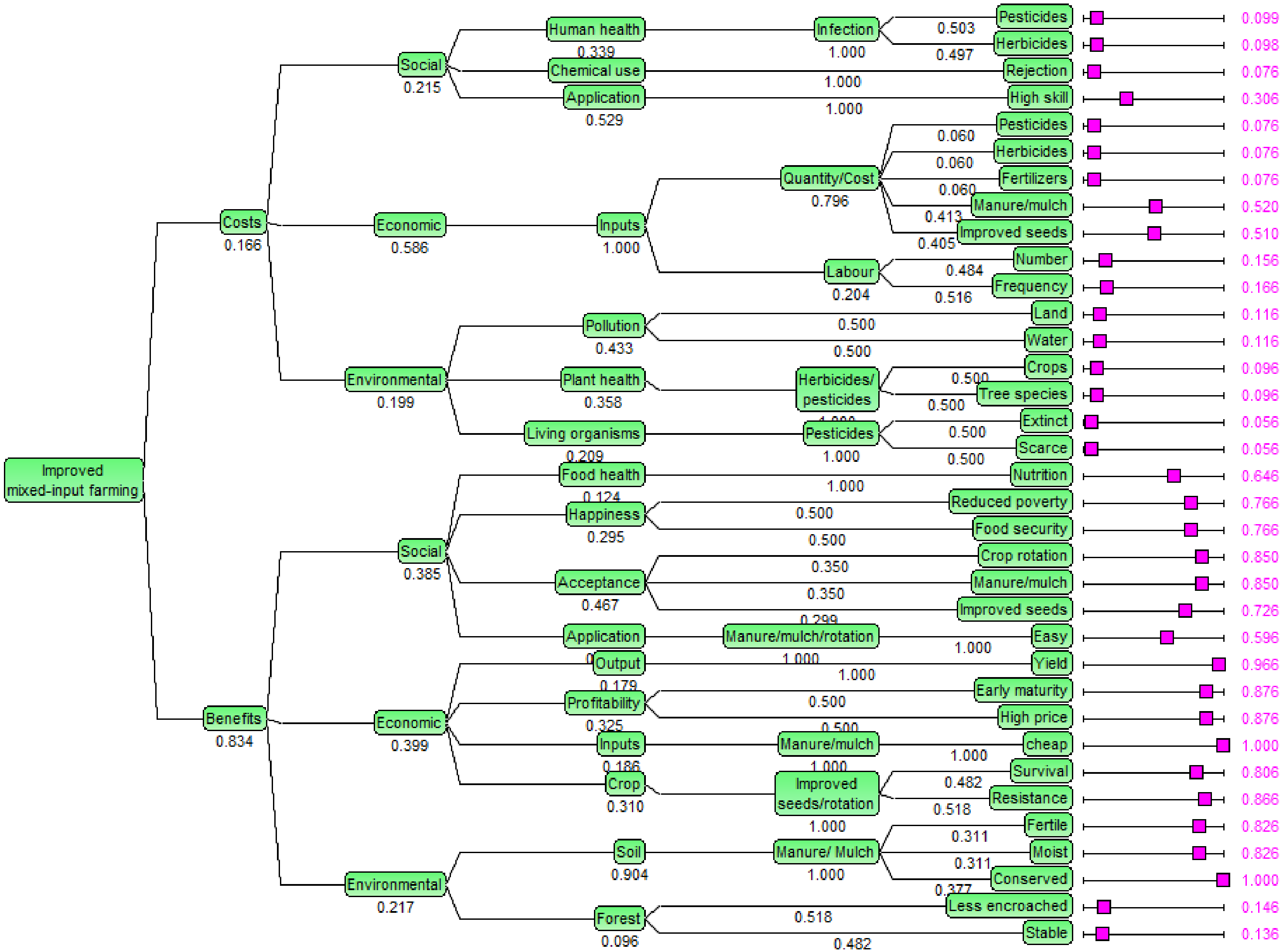


Figure 7.8 Costs and Benefits of Improved Mixed-Input Farming System Based on Weighted Stakeholders' Scores

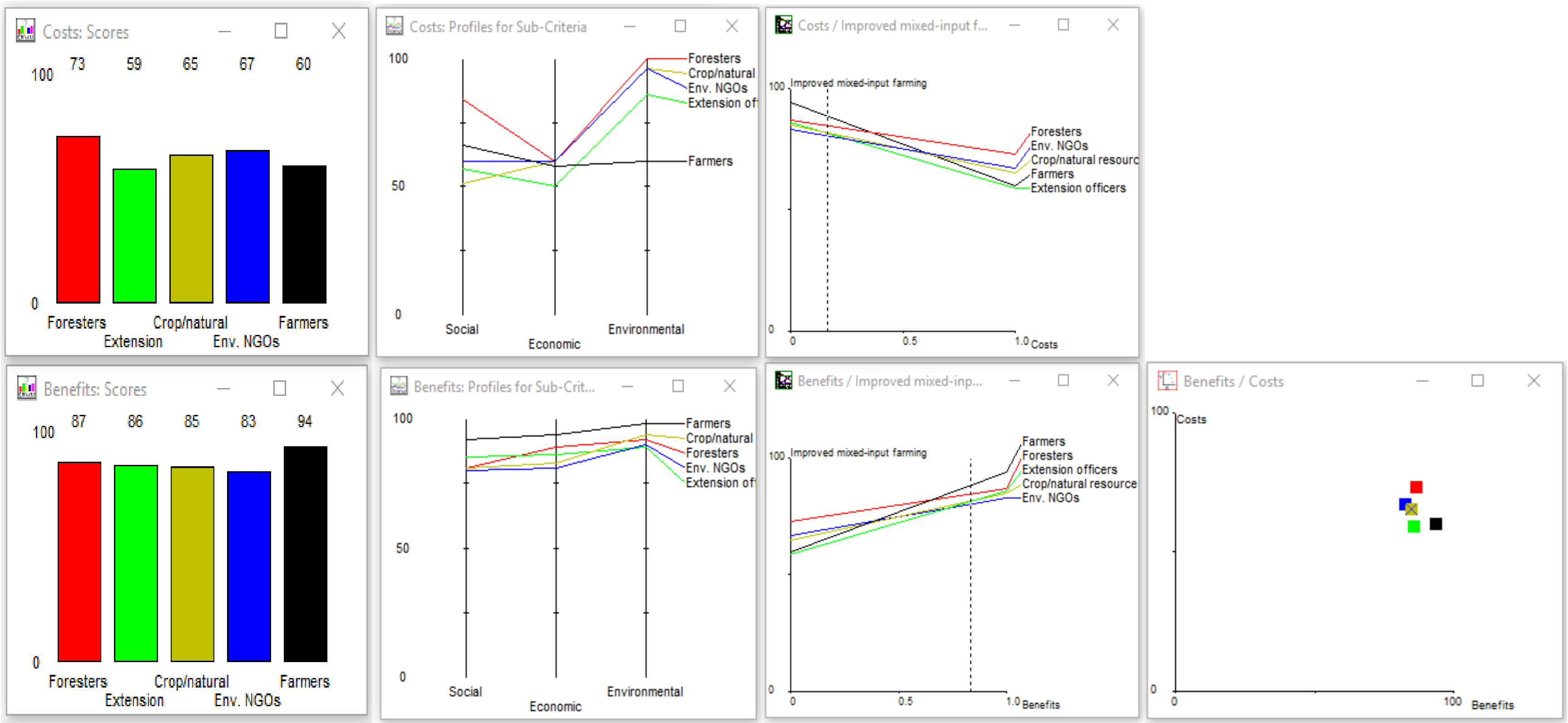


Figure 7.9 Stakeholders' Scores for Costs and Benefits of Improved Mixed-Input Farming System.

Left panel presents the overall average cost and benefit scores from each stakeholder group. Middle panel presents the sum of the scores for social, economic, and environmental costs and benefits. Right panel presents stakeholder sensitivity levels. Bottom graph presents stakeholders' cost-benefit ratio.

Regarding the traditional farming system, the addition of animal manure and mulch and the introduction of crop rotation will improve the system (Figure 7.10). Reduction in the frequency of farm fires will lessen the risk of fire outbreaks which will consequently reduce the environmental impacts and raise the environmental benefits of slash-and-burn agriculture (Figure 7.10). Retention of farm residues and applying manure will conserve, moisturize, and enrich the soil for higher productivity. Traditional farming can therefore be improved organically by poor farmers for increased farm productivity. The environmental consequences resulting from traditional farming, according to the stakeholders, may not reduce significantly (Figure 7.11). Nevertheless, the livelihoods of the farmers will improve from improved traditional farming.

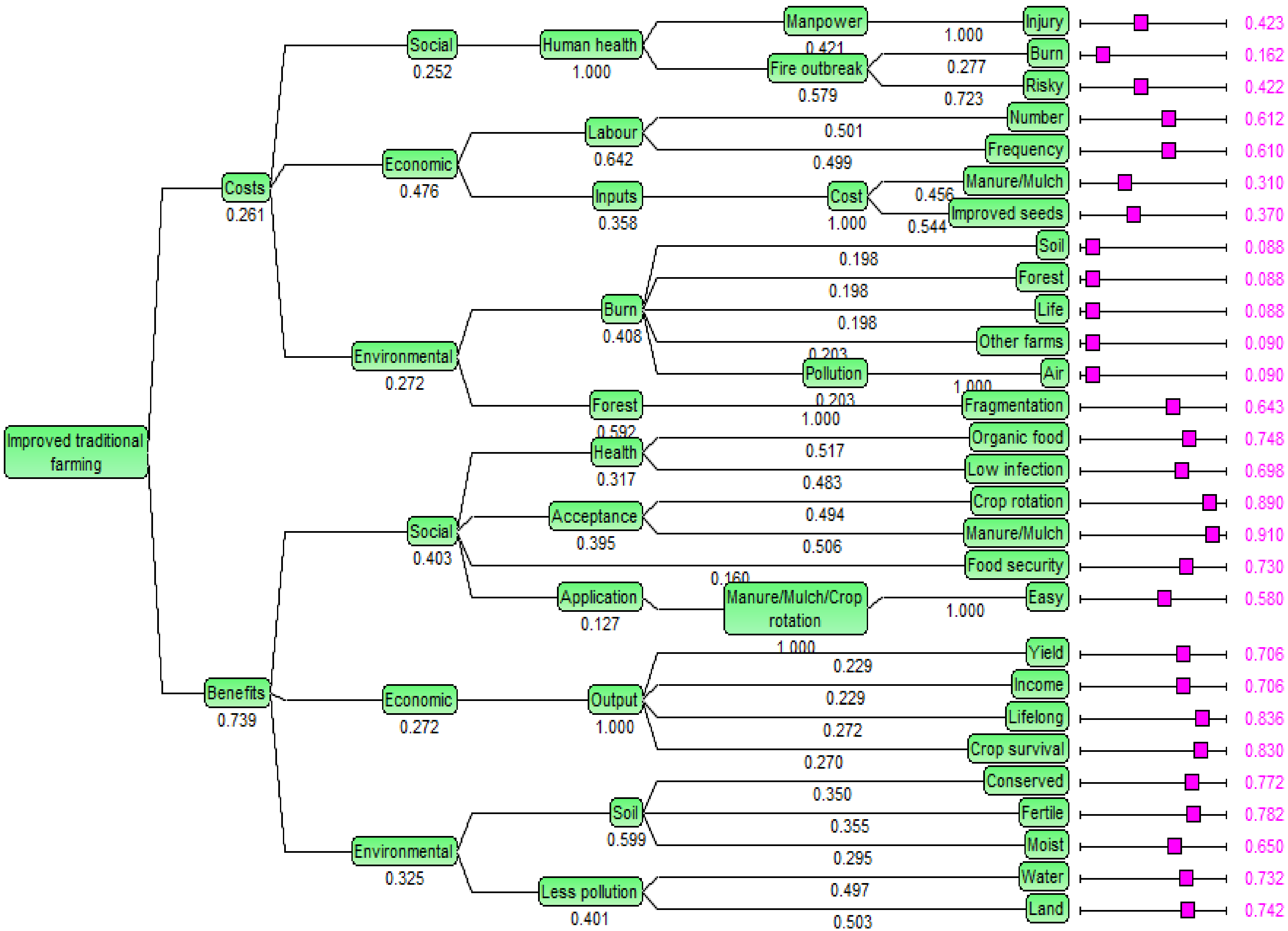


Figure 7.10 Costs and Benefits of Improved Traditional Farming System Based on Stakeholders' Weighted Scores

