KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
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ENVIRONMENTAL VALUES FROM PLANTATION FORESTS: A STUDY OF GHANA'S MODIFIED TAUNGYA SYSTEM IN DORMAA FOREST DISTRICT

BY

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ENVIRONMENTAL VALUES FROM PLANTATION FORESTS: A STUDY OF GHANA'S MODIFIED TAUNGYA SYSTEM IN DORMAA FOREST DISTRICT

A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE MASTER OF PHILOSOPHY DEGREE IN NATURAL RESOURCE AND ENVIRONMENTAL GOVERNANCE

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DECLARATION

I hereby declare that this submission is my own work towards the MPhil and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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DEDICATION

I dedicate this work to the memory of my father, Mr. Ernest Aboagye Bampoh and mother, Madam Augustina Gyadubea who both passed away during the writing of this thesis.

ABSTRACT

Natural resources, such as forests are valuable assets because they yield flows of valuable direct and indirect services to people. Notwithstanding, forest in Ghana have progressively disappeared over the years. This could be attributed to the fact that forest management in Ghana focuses mainly on timber which has direct market benefits. Largely, environmental services (non-market values) of forests are not taken into account in forest management planning. This may be as a result of the lack of knowledge, understanding and estimation of the value of environmental services provided by forests. This study sought to bridge this information gap by estimating the values of environmental services of MTS forest plantation using choice modelling along with the identification of management options that impact the provision of these values. Each step of the research was built on the perspectives of respondents. From literature and reconnaissance surveys, environmental services (attributes) of forest plantation were identified, validated and ranked in order of importance in focus group discussions. The first four environmental services on top of the ranking were selected for the study. Conjoint analysis was employed to estimate the value of these services. SPSS orthogonal design was used to generate different combinations of attribute levels which were presented as choice profiles to respondents. Respondents ranked these profiles from most to least preferred. The payment vehicle selected for this study was direct payment to participating farmers. The results show that water regulation was the most influential attribute in the ranking of choice profiles from the study forest plantation. Increasing money values had no effect on how these choice profiles were ranked. The result of the ordered logistic models shows that those who are not married, respondents from Abonsrakrom community, those with no formal, primary and middle school education placed higher value on choice profiles made up of higher attribute levels. In all, farmers were willing to accept GH¢400/hectare/year as compensation for improving environmental services. The choice experiment technique allowed respondents to indicate the relative value they place on various environmental services from small holder plantations. The findings on the value of forest plantation environmental services have important implications for forest management. Careful management is required to ensure the continuous provision and flow of forest plantation environmental services. Paramount amongst identified management options was fire management strategies. To ensure effective governance of the established forest plantations, institutional arrangements need to be strengthened.

Keywords: Environmental services, modified taungya system, choice experiment, governance

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LIST OF ACROYMNS

CE	Choice Experiment
CFM	Collaborative Forest Management
CFMP	Community Forest Management Project
CV	Contingent Valuation
Dollar rate	1US$=GhC 3.5 (at time of study)
ENGOs	Environmental Non-governmental organizations
ES	Ecosystem Service
FC	Forestry Commission
FLEGT	Forest Law Enforcement Governance and Trade
FSD	Forest Services Division
GLSS	Ghana Living Standard Survey
GNFS	Ghana National Fire Service
GSS	Ghana Statistical Service
ITTO	International Tropical Timber Organization
MEA	Millennium Ecosystem Assessment
MLNR	Ministry of Lands and Natural Resources
MTS	Modified Taungya System

NTFP	Non-Timber Forest Products
PLUM	Polytomous Universal Model
REDD	Reducing Emissions from Deforestation and Forest Degradation
SPSS	Statistical Package for Social Scientists
WTA / WTP	Willingness to Accept / Willingness to Pay

CHAPTER ONE INTRODUCTION

1.1 Background

Natural resource systems, such as forests are valuable assets because they yield flows of valuable services to people (Freeman, 1993; Daily *et al*., 2000). Forests in Ghana produce multiple environmental services alongside consumable goods like timber and nontimber forest products (NTFPs). According to the Ghana Statistical Service (2012), the forestry and wood processing sectors contribute approximately six per cent of Gross Domestic Product (GDP), with timber being the fourth largest foreign exchange earner after minerals, cocoa and tourism. Notwithstanding, forest in Ghana has progressively disappeared over the years. The country has one of the highest rates of deforestation in West Africa (Marfo *et al*., 2012), and while the rates have been reported to be alarming it is becoming increasingly difficult to get precise figures for the state of the forest cover and the rates of deforestation in the country (Hansen *et al*., 2009).

Deforestation in Ghana has several damaging consequences on the environment, economy and results in extreme poverty (Potthoff, 2005). According to the Forest Commission of Ghana (2012), the contribution of the forestry sector to the GDP is offset by an annual economic cost of forest degradation of about ten per cent per year. Moreover, deforestation indirectly accounts for 20% of annual carbon emission into the atmosphere (WRI, 2000) and this has an impact on climate change which is expected to hit developing countries the hardest.

To address this problem of rapid decline in forest cover and avert accompanying consequences, Ghana has made efforts to introduce remedial measures over the years. These measures include policy reforms (Amanor, 2003), strengthening of forest law enforcements (EU, 2007: Beeko and Arts, 2010), and replanting of degraded forest areas among others. In addition, various programmes have been promoted to address the diminishing natural forest resources by forest plantation development.

The government of Ghana in the 1930s, initiated a plantation development programme using the taungya system in which farmers were given plots of degraded forest reserves to cultivate food crops and also to assist in the establishment and maintenance of timber trees (Agyeman *et al*., 2003). This system was reviewed and relaunched in the year 2002 as the Modified Taungya System (MTS) because it was riddled with a lot of challenges (Agyeman *et al*., 2003). Two types of MTS exist in Ghana namely, the national MTS which is coordinated by the Forest Services Division (FSD) of the FC and the Community Forest Management Project (CFMP) MTS, coordinated by the Forest Plantation Development Centre of the Ministry of Lands and Natural Resources (MLNR) (Ros-Tonen *et al*., 2013).

The core objective of these forest plantations in Ghana is timber production (direct use value). But forest plantation ecosystems also provide a wide range of indirect benefits (indirect use and non-use values). Ghana's MTS just like other plantation programmes is capable of providing these indirect benefits which include air quality, carbon sequestration, climate regulation, erosion control, water regulation, water quality, nutrient cycling, recreation, cultural and educational values (Nasi *et al*., 2002; Dyck, 2003). In addition, this plantation development programme has been commended for a number of other reasons which include reducing land scarcity in forest fringe communities (Boakye and Baffoe, 2006), promoting empowerment of local farm households (Larson *et al*., 2010), trees for windbreaks, source of firewood, bushmeat, and medicinal plants (Blay *et al*., 2008; Kalame *et al*., 2011). This MTS is also expected to achieve increased revenues and other benefits to farmers and landowning communities in line with the objectives of the 2001 Ghana Poverty Reduction Strategy (GLSS, 2005).

The benefits provided by forest plantation ecosystem services are public in nature and therefore, are enjoyed by the wider community (Kumar, 2005). This could be motivation enough for forest owners and managers to maintain or improve plantation forest services.

1.2 The Problem Statement

The focus of forest management in Ghana has been on timber which has direct market benefits. Largely, environmental services (e.g. non-market values) of forests are not taken into account in the forest management planning and in the national income accounting particularly in Ghana (Damnyag *et al.*, 2011). Even the provisioning services (i.e. food, fiber, genetic resources) from natural and plantation forest ecosystems which are included in forest management planning and national income accounts are undervalued. The regulatory (climate, erosion, pest) and cultural (aesthetic, religious) services are not incorporated either. At the farm or community level, despite the fact that the forest plantation ecosystem provides these benefits to the farmers, their values are not adequately quantified and included in official forest management planning.

This may be attributed to the lack of knowledge, understanding and estimation of the value of environmental services provided by plantation forests. Not including these nonmarket benefits of plantation forest in management planning could substantially affect the provision of these benefits, and also may increase the pressure for conversion of forest plantation to other land uses. As a result, the expansion, maintenance and protection of these plantation forests have been a concern (Nanang and Nunifu, 2015). Lack of income between plantation establishment and timber harvest add to this insecurity. For all these reasons, the sustainability of these forests plantation development has been and continues to be a great challenge to Ghana. This is not withstanding the latest improvements in benefit sharing arrangements for future timber proceeds from these plantations (Blay *et al*., 2014).