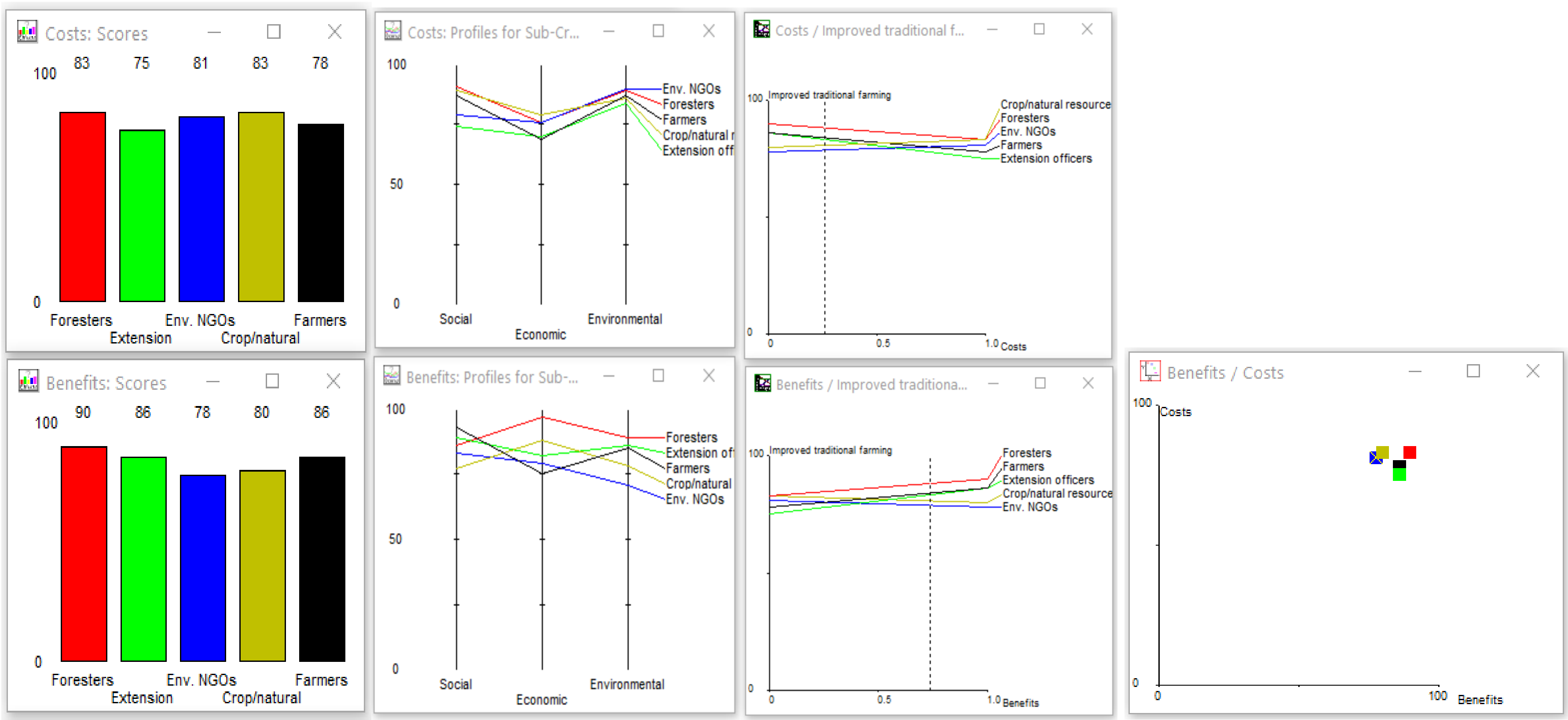


Figure 7.11 Stakeholders' Scores for Costs and Benefits of Improved Traditional Farming System.

Left panel presents the overall average cost and benefit scores from each stakeholder group. Middle panel presents the sum of the scores for social, economic, and environmental costs and benefits. Right panel presents stakeholder sensitivity levels. Bottom graph presents stakeholders' cost-benefit ratio.

7.5 Discussion

Interviews with the key stakeholders of rural resource management regarding the costs and benefits of various farm practices for modern, traditional, and mixed farming systems in Ghana affirmed the general view that chemical fertilizers, herbicides, and pesticides cause more harm than benefit to the farmed environment than do manure, improved seeds, and crop rotations. Sharp discrepancies between stakeholders groups in terms of the attribution of costs and benefits amongst farm practices and systems were apparent, however. Farmers who are able to afford these inputs would not be as willing to abandon their use due to their correspondingly much economic returns, as evidenced by farmers' much greater favour of the economics of the modern over the traditional farming system (Figure 7.2, Figure 7.6) and farmers' much lower appreciation of the costs of modern farming compared to other stakeholders (Figure 7.2). A moderate, and far more sustainable, use of such inorganic inputs is however possible as shown by Jilito and Wedajo (2020) and Pelletier et al. (2020). Complementing organic inputs and practices with moderate inorganic inputs could help elevate both the profitability and sustainability of farming in a conserved forest landscape.

7.5.1 Improving Farm Productivity with Reduced Chemical Contamination in Forest Frontiers

Most farmers in this study rely on inorganic agricultural inputs to improve crop yields. Chemical fertilizers improve farm outputs to meet food demand. However, fertilizers have some negative effects such as soil compaction, salinization, acidification, nutrient imbalance, and change in composition of soil microbiome that could negatively affect the health and productivity of some plants (Huang et al., 2015). Excessive fertilizer use may degrade water and soil quality, and promote the emissions of reactive nitrogen gases harmful to human health. These emissions could increase by 45%-73% if chemical fertilizers are solely relied on to increase production (Pradhan et al., 2015). Our survey revealed that most farmers that use fertilizers also apply herbicides to control weed growth in farms. Manual weeding is tedious and time consuming, and in cases where labourers are not readily available, crop fields are often weeded late, resulting in losses to yields (Rashid et al., 2012). The use of herbicides reduces the amount of time and labour required for hand weeding by up to 90%, improves weed control, and subsequently enhances crop yields (Young et al., 2017).

The negative environmental impacts from herbicides use have raised concerns about the reliance on herbicides for weed control in farms (Norsworthy et al., 2012). The foresters and environmentalists interviewed were concerned about the use of herbicides within and at the fringes of the forests. According to these stakeholders, herbicides affect the health of food crops and kill some tree species that are naturally regenerating. Herbicides have endocrine disruption features that could cause feminization in male frogs and other species (Hayes et al., 2011). Exposure of pregnant women to herbicides could cause increased risks of child birth defects and low birth weight (de Bie et al., 2010). Herbicides do not only affect Ghana's forests and its biodiversity but also the health of the farmers and consumers.

Adopters of fertilizers and herbicides mostly add pesticides to control pests and diseases (Chen et al., 2005; Zadoks, 1996). A third of global crop production is lost to pest infestation and Africa and Asia are the most affected continents (Kabir & Rainis, 2015). However, frequent use of pesticides could contaminate the soil, ground and surface water, and pollute food (Arias-Estévez et al., 2008). Pesticides could also cause health related problems (Athukorala et al., 2012; Kabir & Rainis, 2015), and kill beneficial insects and other living organisms in the forest (Skevas et al., 2013).

Reduced use of chemicals, promotion of organic soil enrichment techniques, and integrated weed and pest management could lessen the effects of chemicals on crops and the environment. Manure introduces more organic carbon to the soil and has neutral pH value, the dominant factor in determining soil microbiome composition (Cai et al., 2017). However, the capacity of manure to increase yield is lower than chemical fertilizers. A combined use of manure with reduced chemical fertilizer application will help reduce the negative impacts of chemical fertilizer overuse and supply the plant nutrients needed to increase crop yields (Ghosh et al., 2004). According to the stakeholders interviewed, manure is cheap and society supports its use. Promoting the use of manure to farmers in forest-fringe communities could reduce farmers' reliance on fertilizers to increase crop yield. Availability of manure in all forest-fringe communities is however uncertain and farmers may have to travel long distances to purchase and/ or collect manure.

An alternative cost-effective farming technique that could increase crop production is legume-crop rotation and intercropping (Fung et al., 2019). Legume-crop intercropping creates competition between the crops for soil nutrients and this triggers the symbiotic rhizobia bacteria in the legume crop to perform biological nitrogen fixation, producing excess nitrogen for other crops to absorb (Foyer et al., 2016). Fung et al. (2019) observed that maize-soybean intercropping system saves 42% of fertilizer application, cuts NH_3 emissions by 45%, and produces the same quantities of maize and additional quantities of soybean when compared to maize monoculture. This system thus improves both fertilizer and land use efficiencies.

Rotating legumes with cereals achieves high grain yield and improves soil fertility resulting in increased production. Dalal et al. (2018) demonstrated that net returns of wheat in wheat-legume rotation more than doubles when compared with non-legume-wheat rotated fields. Smith et al. (2016) found in Malawi that legume-maize rotation produces maize yields that are higher than continuous maize cropping. Two-thirds of the farmers in the study area grow maize as their main crop and some rely on fertilizers to increase yield (Acheampong et al., 2021). The practice of legume-maize rotation could be of more benefit to the farmers economically and food wise. It will however be challenging for farmers with little or no knowledge of legume-maize rotation and intercropping. Farmer education through agricultural extension services will help eliminate this challenge.

Traditional farmers can also improve their farming operations by practicing crop rotation and complementing slash-and-burn with manure usage. Application of manure will improve the fertility of the soil for increased crop yield and output with its multiplier effect of increased income and food security (Figure 7.10). This improved traditional farming may not have significant effect on forest encroachment as farmers may still clear patches of fragmented forest for subsistence farming. However, the economic status of the farmers may improve through sales resulting from the improved farming system. There may be increased food stability since the improved farming system will lead to increased harvests. Soil moisture, fertility and conservation will improve cyclically using manure, crop residue retention, and legume-crop rotation.

7.5.2 Implications for Conservation

Multi-criteria analysis models are used in varied ways (Alencar & Almeida, 2010; Convertino et al., 2013; Hongoh et al., 2011; Linares & Romero, 2000). Using MCA to suggest recommendations for improved agricultural production and sustainable forest conservation is however rare. The models developed here as a result of expert opinions demonstrate that sustainable agriculture within forest reserves, while not compromising forest conservation, is possible. We have demonstrated that MCA can be used as a researcher-stakeholder engagement tool to resolve conflicting issues and allow for trade-offs in situations where complex set of criterion must be considered holistically.

The use of MCA in this research has demonstrated that opinions about agricultural and forest sustainability vary amongst experts. Our models have demonstrated through stakeholders' opinions that inorganic inputs for agricultural production are not necessarily detrimental to forest landscapes unless they are overused. It is presumed that moderate use of inorganic inputs together with organic inputs will improve yields just as modern farming but will also spare the forest environment from damages that could result from excessive use of chemical inputs. Our improved traditional farming model portrays that zero chemical use is possible although not demonstrated, and farmers will still be able to sustain their agricultural production without necessarily expanding farms into forest frontiers. Addition of manure to farmlands, retention of crop residue, and the practice of crop rotation will improve the fertility of the soil for increased agricultural production thereby preventing the adjoining forests from encroachment. This is possible when agricultural education on the above strategies is rolled out to farmers together with effective forest protection strategies.

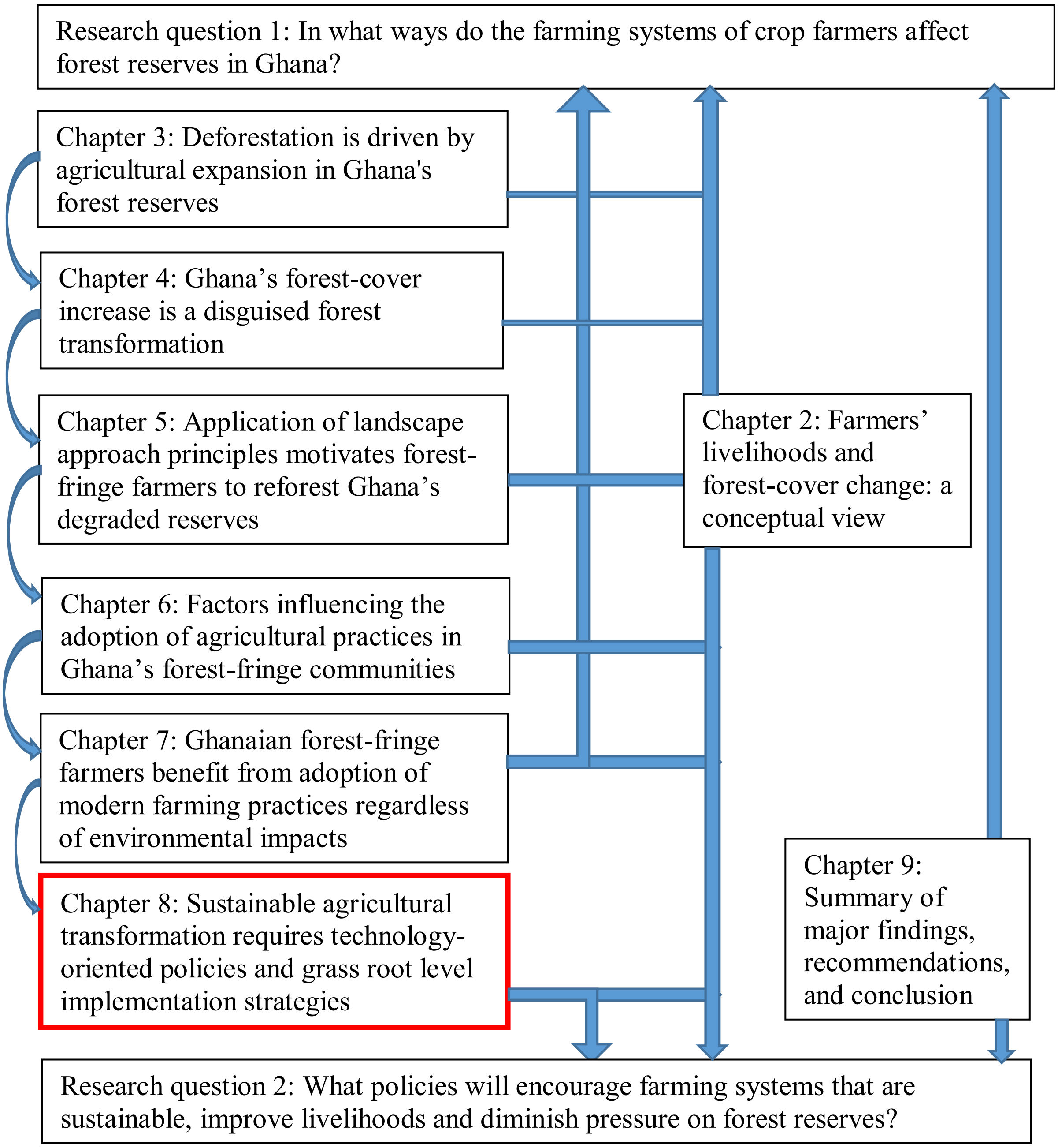
7.6 Conclusion

Agricultural inputs are essential for efficient and effective farming operations. Chemical inputs however have some negative effects on people and the environment. Of critical concern is the application of inputs such as pesticides, herbicides, and fertilizers at forest frontiers. Our study communities are at the fringes of forest reserves and some of the farmers apply chemical inputs on their farms. We identified through stakeholder consultation that the negative effects of chemical inputs outweigh the benefits. While all the stakeholders except the farmers are concerned about the negative impacts of modern farming on the environment, the farmers are motivated by the economic returns they get from investing in such farming system. Mixed-input farmers combine chemical inputs with organic practices such as animal manure and crop rotation. However, this does not make a significant difference since the addition of the organic inputs does not prevent the farmers' perceived need of using the chemicals. Traditional farmers do not use any inputs to enhance their farming. They rely solely on slash-and-burn, a system that results in low crop yield and threatens adjoining forests due to fire outbreaks.