1.3 Justification

The millennium ecosystem approach emphasizes the value of forest ecosystem processes to humans (MA, 2005). Despite the myriad of goods and services forest ecosystems provide, they are under threat in Ghana. Forest degradation poses risks to ecological resilience and human well-being. The causal factors of forest degradation are complex and varied (Damnyag *et al.*, 2011). As such, designing effective policies and management practices to address deforestation requires a thorough understanding of the causes. Population change, agricultural colonization, bush burning, illegal and inefficient logging practices are mostly cited as the main forces behind forest loss. However, environmental economists have drawn attention to a major but mostly ignored factor, i.e. non-market ecological functions of forest (Heal, 2000; Pearce, 2001; Richmond *et al*., 2007). The zero price of non-market forest services to a large extent fuels the conversion of forests to other land uses (Pearce, 2001). The issue is such that when conversion competes with conservation, conversion wins because conservation values appear to be low or zero whereas conversion values have markets (Pearce, 2001). This calls for the estimation of non-market values of forests and the internalization of values in land use decision-making as part of the efforts to halt further degradation.

Most forest related studies in Ghana focus on timber and NTFPs which have direct market values. Little attention is given to the non-market aspects of forest ecosystems hence, the need for this study. Society cannot recognize the economic impact of forest degradation if the ecosystem services they provide are not valued. Richmond *et al*. (2007) argues that, if empirical values for forest ecosystem services were available, degradation could be reduced. Such knowledge when available would help address most of the forces that engender deforestation and also, introduce some innovation in existing forest management regimes (Nasi *et al*., 2002). Translating forest ecological functions into empirical values would also encourage the restoration of degraded forest areas and also make a strong case for conservation when land use changes are being contemplated.

This study therefore seeks to promote the integration of multiple values of forest (with emphasis on environmental services) into management planning. As the MTS plantation forests in the present study has many attributes (Kalame *et al*., 2011), the appropriate technique to use in estimating the non-market benefits is the choice experiment

(CE). While economic valuation alone is neither indispensable nor sufficient for successful policies (Heal, 2000), it can provide important inputs into the policy or management process (Polasky *et al.*, 2005). When forest managers understand people's attitudes towards forest values, it facilitates the comprehension of the contexts for forest management (Schaaf and Broussard, 2006).

1.4 Research Objectives

The aim of the research was to estimate the value of environmental services of MTS plantation forests using choice modelling along with identification of management options that impact the provision of these values.

The specific objectives are:

- To identify attributes of environmental services of MTS forest plantations most relevant to forest managers and farmers.
- To estimate willingness to accept (WTA) compensation for improving environmental services provided by MTS forest plantations.
- To investigate the preferred management options for established MTS forest plantations.

1.4.1 Research questions

The research questions are;

- Which category of environmental services provided by forest plantations is considered essential from stakeholders' perspective?
- What amount of money are individuals willing to accept as compensation for improving environmental services?
- What are the management options that could impact the flow and quantity of these environmental services?

1.4.2 Hypotheses

The hypotheses of the study are;

- The level of importance of forest plantation attributes varies directly with respect to the different livelihoods that stakeholders are engaged in.
- Level of knowledge of environmental services provided by established plantations varies directly with farmer's willingness to accept compensation.
- Continuous production of environmental services is directly related to different management options available.

1.5 Organization of the study

This study is organized into six chapters. Chapter one covers the background of the research, throwing more light on the need for this study. A review of literature on concepts and theories that have been written concerning the study is presented in chapter two. Chapter three contains the methodology employed in this study. The various methods used in collecting data for the research are described in this chapter. Chapter four describes the results of the study. Key findings of the study are all outlined in this chapter. The discussion of results is found in chapter five. Elaborations, views and comments on results and findings are all given in this chapter. The conclusion and recommendations of the study are presented in chapter six.

1.6 Scope and limitations of the study

The study concentrated on a few plantation environmental services due to the limited number of attributes that could be included in a valuation study. As a result, the research focused on the environmental services that were considered most relevant to stakeholders. Translation and explanation of the choice scenario, attributes and their levels in the local dialect was a challenge. This problem was overcome by briefing taungya heads on the study so they could relay explanations better to respondents in 'bono' (their local Akan dialect).

CHAPTER TWO LITERATURE REVIEW

2.1 Deforestation in Ghana

Deforestation is the conversion of forest to an alternative permanent non-forested land use such as agriculture, grazing or urban development (van Kooten and Bulte, 2000). Deforestation is primarily a concern of developing countries in the tropics (Myers and Mittermeier, 2000) as it is shrinking areas of the tropical forests. Forest loss in Africa is a concern as two-thirds of the continent's population depends on forest resources for income and food supplementation (Angelsen *et al.*, 1999). Ghana has one of the highest rates of deforestation in West Africa (Benhin and Barbier, 2001) and the major causes have been associated with population growth, shifting cultivation, unsustainable logging, mining, wildfires, fuelwood and charcoal production (Appiah *et al*., 2009; Cudjoe and Dzanku, 2009). According to the International Tropical Timber Organization (ITTO, 2005), the annual rate of deforestation in Ghana is around 65,000 hectares and the country's substantial forest cover could completely disappear in 25 years.

2.1.1 Impacts of deforestation

Deforestation has many negative effects on the environment as well as societal wellbeing. Deforestation disrupts the global water cycle (Bruijnzeel, 2004). With the removal of part or whole of the forest, the area is no longer able to hold much water creating a drier climate (Chomitz *et al*., 2007). The ability of the forest to filter and treat water is lost which makes treatment and supply of water to urban areas expensive. Additionally, sedimentation in water bodies increases as that regulatory function of trees is lost (Dudley and Stolton, 2003).

The removal or destruction of forest areas results in a degraded environment with biodiversity loss. Tropical forests support about two thirds of all known species and contain 65 per cent of the world's 10, 000 endangered species (Myers and Mittermeier, 2000). When forests are destroyed, wildlife lose their habitat. Forests also help to conserve medicinal plants. Pimentel and Wilson (1997) reported that forest biotopes are irreplaceable source of new drugs such as taxol, and that deforestation can destroy genetic variations irreversibly.

Deforestation disrupts normal weather patterns creating hotter and drier weather thus increasing drought and desertification, crop failures, melting of the polar ice caps, coastal flooding and displacement of major vegetation regimes. Deforestation affects wind flows, water vapour flows and absorption of solar energy thus, clearly influencing local and global climate (Chomitz *et al*., 2007). Again, deforestation disrupts the global carbon cycle increasing the concentration of atmospheric carbon dioxide. Tropical deforestation is responsible for the emission of roughly two billion tonnes of carbon into the atmosphere yearly (Houghton, 2005).

The long term effect of deforestation on soil resources can be severe. Clearing the vegetative cover exposes the soil to the intensity of the tropical sun and heavy rains (Chomitz *et al*., 2007). Overtime, the soil loses its ability to productively support agriculture. Deforesting an area could make such an environment highly prone to flood (Bruijnzeel, 2004). Deforestation has detrimental effect on economic growth of developing countries. It is generally recognized that outside of urban areas, forest products are at the centre of socioeconomic development in Ghana. A study conducted by Appiah *et al*., (2009) in three forest districts, for example, suggests that income from forest products contribute about 38 percent more household income compared to other income generating activities. Removal of forest ecosystems has implications on traditional life styles, customs and religious beliefs (Schmink and Wood, 1992). Colchester and Lohmann (1993), described deforestation as an expression of social injustice.

2.1.2 Response to deforestation

Tropical deforestation and forest degradation has become a global concern (EU, 2007). It has attracted much public attention in recent years. The international community, governments at national level and environmental non-governmental organizations (ENGOs) have raised concerns about the negative effects of forest loss to the environment and humanity (Hobley, 2005). Overtime, concerted efforts and deliberations according to Lamb (2011), have led to three major responses to overcome deforestation. These are the pressing need to protect the remaining natural resources, effort to improve agricultural lands on abandoned lands by using new technologies and the increasing role of reforestation activities (Lamb, 2011). Ghana in this regard has also made efforts to introduce remedial measures to stem deforestation. These measures include policy reforms (Amanor, 2003), strengthening of forest law enforcements (EU, 2007: Beeko and Arts, 2010), and replanting of degraded forest areas among others. The role of reforestation is considered in this study since the research revolves around environmental services of plantation forests.

2.2 Plantation development programmes in Ghana

FAO (2006, p13) defines plantations as 'forests of introduced species and in some cases native species, established through planting or seeding, with few species, even spacing and/or even-aged stands'. Ghana's forest cover of approximately 8.2 million hectares by the turn of the 18th century has reduced significantly to about 1.2 million hectares as at 2010 (Forestry Commission of Ghana, 2012). A significant number of forest reserves are equally in a degraded state as a result of timber over-exploitation, wildfires and agriculture (Blay *et al*., 2008). To salvage the situation, plantation development programmes were instituted as one measure to reforest degraded areas and also to restore over-exploited marketable timber species in Ghana (Agyeman, 2004; Zhang and Owiredu, 2007; Foli *et al*., 2009). The declining forest resources prompted the government of Ghana to come up with the National Forest Plantation Development Programme in 2002 with a target of establishing 200,000 ha of plantations over a ten-year period (Nanang and Nunifu, 2015).