The negative environmental impacts of modern and mixed-input farming could be minimized by reducing the use of chemicals and adopting more organic practices in farming. Applying animal manure is less expensive but effective alternative for chemical fertilizers. Legume-crop rotation and/or intercropping and retention of crop residue on the land supply additional nutrients and moisturize the soil for improved yield. Although the effects of organic inputs on production may be lower than the application of chemical inputs, organic inputs are safe to human health and the forest environment. Addition of organic inputs to traditional farming will improve crop yields and increase production. This alone may not have significant effect on forest encroachment by farmers but it will increase farmers' income through the sales of surplus produce and improve the food security of the farmers' households.

What Next?

The findings from chapter seven indicated the moderate use of high-yielding agricultural inputs not only profits the farmers but also helps minimize farmers' encroachment of forests to increase production. Chapter six and seven also stressed that technology uptake is contingent upon effective promotion and education through agricultural extension services. The government of Ghana has been working towards agricultural modernization since 1997. Chapter eight reviews the performance of the various policies towards agricultural modernization with focus on how crop farming is progressing sustainably.



Chapter Eight: Sustainable Agricultural Transformation Requires Technology-Oriented Policies and Grass-Root Level Implementation Strategies

Abstract

Agriculture is prioritised as the engine for Ghana's economic growth. However, expanding farm size has been the main factor increasing crop production despite the implementation of several agricultural development policies for decades. We reviewed Ghana's development policies since 1997 to assess agriculture development progress and shortfalls. Five medium-term policies have been implemented since 1996 towards achieving Ghana Vision 2020 – a 25-year long-term development policy. These policies envisage several interventions for agricultural development one of which is to increase output through yields improvements. Our review however indicates that the outputs, yields improvements, and extent of land expansion of 16 major crops cultivated from 1997 to 2017 showed mixed results for the five policy regimes. These policies are Ghana Vision 2020: The First Step (1996-2000); Ghana Poverty Reduction Strategy (GPRS I: 2003-2005); Growth and Poverty Reduction Strategy (GPRS II: 2006-2009); and Ghana Shared Growth and Development Agenda (GSGDA I: 2010-2013 and GSGDA II: 2014-2017). Output increment has generally been a result of land expansion rather than yield improvement for most crops. The expected transformation of the agricultural sector has not been realized due to low adoption of improved technologies, seeds and planting materials, inadequate access to agricultural finance and extension services, and inefficient sector governance. Improvements in agriculture are possible through investments that improve productivity and enhance access to markets, flexible agricultural credits, and improved technologies, backed by strong governance. Effective implementation of and investment in targeted interventions are crucial for increased production through yield improvement rather than farmland expansion, a major cause of deforestation and forest degradation in Ghana.

Keywords: Agricultural development; policy interventions; yield improvement; land expansion; improved technology adoption; Ghana.

8.1 Introduction

Although there are claims of an expanding non-farm employment in rural Ghana (Ellis, 2010; Ghana Statistical Service, 2012; Hilson & Garforth, 2013), agriculture is still the main occupation for over 70% of the rural labour force. Agriculture-related activities also offer jobs to 42% of Ghana’s working population (Ghana Statistical Service, 2012). The agriculture sector has been maintaining its role and is making major contributions to the country's Gross Domestic Product (GDP), employment, food security, and foreign exchange earnings since independence in 1957 (MoFA, 2010). A simulation study indicates that agriculture sector-led growth strategies have been more effective at reducing poverty particularly in farming communities in Ghana due to strong income-consumption linkages (Benin et al., 2008). However, agricultural practices in some parts of Ghana do not include innovations capable of reducing poverty or enhancing agricultural development (Agula et al., 2018; Aidoo & Fromm, 2015; Danquah et al., 2019; Onyeiwu et al., 2011). Expanding farm sizes at the detriment of forest cover has been the main factor leading to increased crop production despite the implementation of several agricultural development policies (Acheampong et al., 2019; Acheampong et al., 2018; Rhebergen et al., 2018; Shoyama et al., 2018). We examine Ghana’s development policies since 1997 to assess agriculture development progress and future state of farming in Ghana.

Ghana has had one long-term development policy since 1992 – the Ghana Vision 2020. It was a 25-year policy (1996-2020) articulating the various aims for Ghana's socio-economic development (NDPC, 1997). The goal of this policy was to decrease poverty, increase job avenues and average incomes, and decrease inequities to advance the overall wellbeing of all Ghanaians. Agricultural development was critical to the achievement of Ghana Vision 2020. Five medium-term development policies have been implemented since 1996 to lead towards achieving the Ghana Vision 2020. These policies are, Ghana Vision 2020: The First Step (1996-2000); Ghana Poverty Reduction Strategy (GPRS I: 2003-2005); Growth and Poverty Reduction Strategy (GPRS II: 2006-2009); and Ghana Shared Growth and Development Agenda (GSGDA I: 2010-2013 and GSGDA II: 2014-2017) (NDPC, 1997, 2003, 2005, 2010, 2014). The current policy, Investing for Food and Jobs: An Agenda for Transforming Ghana’s Agriculture (IFJ: 2018-2021), is in progress (MoFA, 2018). The overarching aim of these policies was to make Ghana a middle income country by 2020 and raise the living standards of the people through the various strategies of the policies aligned with Ghana Vision 2020 (NDPC, 1997).

The role of agriculture in Ghana’s socio-economic development has led to sector policies such as the Food and Agriculture Sector Development Policy (FASDEP I and

II) and the Medium-Term Agriculture Sector Investment Plan (METASIP) (MoFA, 2007, 2010). These sector policies and plan were prepared to guide the implementation of agricultural development strategies in medium-term plans. Ghana's agriculture sector is divided into crops and livestock, forestry and logging, and fisheries subsectors. The crops subsector contributes almost half of the sector's GDP, followed by forestry and logging. Assessment of the historical states of crop farming in Ghana will provide insight into the effectiveness of Ghana's policies in achieving agricultural development. We examine the growth and development of Ghana's agriculture sector since 1997 to identify the current state and future positions of crop farming in Ghana.

8.2 Materials and Methods

We reviewed the aforementioned development policies of Ghana spanning 1997 to 2017. We focused on the sections of the policies related to agriculture sector development. Ghana's agriculture sector is categorized into three subsectors. The crops and livestock subsector was our focus. Due to our interest in crop farming and agricultural land cover change, we limited our review to issues relating to only the crops subsector.

We identified the agricultural development issues, policy objectives, and interventions or strategies put in place to address the issues in each policy document. The introduction of a new policy starts with performance review of the previous policy. We reviewed the information provided in the performance review section of each policy document to assess the performance of the crops subsector at the end of each policy period. The variables for performance assessment are the interventions or policy strategies outlined in each policy document (Table 8.1). The Ministry of Food and Agriculture (MoFA) publishes annual reports on Ghana's agricultural performances. We complemented the performance assessment data from each policy document with the published information from the MoFA.

The Ghana Vision 2020 that served as the foundation for all the subsequent policies had one of its focus on agricultural transformation in a sustainable manner. This was to be achieved through improved technology and accessibility to productive farm inputs including improved seeds, soil nutrients, and farm management without necessarily expanding farms to increase production. We therefore selected 16 major crops grown in Ghana to examine the trend in production increase, yield improvement, and land expansion for each policy period to assess the extent of success towards the agricultural transformation agenda. The 16 crops selected were cereals (maize, rice, millet, sorghum), roots, tubers, and suckers (cassava, yam, plantain, cocoyam), vegetables (tomato, onion, eggplant, groundnut), and tree crops (cocoa, oil palm, cashew, orange). Data on production, yield, and cultivated land for each crop from 1997 to 2017 were obtained from Ghana's Ministry of Food and Agriculture (MoFA), the Food and Agriculture Organization of the United Nations (FAO), and the World Bank. The MoFA is the primary source of Ghana's agricultural data for FAO and the World Bank. We relied on FAO and World Bank data only for the years where MoFA data was not publicly available.

Table 8.1 Agriculture Sector Policy Issues, Objectives, and Strategies Related to the Crops Subsector, 1996-2017

	1996-2000	2003-2005	2006-2009	2010-2013	2014-2017
Development issues	Low production and technology adoption; low adoption of inputs and improved planting materials; poor farming practices; poor storage and road infrastructure	Limited access to products market; low adoption of agricultural inputs and technology, improved seeds and planting materials; limited access to extension services; reliance on rain-fed agriculture	Low soil fertility and crops yield; overreliance on rainfall; inadequate access to land; high incidence of pest and diseases and post-harvest losses; limited value addition and access to markets due to poor road conditions; lack of access to finance for small-scale farmers; unsustainable agriculture management practices	Low level of agricultural mechanization, technology adoption, and income; inadequate post-production infrastructure; weak linkages to industry and the services sector; lack of competition in production, processing and distribution	Low crops yield; high post-harvest losses; poor agriculture value chain management; low agriculture mechanization; limited access to extension services; dominance of smallholder farms and over-aged farmers; inadequate access to finance; overreliance on rainfall
Policy objectives	adopt improved technologies to increase crop production; ensure sustainable exploitation of land-based natural resources	Modernize agriculture; increase agricultural production through infrastructure, market and extension service provision	Accelerate growth through modernized agriculture led by a vibrant and competitive private sector; ensure sustainable increase in agricultural production to support industry and provide stable income for farmers	Accelerate agriculture modernization and ensure effective linkage between agriculture and industry; improve agricultural productivity; promote selected crop development for food security, export and industry	Accelerate agricultural transformation; promote the use of research and technology in agriculture; promote efficient land use and management systems
Policy strategies	Strengthen extension services provision; assist farmers to practice agro-forestry; improve agricultural infrastructure – roads, storage and market facilities	Improve access to farming inputs, develop market channels for agricultural produce; increase access to research and extension services; encourage the production of cash crops such as cashew; and ensure sustainable use of productive resources	Reform land administration; develop and multiply new and improved seeds and planting materials of selected crops; enhance access to credit and inputs for agriculture; promote soil fertility management systems; promote an integrated pest and disease management system; promote environmentally sustainable cropping practices; promote processing, preservation and utilization of crops; intensify research-extension-farmer linkages; improve rural road networks	Develop human capacity in agricultural machinery management, operation and maintenance; improve access to affordable credit to farmers; strengthen the research extension-farmer linkages; develop and adopt resilient and high-yielding crop varieties; support the production of certified seeds and improved planting materials; intensify the use of pluralistic extension methods	Adopt high yielding planting materials and improved seeds; use pests and weed control chemicals and improved spraying technologies; ensure improved extension services and institutional coordination for agriculture development; apply appropriate agriculture intensification techniques to reduce forest land clearance

Sources: (NDPC, 1997, 2003, 2005, 2010, 2014)

8.3 Agriculture Sector Development Policies and Implementation Successes, 1997-2017

In 1995, Ghana's 25-year long-term policy – Ghana Vision 2020 (1996-2020) – aimed at making Ghana a middle income country by 2020 was launched. This policy came with the first medium-term policy (Ghana Vision 2020 – The First Step: 1996-2000). One major aim of the medium-term policy, also known as the Coordinated Programme of Economic and Social Development Policies (CPESDP), was to ensure that by the year 2000, agricultural modernization would have led to increased productivity to achieve and maintain food security. Sustainable agricultural production, explained as the application of science and technology in production in ways that do not cause pollution or any other form of environmental degradation, was one of the pathways for the 5-year policy. Various objectives and strategies were set to ensure economic growth through technological innovations and sustainable use of natural resources (Table 8.1).

The subsequent policies, namely, GPRS I (2003-2005), GPRS II (2006-2009), and GSGDA I and II (2010-2017) followed with objectives and strategies similar to that of the first policy. A critical assessment of these policies indicated that they all had the overarching objective of rural development based on modernized agriculture. The reason was that, according to the policies' performance reviews, smallholders with average farm sizes less than one hectare with less adoption of agricultural inputs contributed about three-quarter to the total agricultural production. Similarly, the strategies implemented to achieve the objectives for each policy were similar throughout the policies. Notable among the strategies were a) improve access to extension services, agricultural credits, and inputs, and b) develop and promote the adoption of improved varieties of seeds and planting materials. These policy strategies were implemented to curtail agricultural development issues that were evident in all the policies. These were low crops yield, high post-harvest losses, low level of agricultural mechanization and technology adoption, limited access to extension services, and inadequate access to finance and inputs.