The current strategy under the Forest Plantation Development Programme involves both the public (Modified Taungya System on reserves, Small-farmer Agroforestry Scheme on off-reserves, HIPC Plantation programs, and President Initiative on Forest Plantations) and private (individuals, groups, and companies) sectors (Agyeman, 2004; Wagner *et al*., 2008; Foli *et al*., 2009). Though plantation development is not the ultimate solution to deforestation (FAO, 1995), its role in tackling forest loss is appreciated and has become an important part of national forestry strategies (Evans, 1999). Programmes to establish plantations in the country started in the late 1950s mainly for the production of timber and improvement in environmental quality and wildlife (Foli *et al.*, 2009). Most of the plantations established in many forest reserves by the then Forestry Department (FD) were done through the Taungya system (Odoom, 2002).

2.2.1 Development of plantation under taungya system

The *taungya* system is reported to have originated in Myanmar (Burma) and means hill (*Taung*) cultivation (*ya*) (Blanford 1958 as cited in Abugre *et al.*, 2010). Taungya is an age-old forest plantation practice in many parts of the world. Land is cleared and initially planted with both food crops and tree seedlings which, when grown, are harvested for timber. It has been practiced in Ghana since colonial times to restore degraded forest lands, ensure supply of commercial timber and produce food crops (Abugre *et al.,* 2010). The intention was to produce a mature crop of commercial timber in a relatively short time, while also addressing the shortage of farmland in communities bordering forest reserves (Agyeman, 2003). The farmers are required to tend the forestry seedlings and, in return, retain a part or all of the agricultural produce (Nair, 1993). This agreement would last for two or three years during which time the tree species would grow and expand their canopy (Nair, 1993). The practice stopped in 1984 because it was not effective as the communities involved had no tree ownership, financial benefits or decision-making power in management (Agyeman, 2003).

2.2.2 Modified Taungya System in Ghana

Due to the challenges of the taungya system, it became necessary to review the whole system. After an eighteen-month consultation period (July 2001 to December 2002) with the Government of Ghana, with support from FAO and the World Bank (Agyeman *et al.*, 2003), the taungya system was re-launched in 2002 as the Modified Taungya System (MTS) (Kalame, 2009). The MTS demonstrates a shift in forest management philosophy and is a perfect example of Collaborative Forest Management (CFM). A vital change the MTS brought was the improvement in tenure security and benefit arrangements. Farmers became co-owners of forest plantation products, with the Forestry Commission, landowners and fringe communities acting as shareholders. The ownership of the trees has been transformed from a single entity (the government) to multiple owners (farmers, local communities, government and landowners). All participants in the MTS are entitled to a share of the benefits accruing from the plantation (Agyeman *et al.,* 2003). Under this framework, farmers would carry out most of the labour work including maintenance (e.g. pruning) and receive 40% of the benefit accruing from the MTS (Kalame *et al*., 2011). The FC will contribute technical expertise, training, equipment for the farmers to carry out their functions efficiently and will be responsible for stock inventory and marketing of products and take 40% of the products. Landowners (mostly traditional rulers and individual who inherited land from the parents) contribute land and take 15%, and the forest adjacentcommunities will provide services (such as prevention of bush fires) and receive 5% of the final product (Agyeman *et al*., 2003).

2.2.3 Benefits derived from the MTS

Numerous benefits have been identified with modified taungya scheme. It has been commended for providing employment (offered 83,068 and 80,884 job opportunities to local communities across the country in 2002 and 2003 respectively), access to farm land and increased food security (Agyeman *et al*., 2003). Its gender friendliness (Abugre *et al*., 2010), contribution to reducing human pressure on forest reserves (Boakye and Baffoe, 2006), promoting people's empowerment (Larson *et al*., 2010) and its long term prospects of restoring forest cover and timber stocks (Blay *et al*., 2008) have been widely applauded. The trees serve as windbreaks, source of firewood, medicinal plants and provide protection for soil and watersheds. MTS has also contributed to climate change adaptation and mitigation strategies (Kalame *et al*., 2011).

2.3 Forest Management in Ghana

Forest management in Ghana has a history of different regimes. According to literature, the indigenous population of Ghana and Africa for that matter played a vital role in managing and protecting natural resources through local institutions before the arrival of Europeans (Matose, 2006). With the advent of colonialism, important decisions regarding forest use and management did not involve local communities. The interests of colonial forest policies were not focused on indigenous communities' involvement and benefitsharing but on timber exploitation and export (Asante, 2005). The communities including other stakeholders like traditional authorities at that time had no legal rights, access and economic incentives to manage and use forests (Wily, 2001).

Currently, the Forestry Commission (FC) is the state designated agency responsible for the protection and management of the nations' forest estate. It carries out its mandate by policing the boundaries of forest reserves, through policies and a number of legislations (Marfo, 2006). Contrary to the exclusion of other stakeholders under the previous regime, the agency has realized that sustainable forest management cannot be achieved without the active participation of all relevant stakeholders (Wily, 2001). Some of these stakeholders offer silvicultural support towards forest management.

2.4 Governance and institutional arrangements for forest management

Governance comprises the complex mechanisms, processes, relationships and institutions through which citizens and groups articulate their interests, exercise their rights and obligations and mediate their differences (UNDP, 1997). It includes the state (at its different levels), the private sector and the civil society. Issues of governance and institutional arrangements are very key for sustainable forest management but often, they do not receive the attention they require (Pagiola, 2014). Robledo (2014), proposes an analytical framework governance table which advocates four thematic areas that are vital for securing good governance of forest resources. These thematic areas include i) actors, ii) practices, iii) mechanisms and iv) accountability.

2.4.1 Actors

According to Robledo (2014), for the management of forest resources to be effective, there is a need to identify and involve all stakeholders/actors. Identifying their interests, how they relate to each other and defining their roles is essential to ensuring good governance of forests. In Ghana, stakeholders with regards to forest resource management encompasses local communities, landowners (traditional authorities), Forestry Services Division of the Forestry Commission, Timber and woodworker's associations, office of the administrator of stool lands, private tree growers, scientific community/academia and environmental NGOs (Marfo, 2006).

2.4.2 Practices

An effective forest management plan is needed to ensure robust governance. This should detail what happens in the forest stating areas where protection or harvesting should occur and how these are to be carried out and take into consideration environmental services, how they are produced and managed. The logistics (equipment and funding) required to carry out forestry practices should be provided. The responsibilities and liabilities of each actor, who will do what, and when should clearly be stated in the plan (Klugman 1994; Robledo, 2014).

2.4.3 Mechanisms

These are formal or informal rules that are consciously designed to manage the behaviour of actors as well as deal with failures in the system or process. In an instance where forest plantations are established jointly by different stakeholders, there is a need to clarify issues about property rights (Parto, 2005). The ownership of the environmental service or forest goods should be clearly delineated. It is also necessary to deal with institutional arrangements which do not make forestry practices attractive (Damnyag *et al.,* 2011). In instances of collaboration, agreements should be well documented and issues of equity in benefit sharing resolved. The mechanism for deciding on failure, who is liable for what, and under which conditions and processes for seeking redress should be specified (Robledo, 2014).

2.4.4 Accountability

Accountability is one of the requirement of good forest governance. It involves holding elected or designated officials responsible and liable for their decisions, actions and activities. Accountability tries to know who is obligated to do what and what sort of behaviour is unlawful. Its focus is on the accounting methods and practices that enable a transparent, understandable and feasible monitoring system (World Bank, 2006).

2.5 Environmental services of forests

Environmental services of forests include i) air quality, ii) provision of habitats and biological diversity, iii) carbon sequestration, iv) climate regulation, v) erosion control and soil stabilization, vi) nutrient cycling, vii) water regulation and viii) moderation of extreme events. Forests perform the function of capturing dust particles, refining and purifying air (Haefele *et al*., 1992). They also remove harmful pollutants and volatile compounds that could impact air quality and human health eventually (Dyck, 2003).

Diversity of species is essential for the sustenance of most ecosystem functions (Nasi *et al.*, 2002). Forests play a key role in maintaining species diversity by providing the required milieu for pollinators, resident or transient species and other non-timber forest products (Adamowicz *et al*., 1998; Dyck, 2003). Forests are a refuge for endangered species and help in the protection of gene pools. Without this function of forests, the keystone balance of the forest ecosystem would be disturbed (Daily *et al*., 2000).

Evidence abounds that local and global climates are changing. The build-up of greenhouse gases in the atmosphere has also been proven to be a primary contributor to this phenomenon (Hendrick and Black, 2009). There is likewise enough proof that forest can control the accumulation of these harmful substances in the atmosphere (Costanza *et al*., 1997). Forests through their capacity to act as sinks are able to sequester and store atmospheric carbons. Forests with ample vegetation are especially significant for carbon sequestration (Krieger, 2001).