The implementation of the agricultural development strategies led to some successes over the 20-year period. For instance, agricultural extension officer-to-farmer ratio improved from 1:2500 in 1997 to 1:1500 as at 2017 although falling short of the 2017 target of 1:1200. The use of agricultural inputs such as fertilizers improved from below 5 kg/ha to 10 kg/ha between 1997 and 2017 (MoFA, 2018). The outputs of various crops had mixed results and those that increased were largely due to farm expansion rather than yield improvement. Despite the successes recorded during the implementation of the various strategies, the targeted agricultural development were not fully achieved. None of the policy regimes achieved the growth targets for the agricultural sector (Figure 8.1). The shortfalls were due to poor coordination among sector institutions, misallocation of annual budgets, and lack of political commitment to the implementation of the policies. The growth potentials of the crops subsector were hampered by technological constraints, limited access to agricultural inputs and extension services, and low adoption of improved seeds and planting materials – the same development issues the policies were meant to curtail. Figure 8.1 presents a summary of agriculture's annual growth rate alongside its contribution to the GDP of Ghana.

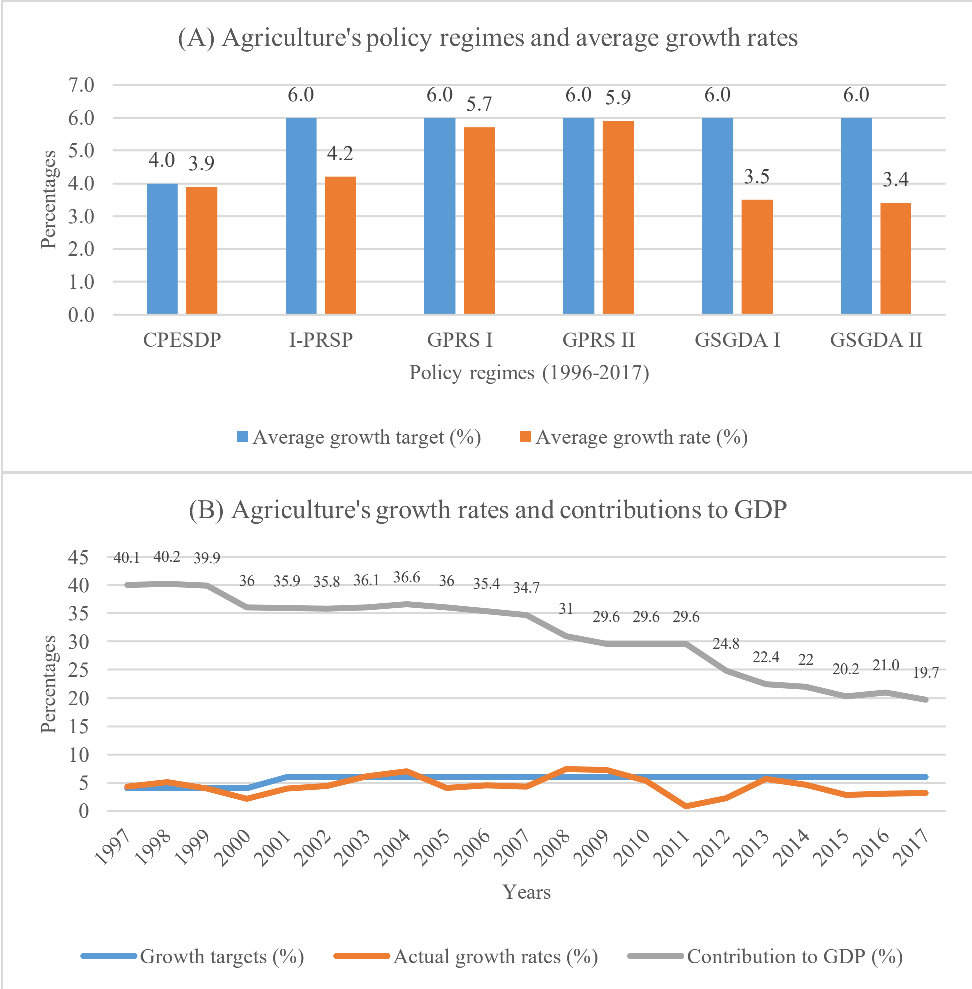


Figure 8.1 Agricultural Sector's Annual GDP Growth and Total Contribution to Ghana's GDP.

Source: (MoFA, 2018; NDPC, 2003, 2005, 2010, 2014)

8.4 Effects of Ghana's Policies on Agricultural Productivity and Land Change, 1997-2017

The 16 major crops selected to assess their outputs, yield improvement, and extent of land expansion from 1997 to 2017 showed mixed results (Table 8.2) (FAOSTAT, 2020; World Bank, 2020). The average outputs for cassava, plantain, maize, eggplant, and onion increased at least twice the percentage of land expansion for the cultivation of the crops from 1997 to 2017. Yields for eggplant and onion more than doubled for the same period while yields of cassava, plantain, and maize improved by 59.4%, 38.2%, and 32.7%, respectively. Cocoa output increased nearly twice (121.7%) the percentage of land expansion while yield improved by 32.9% over the 20-year period. Outputs for oil palm and cashew were almost the same as the extent of land expansion for production. However, the rate of land expansion for cashew and oil palm over the 20-year period warrants concern for yield improvement strategies to ensure that production is not solely dependent on land expansion. Orange was the only tree crop that made significant increase in output even with reduction in cultivated land and this was due to yield improvement of 444.5% from 1996 to 2017. Farmers' interest in the production of millet, sorghum, and cocoyam reduced due to low output levels resulting from poor yields (Table 8.2).

Table 8.2 Extent of Land Expansion. Production Growth, and Yield Improvement of Major Crops Grown in Ghana from 1997-2017

Crop	Land expansion (%)	Production growth (%)	Yield improvement (%)
Maize	50.4	99.6	32.7
Rice	145.5	234.7	36.4
Millet	-13.7	-15.4	-2.0
Sorghum	-30.8	-34.9	-6.0
Cassava	67.7	167.3	59.4
Plantain	60.5	121.8	38.2
Cocoyam	-0.3	-10.6	-10.4
Yam	157.5	245.4	34.1
Cocoa	66.8	121.7	32.9
Oil palm	137.4	150.4	5.5
Cashew	5533.8	5900.0	6.5
Orange	-50.1	171.7	444.5
Eggplant	297.2	744.1	112.5
Groundnut	87.8	168.4	42.9
Onion	130.8	389.5	112.0
Tomato	180.7	102.7	-27.8

Source: FAOSTAT, 2020; World Bank, 2020

Each policy regime experienced different levels of change in land expansion, production growth, and yield improvement of the cultivated crops. During the 1996-2000 policy period, the outputs and yields of maize and millet decreased while land for cultivation for both crops expanded (Figure 8.2). Maize output increased more than land expansion for the rest of the policy regimes with the extent of increase varying in each policy. Millet and sorghum had inconsistent results throughout the policy regimes while rice maintained some consistency – output higher than the average land expansion (Figure 8.2). Yield improvement had mixed results for all the cereals but generally, the rate of improvements were lower than the rate of land expansion for the cereals.

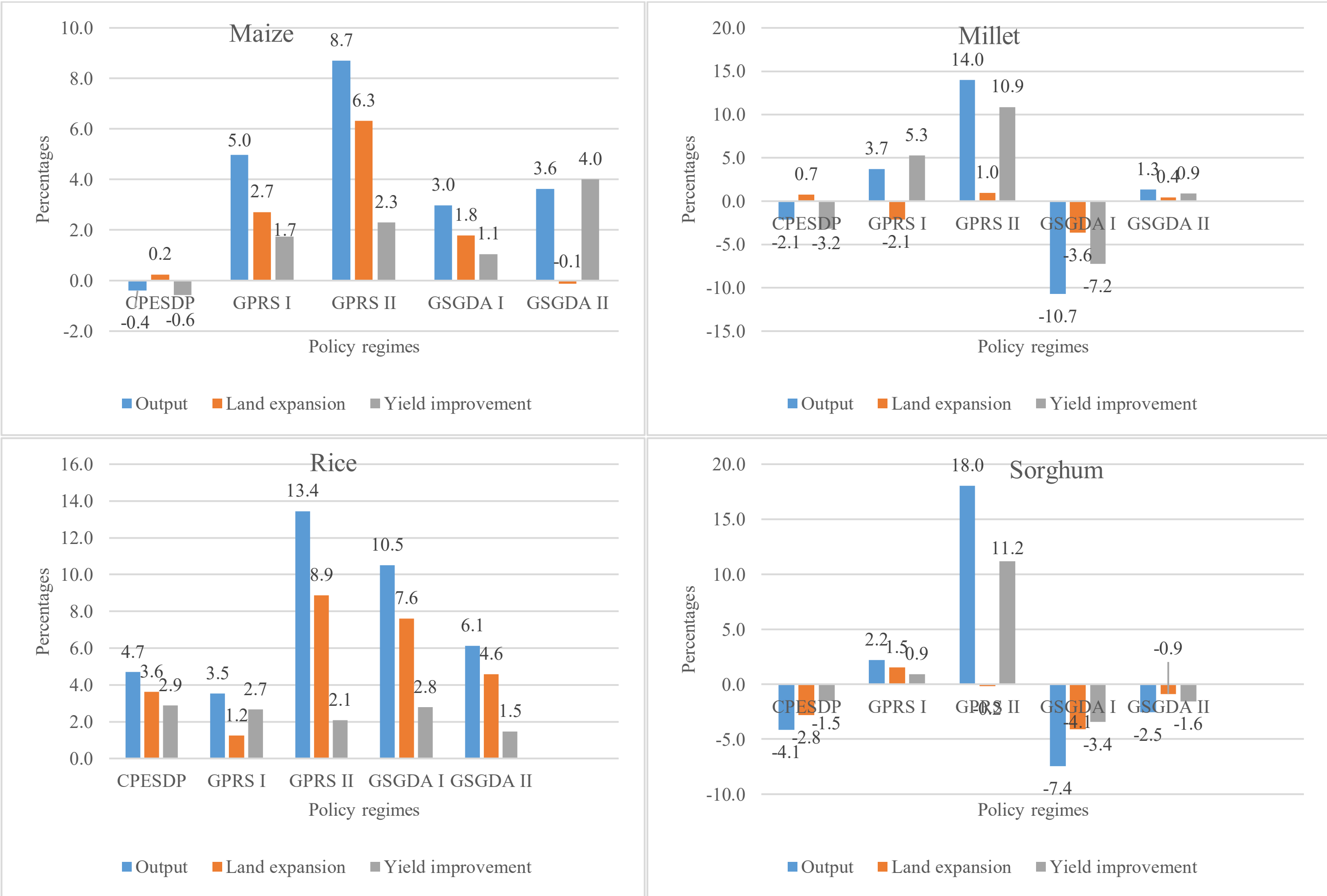


Figure 8.2 Averages of Outputs, Land Expansions, and Yield Improvements of Major Cereals Grown Over the Policy Regimes Spanning from 1996 to 2017.

Source: FAOSTAT, 2020; World Bank, 2020

The patterns of output increment, land expansion, and yield improvement for the vegetables (Figure 8.3), the root and tubers (Figure 8.4), and the tree crops (Figure 8.5) are not different from that of the cereals. The outputs of both the cereals and vegetables increased significantly during GPRS II. This is the period where the effectiveness of yield improvement strategies started becoming evident. The rates at which yields increased for all the vegetables except eggplant were higher than the percentage of land expansion (Figure 8.3). This achievement however did not continue for the rest of the policy regimes.

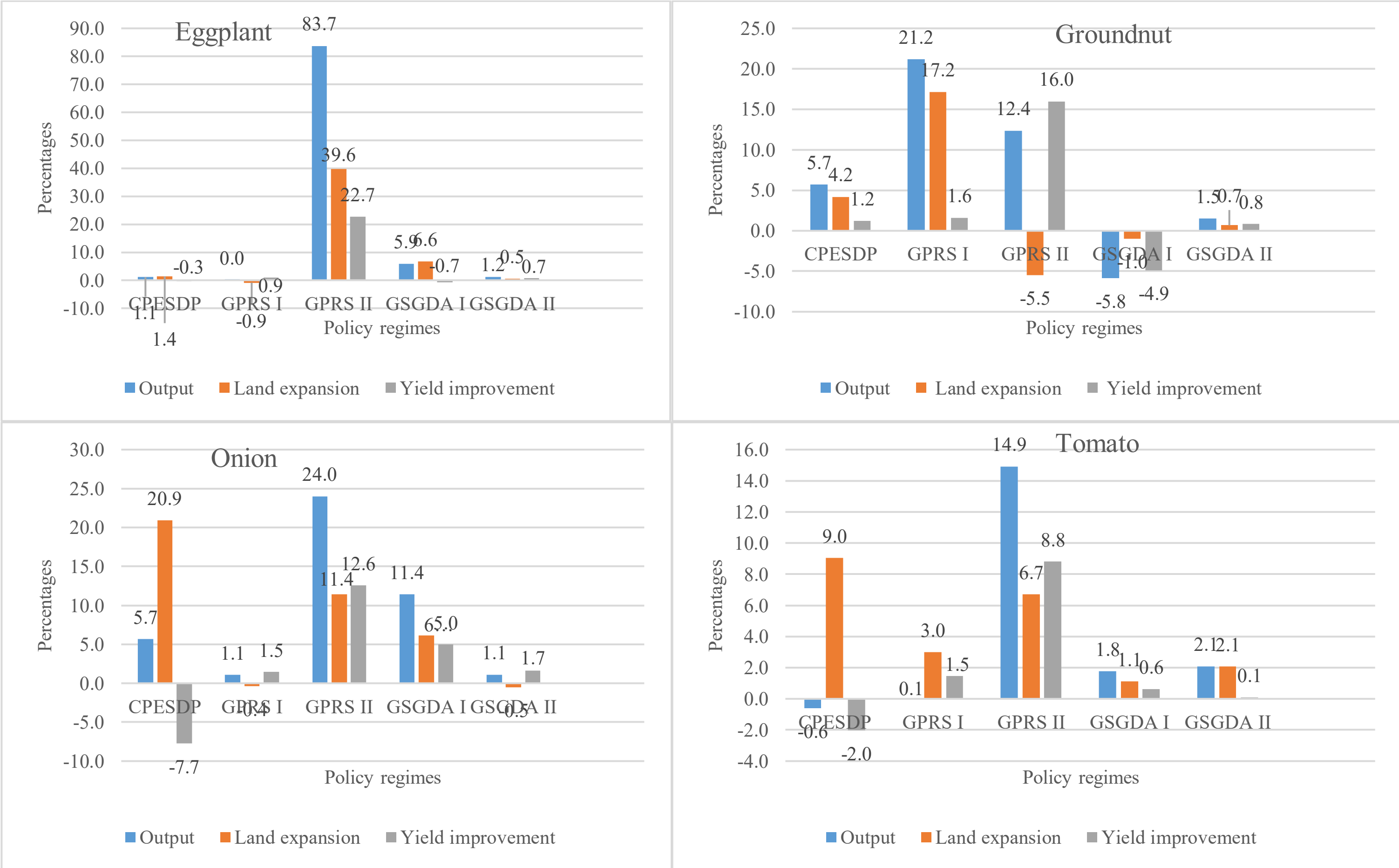


Figure 8.3 Averages of Outputs, Land Expansions, and Yield Improvements of Major Vegetables Grown Over the Policy Regimes Spanning from 1996 to 2017.

Source: FAOSTAT, 2020; World Bank, 2020

Similarly to the vegetables, root and tuber crops experienced significant improvements in yield during the GPRS II. The yields increments of all the tubers except cassava, were higher than the rates of land expansion. Even cocoyam whose outputs and cultivated land decreased had its yield increased during GPRS II (Figure 8.4).

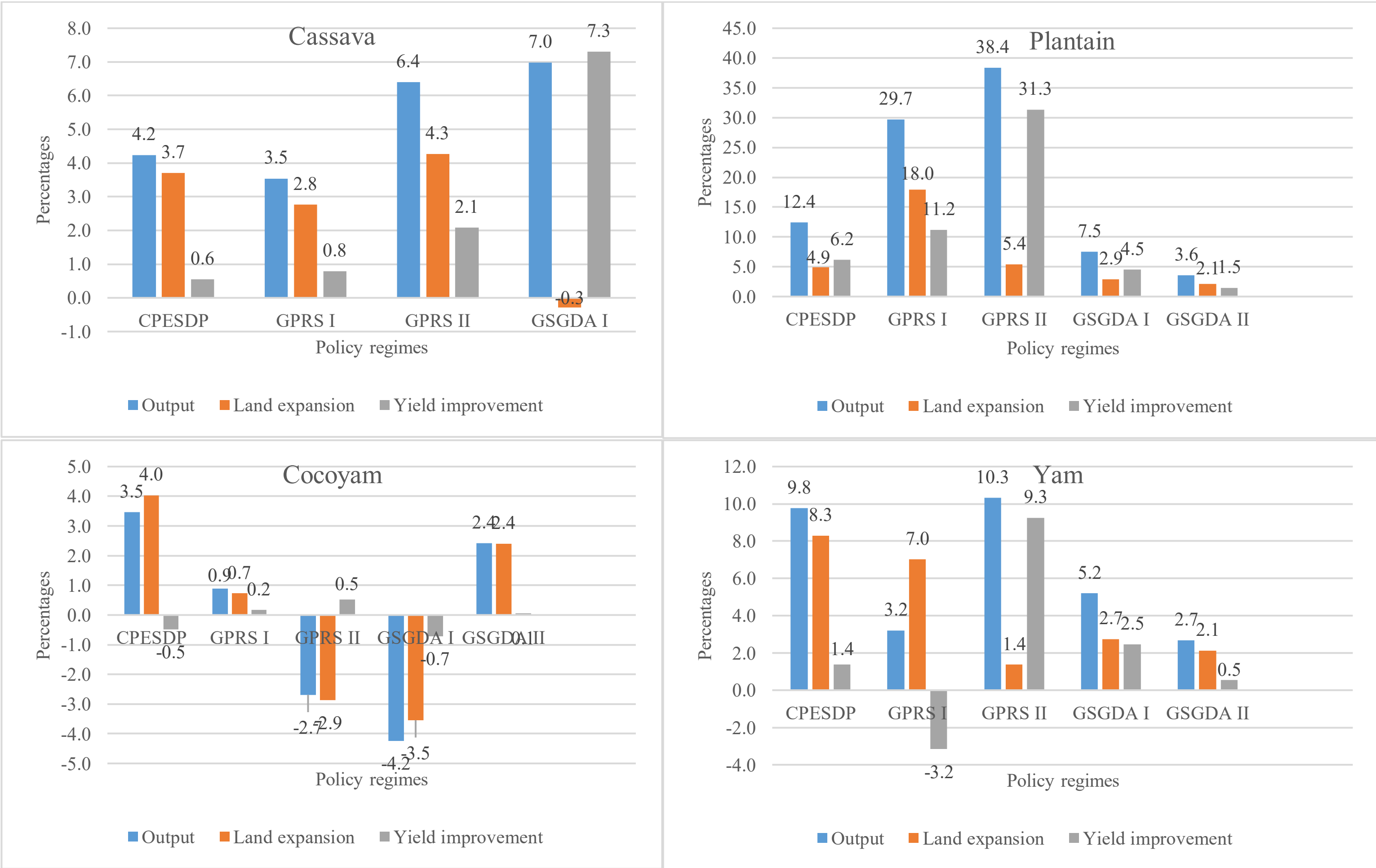


Figure 8.4 Averages of Outputs, Land Expansions, and Yield Improvements of Major Root and Tuber Crops Grown Over the Policy Regimes Spanning from 1996 to 2017.

Source: FAOSTAT, 2020; World Bank, 2020

Tree crops (Figure 8.5) had significant yield improvements for all except cashew. This was because there was no yield improvement strategies for cashew stated in any of the policies. Meanwhile cashew was one target amongst non-traditional export crops whose cultivation was encouraged and promoted from 1997. Cocoa, the major traditional export crop in Ghana, experienced yield improvement for the second, third, and fourth policy regimes, spanning 10 years. Similarly to cocoa, orange also experienced 10 years of significant yield improvement from 2003 to 2013 with extent of cultivated land reducing between 2003 and 2009 while yield continued to improve (Figure 5 lower right). This was attributed to the increasing demand for orange juice processed in Ghana although in competition with other imported ones. These tree crops (cocoa, oil palm, cashew, and orange) as well as others not covered in this review (such as mango, avocado, and other citrus) occupy large expanses of land for their production. Development and adoption of high-yielding planting materials will minimize the extent of land expansion for increased production.

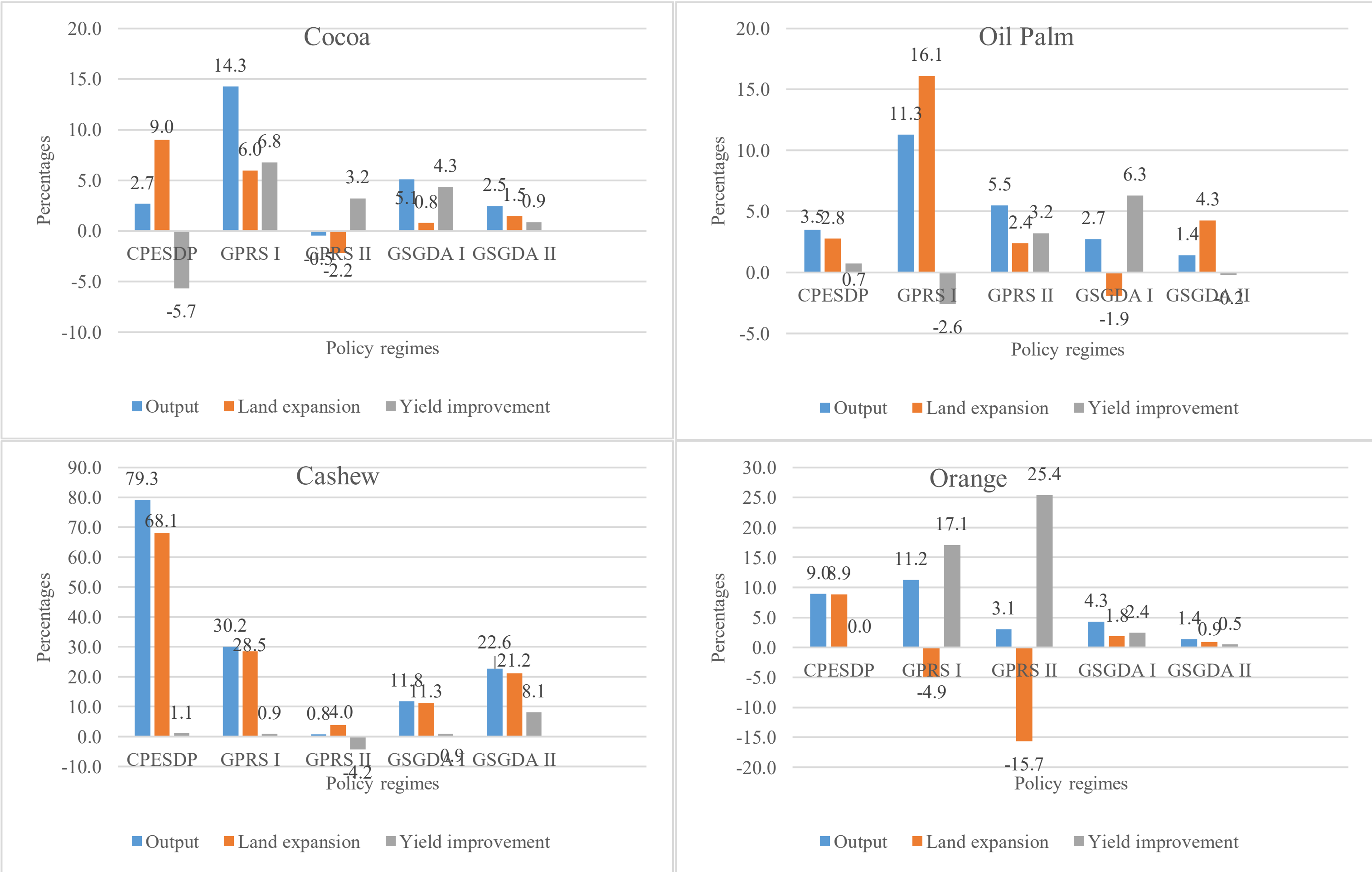


Figure 8.5 Averages of Outputs, Land Expansions, and Yield Improvements of Major Tree Crops Grown Over the Policy Regimes Spanning from 1996 to 2017.

Source: FAOSTAT, 2020; World Bank, 2020

8.5 Ghana's Agricultural Sector is struggling to Achieve Targeted Development Goals

Agriculture has been prioritised as the engine for economic growth in Ghana since 1997 through the implementation of the various medium-term policies. This is because agriculture's contribution to Ghana's economy (40.1% in 1997 to 19.7% in 2017) has been significant although declining due to appreciable industrial (25.6% in 1997 to 30.4% in 2017) and services (31.2% in 1997 to 40.7% in 2017) sectors (FAOSTAT, 2020; World Bank, 2020). This is expected as an economy advances. However, the undulating patterns of agricultural sector growth per annum (Figure 8.1) imply some weaknesses in the implementation of the policies. We identified from our review on the 16 selected crops that increases in production have generally been a resultant of expansions in cultivated lands rather than yield improvements, a phenomenon identified in other studies (Acheampong et al., 2019; Acheampong et al., 2021; Diao & Sarpong, 2011; World Bank, 2007). GPRS I and GPRS II were implemented from 2000 to 2009. These policies had interventions for agricultural development such as: a) increase access to research and extension services; b) develop and multiply new and improved seeds and planting materials; c) enhance access to credit and inputs for agriculture; d) promote soil fertility management systems; and e) promote integrated pest and disease management systems (Table 8.1). These strategies should have resulted in significant increases in outputs through yields improvements. However land expansion caused the majority of the increases in agricultural produce.