Forests create favourable climate for those who dwell close and far from them. This is vital for human health, agricultural productivity, recreation and socio-cultural activities (Verma, 2008). This is realized through the forests' buffering role in allied biological processes, such as being a source and sink for greenhouse gases (Costanza *et al*., 1997; Krieger, 2001). Forests help in soil stabilization through their ability to prevent or reduce soil loss by rain, wind, runoff or other removal methods (Krieger, 2001; Dyck, 2003). Trees protects otherwise bare land, their foliage reduces the impact of falling rain drops and in some cases, their extensive roots prevent or slows down erosion (Kumar, 2005).

Trees contribute to soil formation through the disintegration of rock with their roots. These soils are gradually made fertile through the accretion of animal and plant organic matter and the release of minerals (Pimentel and Wilson, 1997). Well-developed roots of trees are able to dig up leached nutrients, making them available for shallow rooted crops (Nair, 1993). The services provided by this function are very important to maintain agricultural productivity.

Forests regulate water flows or hydrological regimes (natural drainage, water storage for agriculture, drought prevention, groundwater recharge/discharge). This function refers to the filtering (purification, detoxification, waste treatment), retention and storage of water in, mainly, streams, lakes and aquifers (Willis, 2002; Dyck, 2003). This ecosystem function is distinct from disturbance regulation. Forest ecosystem services associated with water supply relate to the consumptive use of water (by households, agriculture and industry).

Forest ecosystems have the ability to ameliorate hazards and disruptive natural events (Kumar, 2005). For example, trees can alter potentially catastrophic effects of storms, floods, droughts and fire. The services provided by this function relate to providing safety for human life and human constructions.

2.6 Economic valuation of forest ecosystem services

Several forest goods and services do not have markets and it is therefore necessary to resort to non-market valuation techniques (Costanza *et al.,* 1997). These techniques seek to elicit people's willingness to pay for a change in the level of provision of a forest good or a set of such goods (Turner *et al.,* 2003). The past decades have been committed to theoretical and empirical efforts to classify and quantify these benefits (Liu *et al.,* 2010). Valuing ecosystem services has become necessary especially when national and international agreements have demonstrated the need to protect and sustainably use forest ecosystem goods and services (MA, 2005). The growing number of practical applications of valuation techniques reinforces the predominant interest for such tools to support decision making and policies to account for and limit forest ecosystem degradation (de Groot *et al.,* 2002). The ensuing challenge was to estimate in monetary terms, the value of these ecosystem services (Fisher *et al.,* 2009). To overcome this, there was a need to better categorize ecosystems services and their associated values, with distinctions between functions, processes and benefits.

The Total Economic Value (TEV) classification which is defined as the sum of use, option and non-use values was subsequently developed to deal with the classification conundrum (Garrod and Willis, 1999; Bateman *et al.*, 2002). Use values refer to current and future, direct or indirect physical interactions with the good. Option values refer to the present value of maintaining several future possible uses of forest ecosystem services (Fisher *et al.*, 2009). Use values are measured by revealed preference techniques since they relate to uses which leave a behavioural trace (Bateman *et al.*, 2002). Non-use values reflect the satisfaction individuals derive from the knowledge that forest ecosystem services are maintained and that other people will have access to them. Non-use value is measured by stated preference methods since there is no behavioural trace (Carson *et al.*, 1994).

2.6.1 Methods of non-market valuation

Methods geared towards ecosystem services valuation have been developed and refined (de Groot *et al.*, 2002), with the key objective of integrating results into governance (Daily *et al*., 2000). The methods can broadly be grouped into two categories: revealed preference (RP) methods and stated preference (SP) methods. RP operates using actual consumer behaviour by examining marketed goods that are related to the public good (Freeman, 2003). RP techniques include market, productivity, travel cost and hedonic pricing methods (Liu *et al*., 2010). SP method is used to value goods and services where no real market data exists. The methods include the contingent valuation (CVM) and discrete choice experiments (DCE) (Adamowicz, 2004; Marre, 2014).

In addition to revealed and stated preference methods, other commonly used approaches in valuation include cost-based methods: replacement cost (estimates the costs incurred by replacing ecosystem services with artificial technologies) and avoided cost (relates to the costs that would have been incurred in the absence of ecosystem services) (Garrod and Willis, 1999). Another method is benefit transfer, which is based on the adaptation of existing valuation data to new policy contexts that have little or no data (Plummer 2009).

2.7 Estimating non-use values

Benefits or cost of losing or preserving ES have been broadly classified into use and non-use values (Bateman *et al.,* 2002). Non-use values are recognised to be an important component of the TEV of ecosystems and as such, certain decisions are required to conserve them (de Groot *et al.,* 2002). Within the neoclassical economics framework, upon which environmental economics and valuation methods are based, non-use values are defined and measured in monetary units of willingness-to-pay (WTP) or willingness-to-accept (WTA). Contingent valuation method (CVM) and discrete choice experiments (DCE) are stated preference methods used to estimate non-use values in the form of WTP/WTA (Adamowicz, 2004).

SP methodologies consist of asking individuals to provide responses to questions about how much they are willing to pay (or willing to accept) for some hypothetical scenario involving changes in the ES of interest. The measures of WTP/WTA are achieved by modelling the data based on utility theory, where choice is explained with regards to the maximization of utility (Adamowicz *et al.*, 1998). This requires a precise definition and understanding of the utility function (Hensher *et al.*, 2005).

The Random Utility Theory (RUT) was suggested by Thurstone (1927), then developed and improved by McFadden (1974) to explain the choice behaviour of humans.
The individual's utility function is described as the sum of two different components: a rational/systematic one (i.e. corresponding to explainable factors of choice), and a random one (i.e. unexplainable factors of choice) (Marre, 2014). Some assumptions are made with regards to the rational component. One such assumption commonly made is the additivity and linearity of the attributes or characteristics relative to the alternative (Lancaster, 1966; Hensher *et al.*, 2005). This multi-attribute utility theory also forms the basis of the choice experiments method (Bateman *et al.*, 2002).

2.7.1 Discrete Choice Experiments (DCE)

The SP methods (CVM and DCE) differ in how they value ecosystem services. DCE focuses on valuing different attributes of goods and services rather than treat them as a whole (Bateman *et al.*, 2002). The questionnaire which is the main data collection tool is designed in a similar way as CVM but here, the respondent is typically presented with a series of alternatives representing various proposed changes to the attributes of the good or service (Bennett and Blamey, 2001) with an added payment/compensation component from which they are to make a choice. The changes are depicted as levels of the attributes listed.

Ranking the alternatives is also another option for the individual. The respondent is showed successively several choice cards involving two or more alternatives usually with a status quo (Bennett and Blamey, 2001). The respondent's duty is to arrange these alternatives from the most to the least preferred (Louviere *et al.*, 2000). Then, in accordance with RUT, the choice data collected are modelled to estimate preferences. DCE also allows the estimation of how much people are willing to pay to receive one unit or accept as compensation for providing one unit more of a particular attribute (Carson *et al.*, 1994).

Various studies over the years have employed the DCE valuation technique. For example, Naidoo and Adamowicz (2005) employed this technique to estimate nature-based tourism value of forest reserves in Uganda, Gelo and Koch (2012) used it to estimate the values of community forestry in Ethiopia. Vecchiato and Tempesta (2013) applied it in valuing the benefits of an afforestation project in the peri-urban area of Veneto region in Italy and Palma *et al.*, (2009) applied it in measuring environmental and social values from plantation forests in New Zealand. In Ghana, Vondolia, (2009) and Damnyag *et al.*, (2011) have estimated the benefits of the forest ecosystem services and their impacts on the welfare of local farm households using this approach.

2.8 Applying discrete choice experiment in valuing forest ecosystem services

The following steps are followed in the application of discrete choice experiment in valuing forest ecosystem services. They include i) identification of salient attributes, ii) specification of attribute levels, iii) anticipating a choice model and designing the choice experiments, iv) presentation of choice alternatives, v) estimation procedures/analysis of results. For the first one, the salient attributes of the environmental good to be measured are identified through focus group discussions, direct questioning, and literature review. The monetary attribute should also be considered. This usually takes the form of a payment or compensation and should suggest a range of quantitative levels (e.g. 5, 10, 20, 50) per month or year. In the case where the respondents are not familiar with monetary payments, other contributions could be used (e.g. time, constraints, and efforts). These attributes should correctly represent the preferences of the respondents. They should also allow some links to be established with possible management actions to conserve the ES (Louviere, 1988; Marre, 2014).

Secondly, the attribute levels are specified. Attribute level specification is influenced by the researchers' study objectives and they should be in a continuous form. A status quo level has to be defined for each attribute. Care must be taken when specifying attribute levels because they can impact the quality of the responses and relevance of one's outcome, particularly if respondents discover them to be inconceivable (Louviere, 1988).