Smallholders account for about 80% of Ghana's crop farmers with average land sizes of about one hectare and characterized by low use of improved technology (Diao & Sarpong, 2011; MoFA, 2010; World Bank, 2007). Yields of most crops have been about 60% of achievable yield for decades and this is partly resulting from low soil fertility (Naab et al., 2004; Rhebergen et al., 2020; Scheiterle et al., 2019; van Loon et al., 2019). The average food crop producer is resource-poor. High prices of agricultural inputs contribute to low adoption of the inputs, a phenomenon common in Ghana and sub-Saharan Africa (Acheampong et al., 2021; Nyantakyi-Frimpong & Bezner Kerr, 2015; Ragasa et al., 2018; Robinson & Kolavalli, 2010). Fertilizer use in Ghana was below 5 kg/ha between 1997 and 2002 which is half the rate in sub-Saharan Africa and lower than in other developing countries (FAOSTAT, 2020). Although fertilizer adoption has been increasing since 2002, their costs prevent most farmers from adoption

(Martey et al., 2014; Wiredu et al., 2015). Crop productivity is also determined by the type of seeds and planting materials farmers use. All the policies had strategies for the development of improved seeds and planting materials. Most farmers however continue to reserve some of their produce to be used as planting materials for the next cropping season even when they used improved seeds (Asare et al., 2018; Maredia et al., 2019; Poku et al., 2018; Ragasa et al., 2013; Robinson & Kolavalli, 2010).

Farmers' lack of access to agricultural finance and poor access to extension services have been contributing to the low agricultural productivity (Acheampong et al., 2021). All the agricultural policies had strategies to improve access to agricultural finance and extension services, signifying the importance of these enabling services to production and productivity. However, institutional and structural inefficiencies have resulted in less impact of these strategies on agricultural development. According to Dznaku and Aidam (2013), Agriculture sector's share of government budgetary allocations has been averaging only 2.1% annually from 2000 to 2012. Despite the funds not being enough, it is also skewed towards recurrent expenditure than direct, targeted investments. Benin et al. (2008) argues that agricultural productivity in Ghana is responsive to public investment. With over 70% of government expenditure on agriculture going into recurrent expenditure, access to agricultural financing and investment in innovations would be limited (Djurfeldt et al., 2011). The government of Ghana in 2009 committed to increase public investment in agriculture by at least 10% of the national budget per year to realise the agricultural development required to achieve food security and poverty reduction (ISSER, 2011). This would have achieved significant result had efficient allocation of funds been made to targeted productive areas. Same financial constraints to agricultural development remained to 2017.

8.6 Agricultural Transformation Requires Adequate Resources, Technology Adoption, Market Integration, and Good Governance

Improvement in agriculture is possible through investments that improve productivity and enhance market access. Investments in extension services delivery, continued development and promotion of improved varieties of seeds and planting materials, and enhancing farmers' access to markets and agricultural credit facilities could help improve agricultural productivity. Adequate expenditure towards extension service delivery will resolve inefficiencies related to staffing and resources needed for service delivery. Agricultural scientists will develop the technologies needed for improved production. The promotion and adoption of these technologies is however contingent upon vibrant extension service operations which cannot be achieved without adequate resources.

Farmers' adoption of agricultural technologies such as improved seeds and planting materials and agro-inputs is one step towards increased agricultural transformation. Our review indicated that yield gaps range from 30% to 60% for maize, rice, cowpea, cassava, and yam, and this is partly due to low adoption of improved agricultural inputs (Acheampong et al., 2021; Ghana Statistical Service, 2008). Improving the yields of these and other crops through the use of certified seeds and agro-inputs will not only increase production for domestic consumption but also for exportation. Adoption of improved seeds and innovative technologies is however determined by the financial capacity of the farmers and accessibility of the inputs. Ghana's agricultural sector is dominated by smallholders operating with limited funds. These farmers source funds from formal and informal financial institutions to carry out their operations (Agyemang et al., 2019; Awunyo-Vitor et al., 2014; Dean et al., 2014; Nkegbe, 2018; Sekyi et al., 2017). Funds from the informal sector (e.g. money lenders, traders and rotating credit associations) are mostly short-term and inadequate for significant investments although more accessible than that from formal financial institutions. Financial credits to the agricultural sector from formal financial institutions have been below 10% of their yearly allocations and this has been declining since the year 2000 (Dznaku & Aidam, 2013). Flexible agricultural credits from the government through the MoFA will enhance the capacity of smallholders to intensify their agriculture.

The degree of smallholders' adoption of new technologies for increased productivity for marketable surpluses partly depends on their integration into national, regional, and global markets and the functionality of these inputs and outputs markets. Better market integration ensures price risks are widely spread and farmers are able to escape poverty (Krishna, 2004). The role of public-private partnerships and farmer-based organizations in organizing ready markets for farm produce will motivate smallholders to invest beyond the subsistence level (Francesconi & Wouterse, 2015; Gramzow et al., 2018; Sinyolo & Mudhara, 2018; Sirdey & Lallau, 2020; Trebbin, 2014).

Strong governance is needed to ensure that policy objectives are achieved and proper accountability is rendered for the implementation of targeted agricultural strategies. Government engagement in Ghana is rigorous in identifying agricultural needs and drafting policy documents. Policy implementation is however weak due to responsibilities fragmented across many different agricultural agencies with no clear specific activities to be carried out and by whom (World Bank, 2017). Action plans are prepared for each policy period but activities to be implemented are mostly broad with implementing bodies broadly categorized into agencies and departments. Breaking down broad plans into specific clear activities will help to monitor and track progress of activities geared towards agricultural transformation.

8.7 Conclusion

We reviewed Ghana's five medium-term agricultural development policies from 1997-2017 to identify the various objectives and strategies related to the growth and development of the crop subsector. We found that the same agricultural issues have been identified as requiring attention since 1997. These include low agricultural yield, production and technology adoption, low adoption of inputs and improved planting materials, lack of access to finance for small-scale farmers, limited access to extension services and products markets, and unsustainable farming practices. Also, same intervention strategies have been implemented since 1996 but with mixed successes. Although some crops achieved high productivity through yields improvements for some policy regimes (e.g. GPRS II and GSGDA I), most of the crops achieved high production mainly through land expansions.

The expected transformation of the agricultural sector especially the crops subsector has not been realized due to yield gaps, low adoption of improved technologies, seeds and planting material, inadequate access to agricultural finance and extension services, and inefficient sector governance system. To achieve sustainable farming and transformative agriculture, first, adequate agricultural finance should be accessible to smallholders. Smallholders account for over 70% of the crops subsector. These farmers rely on subsistence agriculture mainly for household consumption due to limited investment capacity. Smallholders are unable to access agricultural finance from formal financial institutions due to their inability to provide collateral security. As a result, these farmers are unable to adopt improved technologies and high-yielding planting materials due to the costs involved.

Government expenditure could include a proportion allocated to financing smallholders through small agricultural loans via the MoFA. These loans could be in the form of direct inputs given to the farmers. The District Agricultural Development Units (DADU) should be the best bodies to handle the agricultural credit arrangements with efficient book keeping system. The farms for the smallholders could be the collateral for the loans. This will enable asset-poor farmers benefit from government funding. Agricultural finance through the government may come with some challenges including logistical and staffing constraints. Effective revamp of logistics and allocation of responsibilities to specific staff will help reduce the challenges that may be associated with government funding to smallholders.

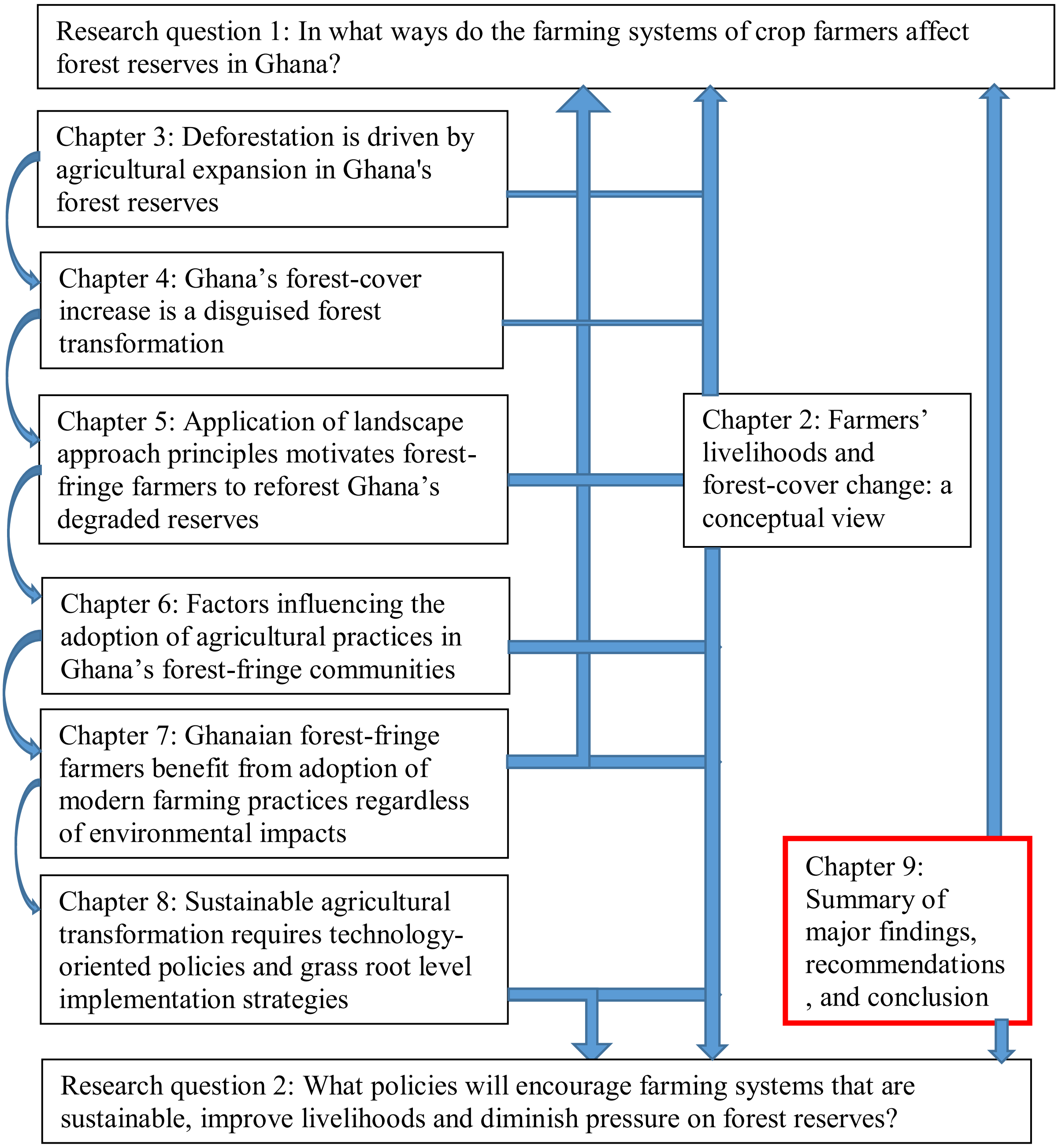
Second, effective and widespread demonstration of new agricultural technologies should be carried out. Government agricultural input loans will not achieve the expected results unless rigorous education and demonstration of the correct application of the agricultural-enhancing inputs are rolled out. A research conducted in the Ashanti region of Ghana found that almost half of 188 adopters of agricultural inputs have no access to extension services (Acheampong et al., 2021). These farmers apply the inputs based on their own knowledge. Lack of education on the use and benefits of agricultural inputs as well as lack of access have caused 103 non-adopters to render agricultural inputs as not useful, difficult to use, and expensive (Acheampong et al., 2021). All the policies reviewed indicated interventions toward improvements in extension services delivery. Implementation of these interventions have not been fully successful due to resource constraints (Asaaga et al., 2020; Birner & Resnick, 2010; Houssou et al., 2019; Poku et al., 2018). As a result, adoption of improved technologies and sustainable farming practices have been low throughout the policy periods. Addressing resource issues of the agricultural sector especially at the local level will make extension services delivery effective which may subsequently lead to technology adoption for transformative agriculture.

Third, there should be continuous development and effective promotion of improved varieties of planting materials. Between 2010 and 2017, about 70% of the targeted improved planting materials were developed including five high-yielding seeds each of maize, millet, and cowpea. However, evaluation of adoption of the improved seeds indicated that only 20% had been adopted as at 2017 partly due to ineffective promotion. Agricultural scientists and seed developers may invest significant amount of time and knowledge into developing high-yielding seeds and planting materials. Without effective promotion through active extension services delivery and the local media, smallholders will continue recycling their planting materials, a phenomenon that leads to gradual decrease in yield and reliance on land expansion for increased production (Asare et al., 2018; Maredia et al., 2019; Poku et al., 2018; Ragasa et al., 2013; Robinson & Kolavalli, 2010).

Finally, the practice of sustainable agriculture with land-sparing objective should be encouraged. While farmers adopt improved technologies for increased productivity, the tendency for maximizing profit by expanding farms beyond arable lands especially at forest frontiers is high. This will likely lead to encroachment of forest and the subsequent degradation of biodiversity. Forest protection strategies will therefore need to be strengthened to prevent this situation from happening.

What Next?

The following final chapter is a summary of the major findings and recommendations from each of the data chapters. This chapter ends with the general conclusion of the thesis.



Chapter Nine: Summary of Major Findings, Recommendations, and Conclusion

9.1 Summary of Major Findings and Recommendations

Chapters one and two framed the conceptual background of the study focusing specifically on the concept of sustainable livelihood (Chambers, 1989; Chambers & Conway, 1992; DFID, 1999; Ellis, 2000) and qualitative change (Macgregor, 2009). The conceptual framework that emanated from the background review informed the subsequent components of the study mainly focusing on factors that influence farmers' livelihood decisions linked to their farming operations and how these decisions affect forest cover, factors that affect farmers' adoption of various agricultural practices and the social, economic, and environmental costs and benefits of those practices, and the determinants of farmers' participation in forest restoration and its effects on farmers' livelihoods and the forest environment. The aforementioned components of the study were executed through desk study, survey, and action research employing both quantitative and qualitative methods of data analyses for presentation and reporting.

Under chapter three, "Deforestation is driven by agricultural expansion in Ghana's forest reserves" the following major findings were revealed.

i. As at 1986, about 80% of Ashanti region's forest reserves remained intact. The 20% disturbed portion was attributed to logging followed by establishment of tree crop estates and annual food crop farms.
ii. By the year 2002, dense forest-cover reduced to 53.3% of the land size of the forest reserves. The residual had been depleted with 78% of the loss caused by expansion of annual food crop farms and tree crop estates.
iii. Between 2002 and 2015, there were some forest-cover gains. However the gains resulted mainly from the maturity of the tree crops that were grown over the years and which had formed dense canopy by 2015. This forest gain is regarded as deforestation in disguise. There were also some forest gains through planned reforestation programs.
iv. Despite the forest-cover gain recorded between 2002 and 2015, the amount of deforestation over the preceding 16 years (1986-2002) had caused a 33.2% net loss of closed dense forest over the 29-year period.

Based on the above findings, the following recommendations have been suggested to minimize the rate of deforestation within the forest reserves.

i. The farmers should be encouraged to practice agricultural intensification via the adoption of various innovative techniques. Agricultural intensification techniques such as the use of high-yielding planting materials, fertilizers, and weed and pest control technologies are needed to improve crops yields and outputs without necessarily expanding farms to cause deforestation.

ii. Forest protection laws should be strengthened and enforced to minimize the extent of farmers' encroachment of the forest reserves.

iii. Farmers should be encouraged to practice mixed tree-crop farming system. This can reduce the effect of 'no tree on farm' system on deforestation and decrease the clearance of trees from farmlands. Mixed tree-crop farming can further augment the delivery of ecosystem services and increase the soil's fertility and moisture content.

Chapter four, "Ghana's forest-cover increase is a disguised forest transformation", affirmed the main finding in chapter three concerning deforestation. Below were the main findings.

i. Ghana's forest-cover has increased based on definition of forest by FAO which seemed to include tree crops that have reached the specified thresholds as forest. A redefinition of forest by the Forestry Commission of Ghana has however excluded tree crops from the categories of forest. Even though FAO data showed overall increase in forest cover for Ghana, the extent of primary forest has decreased over the years.

ii. The forest-cover gain recorded in Ghana's forest reserves between 1990 and 2015 was more of a forest transformation made up of planted commercial forests and tree crops expansion misclassified as forest.

iii. Ghana has been implementing forest recovery programs since 2001. However, since the rate of deforestation is higher than that of forest recovery, reforestation strategies have been ineffective at driving forest transition.

It has therefore been suggested that the government of Ghana through the Forestry Commission could encourage voluntary participation of forest-fringe farmers in reforestation programs as an effective but less expensive alternative to government-funded reforestation programs. This will be a win-win approach – the farmers will get the forestland to grow their food crops while nurturing the planted trees to maturity. This strategy resembles the Modified Taungya System but differs in the sense that there is no benefit-sharing arrangements. The benefits the farmers will get is the forestland on which they will inter-plant their food crops with the tree species.

Chapter five, “Application of landscape approach principles motivates forest-fringe farmers to reforest Ghana’s degraded reserves”, demonstrated the applicability of the recommendation suggested in chapter four. Below were the main findings of chapter five.

i. Access to fertile land for food crop cultivation was the main rationale behind the farmers’ participation in the reforestation project, although 36% extended this motivational factor to include the benefit that the community would get from the restored forest.
ii. Twenty-nine percent of the farmers had inherited farmlands while 71% had insecure tenure under sharecropping arrangements or had encroached the forest. Almost all (77%) of these farmers had infertile lands, a reason for them to join the project.
iii. The adoption of the landscape approach principles achieved greater success than the Modified Taungya System (MTS) because the farmers were part of all decision making and unlike the MTS, the farmers were motivated in cash to carry out any extra activity that did not directly enhance their livelihoods.
iv. The project served as a source of natural capital (land) for the landless farmers and addition to the holdings of the farmers who already had land.
v. The project’s farmers sold more than half of their harvested produce because they had enough to meet their domestic needs, that is, obtaining more financial capital in addition to being food secure.
vi. Overall, the project has contributed to the achievement of the Sustainable Development Goals 1 (eradication of extreme poverty), 2 (ending hunger and achieving food security), and 15 (sustaining life on land through forest restoration).

It is therefore recommended that:

i. To ensure effective restoration and sustainable conservation and management of forest landscapes, collaboration among all stakeholders, especially farmers within and around these forest landscapes, is key.

ii. Forest restoration projects require trained personnel to carry out and this could be costly. Building the capacity of forest-fringe farmers to undertake these projects could yield an equally successful results and yet at a reduced cost. The government of Ghana could adopt the landscape approach to restore degraded reserves in the country instead of heavily relying on scarce trained personnel.

With regards to chapter six, “Factors influencing the adoption of agricultural practices in Ghana’s forest-fringe communities”, the following findings were evident.

i. Some 35.4% of the farmers rely only on slash-and-burn cultivation because they perceive agricultural inputs to be expensive, not useful, and difficult to adopt.

ii. The rest (64.6%) of the farmers adopt at least one of the practices, namely, chemical fertilizers, pesticides, herbicides, improved seeds, animal manure, and crop rotation, to control weeds, pests and diseases, and increase crops yields.

iii. Farmers that are older, have fewer number of farm plots, have to travel long distances to purchase inputs, and that have negative perceptions about complementary agricultural practices, do not adopt any, and for those that adopt, decrease the number of complementary agricultural practices they use.

iv. Farmers that possess more farm plots, travel short distances to purchase inputs, have positive perception about complementary agricultural practices, and have access to agricultural extension services increase the number of practices they adopt.

v. Access to agricultural extension services has a strong correlation with adoption and intensity of adoption of the practices. Nevertheless, a third of both adopters and non-adopters do not have access to extension services. The adopters rely on their own knowledge and farmer-to-farmer diffusion to apply the inputs.

While correct application of agricultural practices could significant increase outputs, wrong application of inputs can cause damage to crops, human health, and biodiversity. It is therefore recommended that:

i. Farmers should be frequently educated on the use of agricultural inputs through effective extension services. This education could be done through the FM stations as well as the information centers within farming communities to ensure that the message reaches a broader audience within a short time. Effective education about the benefits of innovative technologies may inspire older farmers to appreciate the need to complement their activities with inputs as they age.
ii. The government through the Ministry of Food and Agriculture (MoFA) should provide agricultural input subsidies and small loans with flexible payments and low interest rates to needy farmers who are willing to intensify their agriculture.
iii. Rural roads should be improved to enhance farming operations. Improved roads will enhance extension agents' access to farming communities. Input suppliers may be willing to do mobile supply services in areas with good road networks. Produce buyers would be able to access farming communities with ease and buy produce at appreciable prices since poor road conditions can no longer be a factor for low prices of produce.
iv. Forest protection strategies should be strengthened to prevent profit-maximising farmers from expanding their farms into the adjoining forests after adopting the yield-enhancing practices.

Chapter seven, "Ghanaian forest-fringe farmers benefit from adoption of modern farming practices regardless of environmental impacts, which analysed the costs and benefits of the various agricultural practices have the following major findings.

i. The stakeholders perceived modern farming (the use of chemical fertilizers, herbicides, pesticides, and improved seeds) to be economically beneficial to the farmers but socially costly and environmentally damaging.
ii. The stakeholders viewed mixed-input farming (the use of inorganic inputs in addition to animal manure usage and /or the practice of legume-crop rotation) as having the same social and environmental consequences since

the chemical inputs used in modern farming is also optimized in mixed input farming.

iii. The stakeholders had mixed opinions on traditional farming. While they favour traditional farming because of its zero use of chemicals, the stakeholders were also concerned about the risk of the slash-and-burn method spreading fire into the adjoining forest. However, the farmers stressed that all subsistence farmers clear land through burning before cultivation and that fire outbreaks is a result of a careless farmer.

Based on the above findings, two main recommendations for sustainable agricultural production without compromising forest conservation were suggested.

i. Reducing the use of chemical inputs and encouraging the use of more manure, improved seeds, and crop rotation will maintain and even improve the economic benefits of mixed-input farming and minimize the environmental consequences of the system due to the reduced use of chemical inputs.

ii. Encourage traditional farmers to complement their practices with animal manure and mulch, and those who have the capacity should practice legume-crop rotation.

iii. Farmers should be encouraged to retain more of their farm residues to serve as mulch instead of frequently burning the land. Residue retention in addition to the application of manure will conserve, moisturize, and enrich the soil for higher productivity, a strategy that resource-poor farmers can adopt.

iv. The acceptance and adoption of the above recommendations by the farmers depend on effective agricultural education through agricultural extension services.

Chapter eight, “Sustainable agricultural transformation requires technology-oriented policies and grass root level implementation strategies”, had three major findings.

i. Despite the implementation of the five consecutive policies spanning 1997-2017 geared towards agricultural modernization, expanding farm size has been the main strategy for farmers in increase crop production.

ii. All the agricultural policies had strategies to improve access to agricultural finance and extension services. However, institutional and structural inefficiencies have resulted in less impact of these strategies on agricultural development.

iii. The expected transformation of the agricultural sector was not realised in any of the policy regimes due to challenges including to low adoption of improved technologies, seeds and planting materials, inadequate access to agricultural finance and extension services, and inefficient sector governance.

It is therefore recommended that:

i. Future agricultural policies should have a strong governance backing so that investments targeted at improving productivity, enhancing access to markets, and promoting the development and adoption of improved technologies will achieve the expected results.

ii. The achievement of agricultural modernization depends on farmers' capacity to adopt strategies that will modernize agriculture, such as the adoption of high-yielding planting materials. Inadequate access to agricultural finance will lead to low adoption of improved technologies no matter how effective they are at improving yields and increasing outputs. It is reiterated that flexible agricultural credits from the government through the MoFA will enhance the capacity of smallholders to intensify their agriculture and consequently lead to the expected growth of the sector.

iii. It is also reiterated that adequate investment should be made towards extension service delivery. This will help resolve inefficiencies related to staffing and resources needed for service delivery. As stressed above, scientists will develop the technologies needed for improved production. The promotion and adoption of these technologies depends on active extension services which cannot be achieved without adequate resources.

9.2 Concluding Remarks and Areas of Future Research

Smallholder farmers in forest-fringe communities take critical decisions about their livelihoods. These decisions are based on the assets they possess, the land tenure system available to them, and the farming systems they are accustomed to. Accessibility to agricultural institutions and services, markets, inputs, technologies, and finance influence the farming operations of smallholders and consequently affect the forests within and around which smallholders cultivate.

Farmers who are financially capable and have secure tenure tend to intensify their agriculture to maximize profit so far as they have the requisite knowledge in agricultural intensification technologies and access to inputs and outputs markets. The predominant means by which asset-poor farmers increase agricultural production is expansion of farms. The above two distinct realities both have effects on the forest landscape.

Farmers who adopt yield-enhancing inputs such at fertilizers, pesticides and herbicides to increase agricultural production may be tempted to overuse such inputs which will in effect cause significant damage to the forest environment. Some of these input adopters may even expand their farms into forest areas having realized the benefits derived from adopting innovative technologies, hence, causing more encroachment and degradation. Non-adopters of agricultural inputs will not damage the forest biodiversity with chemicals. Instead, they will degrade the forest through encroachment. These two complex issues require strategic actions to resolve. While inputs such as herbicides and pesticides are detrimental to the forest environment, the farmers adopt them to control weeds, pests and diseases in their farms and subsequently enhance farm productivity.

Input adopters will therefore need to be sensitized on the significance of complementing moderate use of inorganic inputs with more use of organic inputs. This sensitization process will require series of demonstrations or evidence to prove to profit-maximizing farmers that modifying their farming practices will not impact negatively on their economic welfare but will rather minimize the environmental damages caused by their original farming operations.

The farmers who adopt no inputs will also need to be sensitized on the importance of adding organic inputs to their farming operations. These inputs serve as soil enrichment, weed, and pest control techniques to increase production without necessarily expanding farms. In most cases, these farmers are financially weak and will therefore not accept any local technology that will bring extra cost to them. Again, it is difficult to win the trust of most of these farmers due to their risk averse nature. Careful assessment of farm-enhancing techniques would have to be considered before making recommendations to resource-poor farmers.

The extent to which resolutions about the use of agricultural technologies in ways that do not undermine the sustainability of the forest environment would be achieved is contingent upon effective collaboration between forestry and agricultural extension officers in educating farmers. Working together to educate farmers on environmental sustainability strategies will help sustain agriculture while conserving the forest environment.

This research is not conclusive enough. There under listed are other areas that need further investigation in the future. Nevertheless, this thesis sufficiently answers the research questions identified.

i. The extent of agricultural intensification and forest protection strategies that will stop forest encroachment by farmers.
ii. The effects of various planted tree species on the growth and yield of food crops in a restored forest landscape.
iii. What next, after degraded forest is restored by landless farmers
iv. The effects of adoption of agricultural enhancing technologies on yields and outputs of crops and incomes of farmers.

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Appendix A. Farmer household survey instrument

VERBAL INFORMED CONSENT

PRINCIPAL INVESTIGATOR: **EMMANUEL ACHEAMPONG**
PROJECT TITLE: **DRIVERS OF CHANGE IN FARMING SYSTEMS AND FOREST COVER IN GHANA**
COLLEGE: **SCIENCE AND ENGINEERING**

Good day, my name is Emmanuel Acheampong and I am a student at James Cook University, Australia. I am studying **"Drivers of change in farming systems and forest cover in Ghana"** with the focus on farmers**.** I will appreciate it if you can spare about an hour of your time to answer a few questions.