Thirdly, a choice model is specified and the choice experiment designed. A statistical experiment which combines attribute levels into choice profiles/alternatives is developed with the aid of statistical design concepts (Louviere, 1988). Factorial design is one of such concepts. It allows one to create descriptions of choice alternatives so that, statistical effects of the attributes can be estimated independently (Adamowicz *et al.*, 1994). Largely, complete factorial designs are rarely used because the number of possible combinations would be impractically large. Fractional factorial designs are preferably used to construct profiles

(Sanko, 2001). This requires an assumption that certain interaction effects among the attributes are not statistically significant. Generally, they are associated with main effects plans, which permit one to estimate only the additive, main effects of the attributes (Adamowicz *et al.*, 1994). To use main effects designs correctly, it must be the case that individuals process attribute information in a strictly additive manner, which implies that the effects of each attribute on the stated responses is independent of the effects of the remaining attributes (Louviere, 1988).

Experiments in which respondents are required to make choices among competing options are called stated choice tasks. Those that necessitate ranking sets of alternatives, or judging each alternative in a choice set on a category rating scale are called ranking or rating tasks (Louviere, 1988). In presenting the choice alternatives, a questionnaire is created with several sections to gather data (socioeconomic, demographic, environmental perceptions and awareness) (Marre, 2014). Short phrases, sentences, drawings, and photographs are used to make interpretation of attribute levels easier. The questionnaire is pre-tested and the methodology fine-tuned. After final reviews, the full survey is carried out (Marre, 2014). The next step is to analyze the data gathered.

The design and analysis of choice tasks is more complex than that of rating and ranking tasks because the latter are based on design theory associated with the estimation of general linear models, whereas the former are based on design theory for the estimation of discrete multivariate, nonlinear models (Louviere, 1988). Estimation procedures depend on the type of data collected. If data is collected using the ranking procedure, the OLS regression techniques are used to estimate the parameters of utility specifications. OLS estimates predict the overall utility of each choice profile. Deterministic rules are mostly used for mapping, such as assuming that the choice alternative with the highest predicted overall utility would be chosen (Louviere, 1988; Adamowicz *et al.*, 1994). More complex models for estimation include Multinomial Logit model (MNL), Random Parameters Logit (RPL), and Latent Class models (LCM) (Louviere, 1988).

CHAPTER THREE METHODOLOGY

3.1 The study area

The study was conducted in selected communities fringing the Pamu-Berekum forest reserve in the Dormaa forest district (Figure 3.1). Pamu-Berekum forest reserve (7°25N and 2°56W) covers a land area of 189.1 km^2 and its forest type is dry semi-deciduous to moist semi-deciduous (DS–MS) with a mean annual rainfall of over 1000mm (Dormaa Municipal Assembly, 2013). The reasons for selecting this site are the large and increasing degraded forest reserve lands and the restoration of these degraded forest reserves (Blay *et al*., 2008). Three communities namely, Abonsrakrom, Twumkrom and Ntabene were selected for the study. The criteria for selecting these communities were nearness to the degraded forest reserve and their involvement in reforestation of the degraded forest reserve under the Modified Taungya System (MTS).

Pamu-Berekum forest reserve is under the jurisdiction of the Dormaa forest district

(Dormaa municipality). The Dormaa municipal is sited at the western part of the Brong Ahafo region lying within longitudes 3° West and 3° 30’ West and latitudes 7° North and 7° 30’ North. The Municipality occupies a land area of 917 km^2 (Dormaa Municipal Assembly, 2013). According to the 2010 population and housing census, the total population of the municipality is 159,789 (GSS, 2012). The municipal’s topography is generally undulating and rises between 180 metres and 375 metres above sea level. The high range can be found near Asunsu in the north-western part of the municipality. A larger part of the municipality is occupied by the Pamu-Berekum Forest Reserve.

The major vegetation types are fragmented forest, grassland, extensive cultivable agricultural lands and degraded forestland (Dormaa Municipal Assembly, 2013). The municipality is largely rural in character, with agriculture as the predominant occupation. As a result of the farming activities in the municipality, these vegetation types are threatened and the forests especially, keep on changing to grassland.

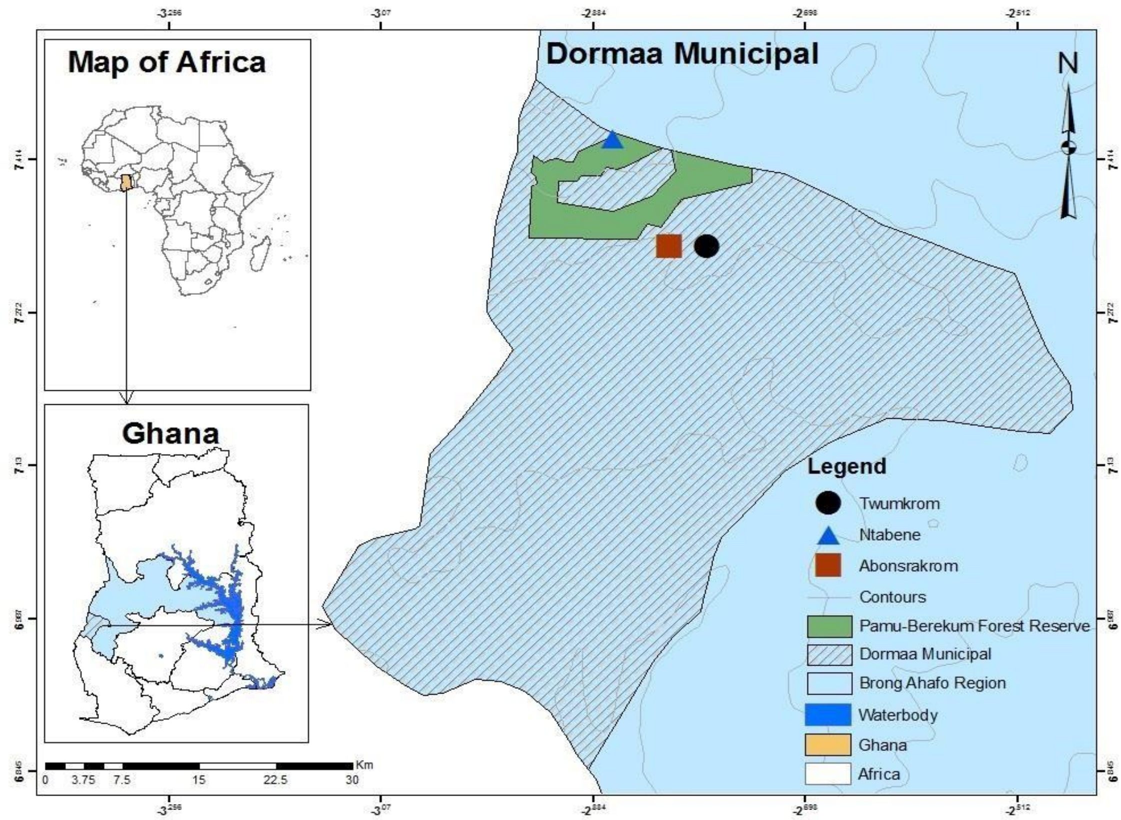

Figure 3.1: Map of Ghana showing the study sites

3.2 Reconnaissance survey and data collection

A reconnaissance survey was carried out at each of the study sites to get a general idea of the communities to help streamline the study. Their cultural values and taboo days were considered. During such visits, range supervisors of the Forest Services Division (FSD), taungya/plantation heads and participating farmers were identified as key informants. Focus group discussions were held to solicit attributes of environmental services of plantation forests to supplement those identified in literature. Participants were also asked to suggest management strategies for their established plantations. Responses from such interactions generated information for the construction of the questionnaire (Appendix I).

The questionnaire was administered in the local dialect of farmers to enhance their understanding of the study. Secondary data collected included published and unpublished literature relevant to the objectives of this study from the Forestry Research Institute of Ghana library and the internet.

3.3 Sampling design

Convenient and simple random sampling techniques were used to select participating farmers and available FSD officials for interview. A list of farmers participating in the ITTO project PD 530/08 Rev.3 (F) (ITTO, 2012) in the selected communities was obtained from the Dormaa FSD office. The list was updated with the help of taungya heads as some of the participating farmers had either passed on and had been replaced by a relative or they had left the community entirely. A total of 100 participating farmers (35 out of 40 from Abonsrakrom, 35 out of 40 from Twumkrom, and 30 out of 40 from Ntabene) and 11 Dormaa FSD officials were selected and interviewed for the study. Simple random sampling was used to select the individual farmers in the target communities for the interview, whilst the convenient sampling was used to obtain the 11 FSD officials. This sample size is large enough to ensure reliability and again, it satisfies the requirement for the conjoint analysis.

3.4 Questionnaire and experimental design

The questionnaire used to collect the CE data was constructed to include environmental attributes of MTS forest plantation and other socio-economic information about the respondents. The designed questionnaire was pretested on the field to fine tune the methodology before conducting the final survey. The mode of delivery of the questionnaire was through personal interview (paper and pencil method) (Adamowicz, 2004).

3.4.1 Presenting the CE questionnaire

Respondents in the study were introduced to the valuation research and the identity of the researcher was made known to them as well. The questionnaire included an introductory section that provided the respondents with information about the purpose of the study and also dealt with issues of confidentiality. The CE scenario was presented to highlight the negative impact of forest degradation and the environmental services that are lost accordingly. An already implemented course of action (rehabilitation of degraded forests by local communities under ITTO project PD 530/08 Rev.3 (F) to restore/enhance the benefits lost to deforestation) was also presented to solicit respondents' willingness to accept compensation for their contribution towards the restoration of environmental services.

3.4.2 Payment vehicle

Two payment vehicles were considered for the purpose of this study; direct payment to participating farmers and donation to a community development fund. Upon a focus group discussion, the former was selected as the preferred vehicle.

3.4.3 Attributes and levels selected

From different studies on MTS (Kalame *et al*. 2011; Ros-Tonen *et al*. 2013), attributes of MTS were identified. These were validated with forestry experts, managers and in focus group discussions with participating farmers engaged in the restoration of degraded forest reserves at the study sites. Through the focus group discussions, respondents identified the most important environmental services that MTS plantations provide. Four of the environmental attributes (Table 3.1) which participants were familiar with and which appeared more pronounced amongst them were selected for the valuation survey (Palma *et al.*, 2009).

Table 3.1: Attributes and levels used in the choice experiment

Attributes	Status quo level	Alternative levels
Increasing output of crops (Nutrient cycling)	Low output	Moderate output, High output
Improving water yield in water courses and storages (Water regulation)	No retention	Moderate retention, High retention
Prevention against windstorms	No Protection	Low Protection, High Protection
Biodiversity promotion	10% NTFP habitat	40% NTFP habitat, 70% NTFP habitat
Money	Gh₵0 per year	Gh₵400 per year, Gh₵450 per year, Gh₵500 per year

The levels for the first three attributes were agreed upon in the focus group discussion. The levels for biodiversity promotion were obtained from the work of Siikamäki (2001) and were validated by the focus group as well. The biodiversity promotion attribute was not a count of the flora and fauna present but rather the milieu that the MTS plantation forest had created for other non-timber species to thrive. Ahiale (2012) and Shaikh *et al*., (2007) gave the rationale for selecting the levels of the monetary attribute. In the study conducted by Shaikh *et al*. (2007), WTA for tree planting was quoted in dollars and as such, the cedi equivalent was calculated to enhance the selection of levels. The amount was scaled up to that of a hectare since their estimation was made per acre. Again, these were validated in the focus group discussion. To enhance understanding among less literate respondents, pictures were used to reflect both the meaning and the variation in the different levels of the attributes (Table 3.2) (Rasid and Haider, 2003).

Table 3.2 Photographs used to interpret attribute levels

Attribute	Levels		
Increasing output of crops	 Low output	 Moderate output	 High output
Water yield and storage	 No retention	 Moderate retention	 High retention
Protection against windstorm	 No protection	 Low protection	 High protection
Biodiversity promotion	 10% NTFP habitat	 40% NTFP habitat	 70% NTFP habitat

Concerning the definition of the attribute levels, the following were considered; (i) plausibility of the levels; (ii) respondents' experience of each attribute; (iii) the values attached to the attributes ensured that competitive trade-off decisions were presented; (iv) the values attached to the attributes presented trade-offs that covered the range of valuations held by each respondent.

3.4.4 The orthogonal design

The experimental design for this study was the orthogonal array/design. The orthogonal design (an alternative to the full factorial design) was employed to deal with instances where there would be too many cases for a subject to judge in a meaningful way (Pearmain *et al*., 1991; Louviere *et al*., 2000). Fractional designs are used if presenting all alternatives would be too much time-consuming, cost too much, or fatigue the respondent, thereby potentially invalidating the responses (Hensher, 1994). In a bid to reduce the number of cases, the status quo levels were not included in the generation of the orthogonal plan (Palma *et al.*, 2009). For this study, only main effects (subset of all possible profiles) were considered. No holdouts or simulations were specified. The attribute levels coding used for generating the orthogonal plan in SPSS is presented in Table 3.3. The orthogonal design used in the survey is subsequently presented in Table 3.4.

Table 3.3: Coding of attribute levels for experimental design (Kuhfeld, 2002)

Attribute	Levels	Number in experimental plan
Increasing output of crops (Nutrient cycling)	Moderate output	0
	High output	1
Water yield and storage (Water regulation)	Moderate retention	0
	High retention	1
Protection against windstorm	Low Protection	0
	High Protection	1
Biodiversity promotion	40% NTFP habitat	0
	70% NTFP habitat	1
Money	Gh₵400 per year	0
	Gh₵450 per year	1
	Gh₵500 per year	2

Table 3.4: Orthogonal design used in choice sets

Profile	Card	Main Effects				
		Increasing output of crops (Nutrient Cycling)	Water yield and storage (Water regulation)	Protection against windstorm	Biodiversity promotion	Money
1	1	0	0	0	0	0
2	1	1	1	1	1	0
3	2	1	1	0	0	0
4	2	0	1	1	0	2
5	2	0	1	0	1	1
6	3	1	0	1	0	1
7	3	0	0	1	1	0
8	3	1	0	0	1	2

3.4.5 Choice sets

Three choice sets were created from the experimental design. Each choice set consisted of three possible options: Baseline, Alternative A and Alternative B. The alternatives presented in the questionnaire were labelled as Alternative A, B, C, D, E, F, G, and H. The respondent's task was to rank all the profiles in the choice sets from most to least preferred (Sanko, 2001). Choice sets were constructed at a reasonable length in order to attain valid answers. The survey included a section which solicited socio-economic information from respondents.

3.5 Data analysis and model estimation

Collected data was cleaned, coded and fed into IBM SPSS statistical software (version 23) to extract meaningful information in accordance to the study objectives. The first and third objectives (most relevant environmental attribute and management strategies respectively) were analyzed using quantitative methods involving means and rankings. After which, chi-square (Kruskal Wallis H and Mann-Whitney U) tests were used to validate the significance of the responses from various groupings of respondents (communities, gender, age, level of formal education attained and annual household income).

For the second study objective (estimation of WTA), SPSS conjoint which uses the full-concept approach for analysis was employed. The approach performs conjoint analysis using the ordinary least-squares estimation method. A command syntax file was created to link the orthogonal plan to the ranked choice profile data file for analysis. In writing the syntax, discrete model was specified for nutrient cycling, water regulation, protection against windstorm and biodiversity promotion (MORE) factors whilst linear (MORE) model was specified for the monetary factor since it was expected that higher amounts would increase preference for a profile. Part-worths for each factor level was estimated for each factor level and their scores were added together to give the total utility of a combination.

To get an idea of how the factors compare, importance scores for each factor was computed. The Pearson's R and Kendall's tau statistics were used as an indication of how well the model fitted the data.

3.5.1 Ordinal regression model

The ordinal logistic method is a generalization of the linear regression method. This method was employed to model the relationship between response variables (ranking of choice profiles from most to least preferred) and a set of explanatory variables (attribute levels and characteristics of respondents). A normality test (Shapiro-Wilk; $p<0.05$) was performed to enable the determination of the appropriate link function and subsequently the statistical model to use in the analysis. For this study, the complementary log-log (clog-log) link function was considered suitable for the dataset. Clog-log link function is often used to analyze ordered categorical data when higher categories are more probable (Cheng, 2007). The parallel line assumption test was done to ascertain the use of the ordered logistic regression analysis in this study. SPSS PLUM procedure (an extension of the general linear model to ordinal categorical data) was utilized for the analysis. Model fitting information, goodness of fit, pseudo R-square and test of parallel lines were used as indicators of how well the model fitted the data.