The project is purely for academic purpose and the results will be used for academic reports.

Taking part in this study is voluntary, and you can stop taking part in it at any time without explanations or prejudice and to withdraw any unprocessed data you have provided.

Any information you give will be kept strictly confidential and that no names will be used to identify you in this study without your approval.

Please, if you require further information or to contact the researcher, the Village Chief has an information sheet.

Do you consent to participate in this project?

RESPONDENT'S ID (QUESTIONNAIRE NUMBER): …………………………

PART A: HOUSEHOLD CHARACTERISTICS

1) Age………………………………… 1b. Gender a) Male b) Female
2) Educational attainment (e.g. P6, JSS1)…………………………………………
3) Marital Status a) Married b) Single/Never married c) Divorced d) Widowed
4) Is here your hometown? a) Yes b) No
5) How long have you lived in this community if not your hometown (e.g. 30 years)?……….
6) Where were you living previously if not your hometown? ....
7) What work were you doing in you previous place? ....
8) Why did you move to this town?
   ....……………………………………………
   ………………………………………………………………
9) How many people have left your household for the past 5 years? ....
   i. Where have they moved to (Name of places)?
      ....…………………………………………………
   ii. Why did they move to those places (please provide reason for each of the places)? …………………………………………………………
10) How many people have joined your household for the past 5 years? …….........
   i. Why did they come here?…………………………………………
   ii. Where did they come from (e.g. region/town)?
      ………………………………………………….
11) How many people are currently in your household (including you)?…………….
12) Please fill the table below for the other members of your household (from the oldest)

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

PART B: LIVELIHOOD STRATEGIES AND RISK MITIGATION TECHNIQUES

13) What jobs have you done since you started working (e.g. teaching – 1991, trading – 1994 …...)

…..

....

14) Why have you (not) been changing your jobs? ……………………………

………………………………………………………………………………………

15) What are the opportunities and risks associated with your current jobs? (Fill the table below)

   a. In case of risk/unfavourable season, what do you do to sustain your jobs? (Fill table below)

Jobs	Opportunities	Risks	Mitigation
1.			
2.			
3.			

16) Will you change your jobs in the future? ………………… Why this answer?

………………………………………………………………………………………

PART C: FARMING

17) How many years have you been farming? …………...………………………

18) How many days in a week do you go to farm? ………………………………

19) How many plots do you farm on? ....Please complete the table below

Plot No.	Year acquired	Size (Acres)	Location	Acquisition (e.g. leased)	Lease arrangements	Duration (e.g. farm for 10 yrs)	Crops grown (please list all)
1.							
2.							
3.							
4.							

i. Location a) in the forest b) fringes the forest (add distance e.g. 1 mile) c) far from forest (e.g. 3 miles)

ii. If lease for acquisition method, write number of years left (e.g. lease – 5)

iii. Lease arrangements a) Annual payment of………. b) Abunu c) Abusa

20) Please describe each of the acquisition methods……………………………….

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

21) When the acquisition period expires, what will/ do you do? ....

…………………………………………………………………………………

………………….

22) Does the acquisition method influence the crops you should grow? a) Yes b) No

i. Please explain your answer

………………………………………………………………………….…

………………………………………………………………………

………………………………………………………………………

23) Does the location influence the crops you should grow? a) Yes b) No

i. Please explain your answer

……………………………………………………………………….

………………………………………………………………………

24) Has the acquisition methods been the same for the past 10 years? a) Yes b) No

i. If no, what has influenced the current trend?

………………………………………………………………………

………………………………………………………………………

25) What farming system do you practice (e.g. mixed cropping, please describe all)?

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

26) What strategies do you take to increase farm produce (e.g. fertilizer usage, expand farm size)?

....

27) Please fill the table below for the crops you grew last year or your last cropping season

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

28) Please fill the table below for the crops grown for the past five years

Year	1st 3 major crops and farm size (e.g. maize=5acres)			Location	Farm size
2017					
2016					
2015					
2014					
2013					

29) Why do you have the above cropping pattern?

…………………………………………………………………………….

30) Do you experience post-harvest losses? a) Yes b) No

31) Why does this happen?

…..………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

32) Why do you grow these crops but not other ones?

…………………………………………………………………………………

…………………………………………………………………………………

33) Will you change the crops you will grow in the future? a) Yes b) No

34) Why this answer?

………………………………………………………………………………………

………………………………………………………………………………………

35) Are your outputs increasing or decreasing when you assess it for the past five years? ……………………………………………………………………………….

36) What is the reason for the answer above?

………………………………………………………………………………………

………………………………………………………………………………………

37) a. Do you hire labourers for your farm work? a) Yes b) No

b. How many labourers do you hire at a time? (e.g. 4)…………………………

c. How many times in a cropping season do you hire labourers? (e.g. 3 times).

d. How much do each labourer charge per hire? …………………………

e. How many members in your household help you in your farm? E.g. 2,….

38) Please fill the table below for farm inputs used

Item	Cost per 1	Source (e.g. supplier)	Payment (e.g. cash/credit)
Agricultural inputs per season:			
1. Fertilizers (Qty……………)			
2. Weedicides (Qty…………..)			
3. Pesticides (Qty…………….)			
5. Manure (cow dung, poultry)			
Plant seeds (pls list all and qty)			
e.g. maize, 10 packets			
1.			
2.			
3.			

39) Why do you use these farm inputs? ....

PART D: NON-FARM ECONOMIC ACTIVITY

40) What non-farm job(s) do you do? ……………………………………….

41) Why did you adopt these activities?

....……………………

…………………………………………………………………………………

42) How many members of your household are into these and other activities?

....

a. Please state the other activities (if applicable)

……………………………………………………………………………..

43) How many days and hours per week do you spend on these activities? (e.g. 5 days, 7am-6pm)

……………………………………………………………………………

44) If you are to weigh this/these activity(ies) on a scale of 10 with your farm work in terms of income, what scale will you give (e.g. 7= trading, 3= farming)?...

45) How much/ proportion of your non-farm income is saved (e.g. ₵1 a day)?

....

46) How much/ proportion of your non-farm income is consumed?

....

47) How much/ proportion of your non-farm income is invested in farm per season?

....

48) Have you been changing your non-farm jobs for the past 5 to 10 years? a) Yes b) No

49) Please explain why you have/ have not been changing your non-farm jobs…………………………………………………………………………

…………………………………………………………………………………

Appendix B. Interview Guide for Forest Officials

INTERVIEW GUIDE FOR FORESTRY OFFICERS ON THE DRIVERS OF CHANGE IN FOREST COVER

1. How do you protect the forest in this area?
2. Do you involve other stakeholders in the protection of the forest?
3. Do people have free access to the forest and its products?
4. How do people get access to timber?
5. What happens to illegal operators when they are caught?
6. How do you regulate farms in the forest?
7. Do you have timeframes within which you check whether legal farmers are encroaching the forest?
8. Do you have instances of illegal farms in the forest?
9. What do you do to them when you find out?

Appendix C. Stakeholder Survey Instrument

INFORMED CONSENT

PRINCIPAL INVESTIGATOR: **EMMANUEL ACHEAMPONG**
PROJECT SUB TITLE: **ADOPTION OF SUSTAINABLE AGRICULTURAL PRACTICES IN FOREST FRINGE COMMUNITIES OF GHANA**
COLLEGE: **SCIENCE AND ENGINEERING**

Good day Sir/Madam, my name is Emmanuel and I am a student at James Cook University, Australia. I am studying the **"adoption of sustainable agricultural practices in Ghana"** with the focus on farmers in forest fringe communities. Sustainable agricultural practices simply means farmers' use of **weedicides, pesticides, fertilizers, improved seeds, mulch, animal manure, and legume-crop rotation** to sustain and enhance their farming activities. I will appreciate it if you can spare me about 15 minutes of your time to answer a few questions.

- This project is purely for academic purpose and the results will be used for academic reports.

- Taking part in this survey is voluntary, and you can stop taking part in it at any time without explanations or prejudice and to withdraw any unprocessed data you have provided.

- Any information you give will be kept strictly confidential and that no names will be used to identify you in this study without your approval.

If you consent to participate in this survey, kindly go to the next page to answer the questions. Thank you.

INSTITUTIONAL/EXPERT QUESTIONNAIRE

Please tick one of the following (1 to 5) to show your level of agreement to each of the statements. You can also type the number in the box if you are doing it on a computer

1 = lowest agreement to the statement.

5 = highest agreement to the statement

No.	Statements about some farming practices in forest areas	Agreement with statements (1-5)					
The use of fertilizers, weedicides, pesticides, improved seeds, manure, mulch and crop rotation in forest fringe communities		1	2	3	4	5	No idea
1.	Fertilizers, weedicides and pesticides can pose health risk to the farmer						
2.	Mulch, manure and crop rotation has no health effect on farmers						
3.	Society does NOT support the use of fertilizers in farms						
4.	Society does NOT support the use of weedicides in farms						
5.	Society does NOT support the use of pesticides in farms						
6.	Society supports the use of manure, mulch, improved seeds and crop rotation						

7.	It is difficult to apply fertilizers, weedicides and pesticides in farms						
8.	It is easy to apply much, manure and crop rotation in farms						
9.	Fertilizer is expensive to buy						
10.	Weedicides, pesticides, and improved seeds are expensive						
11.	Improved seeds are expensive to buy						
12.	Mulch is free and manure is cheap						
13.	You need more labourers to apply fertilizers, manure and mulch in the farms						
14.	You need more labourers to spray weedicides and pesticides						
15.	You have to apply these chemicals frequently						
16.	Weedicides, pesticides and fertilizers can destroy the soil						
17.	Weedicides, pesticides and fertilizers can pollute water bodies						
18.	Wrong application of the chemicals can destroy food crops						
19.	Weedicides can kill tree species in farms						
20.	Pesticides can kill other insects needed for e.g. pollination						
21.	Fertilizer, mulch, manure and improved seeds can increase the nutrient and organic content of crops						
22.	Fertilizer, mulch, manure, improved seeds and crop rotation increase yield and output of crops						

23.	Society supports the use of improved seeds, mulch, manure and crop rotation						
24.	Pesticides protect crops from insects and diseases						
25.	Weedicides kill weeds that share soil nutrients with crops						
26.	Fertilizers, weedicides, pesticides and improved seeds help crops mature early						
27.	Fertilizer, mulch, manure and crop rotation improve the fertility of the soil						
28.	Mulch and manure conserves and moisturises the soil						
29.	Fertilizer, mulch and manure usage will make farmers not encroach the forest						
Traditional or slash-and-burn farming in forest fringe communities		1	2	3	4	5	No idea
30.	Uses more energy that can cause body injuries						
31.	Frequent fire can cause body burns to the farmer and be life threatening to other farmers						
32.	More labourers are required to clear the land unlike using weedicides						
33.	You have to weed the farm more frequently unlike using weedicides						
34.	Crops delay in maturity due to natural growth						

35.	Crops are not able to survive pests and diseases attack						
36.	The fire burns the soil and the living organisms in it						
37.	The fire can spread to other farms and forest and destroy them						
38.	Smoke from the fire causes air pollution						
39.	Slash and burn fragments forests						
40.	Traditional farming produces organic foods and is chemicals free						
41.	Society supports chemicals free farming						
42.	Good maintenance can increase yield and output of crops						
43.	Most people prefer organic crops with no chemicals						
44.	Crops can be stored for a long time unlike GM crops						
45.	Residue from slash-and-burn may enrich the soil						
46.	Slash-and-burn causes less water and land pollution since no chemicals are used						

END OF PART 1. PLEASE SEE THE NEXT PAGE FOR PART 2.

Please tick one of the following (1 to 5) to show your level of agreement to each of the statements.

You can also type the number in the box if you are doing it on a computer

1 = lowest agreement to the statement.

5 = highest agreement to the statement

No.	Statements about farmers' use of inputs (namely, improved seeds, weedicides, pesticides, fertilizers, animal manure)	**Agreement with statements (1-5)**					
		1	**2**	**3**	**4**	**5**	**No idea**
1.	Almost all farming communities have agrochemical shops						
2.	All shops in fringe communities have the needed inputs						
3.	Farmers teach their fellow farmers how to use the inputs						
4.	Farmers are well experienced in using inputs (e.g. weedicide)						
5.	Farmers always have money to buy inputs (e.g. fertilizers)						
6.	Farmers can buy inputs on credit from their communities						
7.	Inputs are more expensive in communities than in the city						
8.	Farmers find it difficult to apply inputs (e.g. pesticides)						
9.	Farmers are not always sure if the inputs will work						
10.	Farmers travel long distances to other towns to buy inputs						
11.	High transport cost prevent farmers from going to buy inputs						
12.	Extension officers educate farmers on how to use inputs						

13.	Extension officers visit farming communities regularly						
14.	All farmers get subsidies on inputs (e.g. fertilizers) from the government						
15.	Only some farmers (e.g. maize and cocoa farmers) get subsidies on inputs from the government						
16.	Farmers can always take loan from the bank to do their farm						
17.	Farmers get loans from the bank to buy inputs for farm work						
18.	Wrong use of inputs can cause loss of crops, trees, other life						
19.	Forest policies restrict the use of inputs in forest areas						
20.	Agric policies restrict the use of some inputs in farms						
21.	Poor roads make it difficult for input suppliers and extension officers to reach farming communities						

End of survey. Thank you for your time.