The ordered logistic model is specified as equation 1, where the indirect utility that is derived from a choice profile is a function of the attributes of the profile and the respondent's characteristics.

$$V_i(P_h)^* = b_1Z_{1h} + \dots b_5Z_{5h} + c_1X_1 + \dots c_{Rh}X_R + \varepsilon_{ih} \quad (1)$$

where $V_i(P_h)^*$ is an unobserved measure of the utility that respondent i derives from the attributes of the profile, $Z_{1h} \dots Z_{5h}$ is a vector of levels of the observed attributes of the profiles, $X_1 \dots X_R$ is a vector of the respondent's characteristics, $b_1 \dots b_5$ and $c_{1h} \dots c_{Rh}$ are unknown parameters. ε_{ih} is a random error term. While the indirect utility derived from a particular alternative cannot be observed (Arifin *et al.*, 2009), the rankings of each choice profile/alternative of 1 to 8, could be observed where:

Ranking = 1 if $P_h^* \leq \mu_1$

Ranking = 2 if $\mu_1 < P_h^* < \mu_2$

Ranking = 3 if $\mu_2 < P_h^* < \mu_3$

Ranking = 4 if $\mu_3 < P_h^* < \mu_4$

Ranking = 5 if $\mu_4 < P_h^* < \mu_5$

Ranking = 6 if $\mu_5 < P_h^* < \mu_6$

Ranking = 7 if $\mu_6 < P_h^* < \mu_7$

Ranking = 8 if $P_h^* < \mu_7$

Where $\mu_1 \dots \mu_7$ are the intercepts or 'cut points'. The probability that the farmer will give a ranking of j to an alternative is given as:

$$P_{hj} = \Pr[\text{Ranking}=j] = \Pr[\mu_{j-1} < (\beta_1Z_{1h} + \dots + \beta_5Z_{5h} + c_{1h}X_1 + \dots + c_{Rh}X_R) < \mu_j] \quad (2)$$

ZX is the vector of attributes of the profiles and respondent characteristics while β and c are vectors of parameters to be estimated. Because higher categories (utility from most preferred choice profile made up of higher levels of observed attributes) were more probable, the clog-log link function was used. In the clog-log function, the form of the link is defined as:

$$\log[-\log(1- P_{hj})] = \Pr [\mu_{j-1} < (\beta_1 Z_{1h} + \ldots + \beta_5 Z_{5h} + c_{1h} X_1 + \ldots + c_{Rh} X_R) < \mu_j] \quad (3) \text{ or}$$

$$P_{hj} = 1- \exp(- \exp(\Pr (\mu_{j-1} < (\beta_1 Z_{1h} + \ldots + \beta_5 Z_{5h} + c_{1h} X_1 + \ldots + c_{Rh} X_R) < \mu_j)) \quad (4)$$

Results of the study were presented in tables and charts.

CHAPTER FOUR RESULTS

4.1 Socio-demographic characteristics of respondents

The modal age class of the survey was 55-64 representing 33% of respondents. Females were dominant (54%) and a significant portion (34%) of the respondents had attended middle school. Aside farming, 51.6% of respondents were engaged in trading.

Twenty-five percent of the respondents earn between GH¢1001-1500 annually. Majority (56%) of the respondents had knowledge about environmental services of plantation forests (Table 4.1).

Table 4.1: Demographic characteristics of respondents

Variable	Total number of respondents	Class (Frequency)	Percentage

Gender	100	Male (46)	46
		Female (54)	54
Age (years)	100	18-24 (1)	1
		25-34 (7)	7
		35-44 (19)	19
		45-54 (31)	31
		55-64 (33)	33
		+65 (9)	9
Highest formal education attained	100	No formal education (25)	25
		Primary (20)	20
		Junior high (17)	17
		Middle school (34)	34 1
		Senior high (1)	3
		University (3)	
			51.6
Other occupation(s)	31	Trading (16)	35.5
		Artisan (11)	12.9
		Civil servant (4)	
			56
Knowledge about plantation forest services	100	Yes (56) No (44)	44

Table 4.1 continued: Demographic characteristics of respondents

Variable	**Total number of respondents**	**Class (Frequency)**	**Percentage**
Number of years resident in community	100	1-15 (12)	12
		16-30 (20)	20
		31-45 (27)	27
		46-60 (32)	32
		>60 (9)	9
Household size	100	1-3 (7)	7
		4-6 (36)	36
		7-10 (51)	51
		+10 (6)	6
Annual household income (GH¢)	100	<100 (3)	3
		101-500 (20)	20
		501-1000 (21)	21
		1001-1500 (25)	25
		1501-2000 (18)	18
		>2000 (13)	13

4.2 Ranking of environmental services of MTS plantation forests

Table 4.2 shows how respondents ranked environmental services from MTS plantation forests. Ranking was done on a scale of 1 to 7 with 1 indicating most important and 7 the least important. The mean indicates the average ranking score obtained by each environmental service. From the survey, the most important environmental service was water regulation, with the lowest mean ranking score of 2.53. The second and third most important environmental services were nutrient cycling ($\bar{x}$ = 2.85) and biodiversity promotion ($\bar{x}$ = 3.09) respectively. Soil erosion control had the highest mean ranking score ($\bar{x}$ = 5.82) and was the least ranked environmental service (Table 4.2).

A Kruskal-Wallis H test revealed statistically significant differences among communities who ranked water regulation ($p<0.001$), nutrient cycling ($p=0.009$), protection against windstorm ($p<0.001$), carbon sequestration ($p=0.001$) and soil erosion control ($p<0.001$). However, the ranking scores of biodiversity promotion ($p=0.114$) and air quality ($p=0.101$) were not statistically significant (Table 4.2).

Table 4.2: Ranking of environmental services of MTS plantation forests

Forest environmental services	Number of respondents	Minimum	Maximum	Mean	H test statistics, mean rank, p-value in TANF
Water regulation	111	1	7	2.53	**TANF:52,49,55,94 H(3)=19, p<0.001
Nutrient cycling	111	1	7	2.85	**TANF:41,59,66,65 H(3)=12, p=0.009
Biodiversity promotion	111	1	7	3.09	**TANF:67,50,52,53 H(3)=6, p=0.114
Protection against windstorm	111	1	7	3.18	**TANF:59,44,52,95 H(3)=23, p<0.001

Air quality	111	1	7	4.86	**TANF:49,55,67,48 H(3)=6, p=0.101
Carbon sequestration	111	1	7	5.68	**TANF:60,55,64,22 H(3)=17, p=0.001
Soil erosion control	111	1	7	5.82	**TANF:67,74,39,11 H(3)=51, p<0.001

*The significance level is .05
**TANF: Twumkrom (T), Abonsrakrom (A), Ntabene (N), Dormaa FSD (F)

Mann-Whitney U test revealed communities that differed significantly in the ranking of environmental services (Table 4.3). Gender, age, level of formal education attained and annual household income did not have any significant influence on how respondents ranked environmental services of MTS plantation forests (Appendix III, Table A).

Table 4.3: Mann-Whitney test for environmental services ranking

Forest environmental services	U test statistics (mean rank, p-value) in **TANF
Water regulation	Abonsrakrom and Dormaa FSD:19,38, U=19, p<0.001 Twumkrom and Dormaa FSD: 19,37, U=43, p<0.001 Ntabene-Dormaa FSD: 17,32, U=48, p<0.001
Nutrient cycling	Twumkrom and Ntabene: 27, 40, U = 301, p=0.003 Twumkrom and Abonsrakrom: 29, 42, U = 395, p=0.009
Protection against windstorm	Abonsrakrom and Dormaa FSD: 19, 38, U = 29, p<0.001 Twumkrom and Abonsrakrom: 41, 30, U = 435, p=0.032 Ntabene and Dormaa FSD: 17, 32, U = 46 p<0.001 Twumkrom and Dormaa FSD: 19, 37, U = 48, p<0.001
Carbon sequestration	Dormaa FSD and Abonsrakrom: 11, 27, U = 58, p<0.001 Dormaa FSD and Twumkrom: 11, 27, U = 57, p<0.001 Dormaa FSD and Ntabene: 12, 24, U = 63, p=0.002
Soil erosion control	Dormaa FSD and Twumkrom: 6, 29, U = 5, p<0.001

Dormaa FSD and Abonsrakrom: 7, 29, U = 11, p<0.001
Dormaa FSD and Ntabene: 10, 25, U = 41, p<0.001
Ntabene and Twumkrom: 23, 42, U = 222, p<0.001
Ntabene and Abonsrakrom: 22, 43, U = 182, p<0.001

*The significance level is .05
**TANF: Twumkrom (T), Abonsrakrom (A), Ntabene (N), Dormaa FSD (F)

4.3 Analysis of the choice experiment

4.3.1 Estimates of WTA compensation for planting trees

Pearson's R and Kendall's tau statistics were computed as two measurements of correlation between the observed and estimated preferences. In this study, the Pearson's R statistic value for the overall model was 0.723 indicating a good fit of the data. The Pearson's R statistic was found to be significant for all cases (p=0.021) (Table 4.4).

Kendall's tau statistic also showed a significant positive association (τ = 0.500, p=0.042) between the observed and predicted rank orders (Table 4.4). Both are an indication of how well the conjoint models fit the data for the overall sample.

The utility (part-worth) scores and their standard errors for each factor level are also presented in Table 4.4. Higher utility values signify greater preference. Contrary to expectation, there was an inverse relationship between money and utility (highest monetary level corresponded to the lowest utility). However, higher crop output (nutrient cycling) corresponded to a higher utility, as anticipated. Based on the aggregate preference estimates, the utility of any combination of attributes and their levels was calculated.

Table 4.4: Utility scores of aggregate preference

Attribute	Attribute levels	Utility estimate	Std. error

Nutrient cycling:	Moderate output	-0.077	0.300
	High output	0.077	0.300
Water regulation:	Moderate retention		
	High retention	0.390	0.300
Protection against	Low protection windstorm:	-0.390	0.300
High protection			
		0.188	0.300
Biodiversity promotion:	40% NTFP habitat	-0.188	0.300
	70% NTFP habitat		
Money:	GH¢400		
		-0.060	0.300
	GH¢450		
		0.060	0.300
	GH¢500		
B Coefficient			
		0.000	0.000
		-0.025	0.362
(Constant)			
		-0.051	0.723
		-0.025	
		4.519	0.404

Pearson's R statistic = 0.723, p=0.021; Kendall's tau statistic = 0.500, p=0.042

The total utility of Alternative (Profile) A with moderate crop output, moderate water retention, low windstorm protection, 40% NTFP habitat and GH¢400 is: -0.077 + 0.390 + 0.188 + (-0.060) + 0.000 + 4.519 (constant) = 4.959. Table 4.5 contains a list of alternatives (profiles) and their corresponding total utilities.

Table 4.5: Total utilities of profiles used in the conjoint survey

Alternative (Profile)	Total utility	Std. Deviation
A	4.959	1.772
B	4.079	1.971
C	4.334	1.675
D	3.753	2.241
E	4.274	1.584
F	4.714	1.520
G	4.704	2.195
H	5.183	2.092

The ideal amount as compensation for the overall conjoint study was calculated to be GH¢400 based on utility values. This amount was calculated by dividing the sum of the three money levels (GH¢400, GH¢450 and GH¢500) by the sum of the utility values for the money levels (0.000, -0.025 and -0.051). This resulted in each unit of utility being worth GH¢18000. The ideal amount is found at a utility value of zero (which does not add or subtract from the perceived value). The utility value at zero for the three price points was 0.000. This number was multiplied by -GH¢18000 to get 0 and subtracted from the amount with zero utility to get, GH¢400. This resulted in the amount of GH¢400/hectare/year as ideal compensation.

4.3.2 Relative factor importance scores

Relative factor importance scores were computed from average part-worth scores of attributes to ascertain the difference each attribute made in the total utility of a profile. The computation indicated that water regulation (24.62%) was almost equally important as money (22.62%), followed by biodiversity promotion (18.93%). The relative importance of the remaining two factors studied decreased from windstorm protection (17.53%) to nutrient cycling (16.30%) (Figure 4.1).

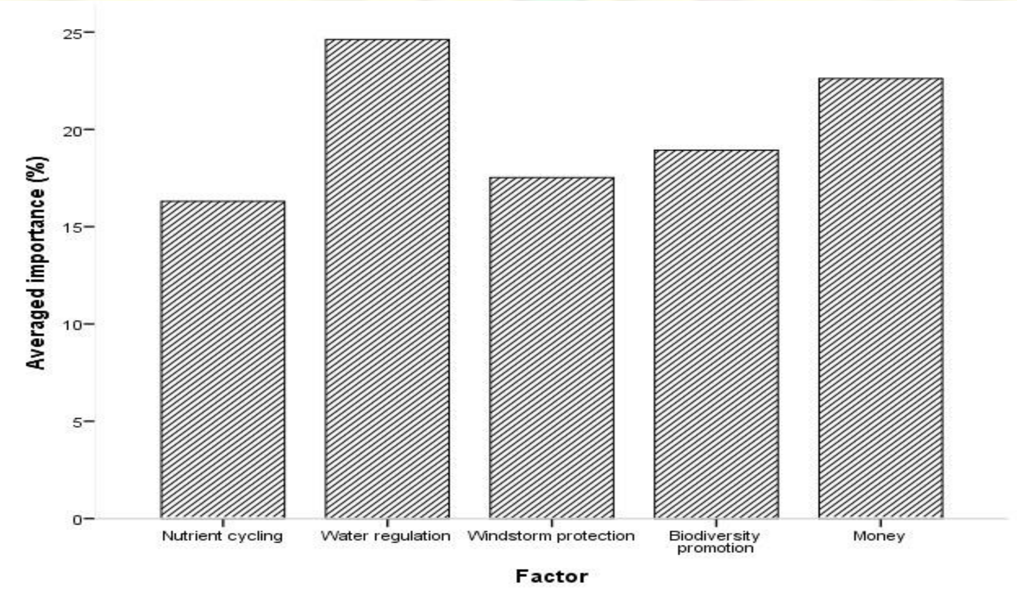

Figure 4.1: Relative importance scores of attributes of environmental services

4.3.3 Ordered logistic regression results

Table 4.6 contains the estimated coefficients for the two equations (1 with only attributes levels and 2 with only respondent's characteristics). From the results, educational level of a respondent, community a respondent belongs to and marital status are the significant variables explaining the ranking of profiles. Respondents who were not married (*p*=0.015) are more likely to be in higher categories (utility from most preferred choice profile made up of higher levels of observed attributes) compared to widows. Again, respondents from Abonsrakrom community (p=0.032) are more likely to be in higher categories compared to their counterparts in Ntabene community. Those with no formal education (*p*=0.013), primary (*p*=0.007) and middle school education (*p*=0. 014) are also more likely to be in the higher categories compared to those with university education. The results also revealed that attribute levels had little effect on the ranking of the profiles.

Respondent's gender and age had insignificant effects on how profiles were ranked (Table 4.6).

Table 4.6: Ordered logistic results on ranking of profiles

Variable		Estimate	Std. Error	Wald	df	Sig.
Model 1						
Attributes and levels						
Nutrient cycle	Moderate crop output	-4.057	2.233	3.301	1	.069
	High crop output	0[a]	.	.	0	.
Water regulation	Moderate water retention	-1.164	1.981	.345	1	.557
	High water retention	0[a]	.	.	0	.
Windstorm protection	Low windstorm protection	1.053	1.812	.337	1	.561
	High windstorm protection	0[a]	.	.	0	.
Biodiversity promotion	40% NTFP habitat 70%	-1.840	1.822	1.020	1	.312
	NTFP habitat	0[a] -	.	.	0	.
Money	Ghȼ400	2.939	3.353	.769	1	.381
	Ghȼ450	-2.893	3.388	.729	1	.393
	Ghȼ500	0[a]	.	.	0	.

Table 4.6 continued: Ordered logistic results on ranking of profiles

Variable	Estimate	Std. Error	Wald	df	Sig.
Model 2					

Characteristics of respondent						
Gender	Male	.028	.332	.007	1	.933
	Female	0[a]	.	.	0	.
Marital status	Single	3.136	1.285	5.953	1	.015
	Married	.663	.576	1.322	1	.250
	Separated	.955	.831	1.321	1	.250
	Widowed	0[a]	.	.	0	.
Age	25-34	-.617	.840	.540	1	.462
	35-44	-.553	.641	.743	1	.389
	45-54	-.065	.620	.011	1	.917
	55-64	-.831	.586	2.012	1	.156
	>65	0[a]	.	.	0	.
Education	No formal education	2.560	1.034	6.130	1	.013
	Primary	2.824	1.043	7.330	1	.007
	Junior high	1.705	.971	3.086	1	.079
	Middle school	2.483	1.010	6.040	1	.014
	University	0[a]	.	.	0	.
Communities	Twumkrom	.369	.309	1.424	1	.233
	Abonsrakrom	.709	.330	4.607	1	.032
	Ntabene	0[a]	.	.	0	.

*Link function: Complementary Log-log.
**a. This parameter is set to zero because it is redundant.

Various measures of model fitting were used as indicators of how well the models fitted the data. Both model 1 (χ^2=17.105, p=0.025) and model 2 (χ^2=75.445, p<0.001) outperformed their null models. Hence, the null hypothesis that the model without predictors is as good as the models with the predictors was rejected (Table 4.7).

Table 4.7: Model Fitting Information

Model 1	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	36.585			

Final	19.480	17.105	6	.025
Model 2				
Intercept Only	296.713			
Final	221.268	75.445	16	.000

The Pearson and Deviance Chi-square values were statistically insignificant at a pvalue of 0.05 which is an indication that the models adequately fit the data (Table 4.8). Again, the Cox and Snell and Nagelkerke R^2 values for model 1 explains over 40% of the variation in the dependent variable while that of model 2 explains over 80% variation (Table 4.9).

Table 4.8: Goodness-of-Fit

Model 1	Chi-Square	df	Sig.
Pearson	14.710	15	.473
Deviance	13.844	15	.537
Model 2			
Pearson	11.211	15	.738
Deviance	11.607	15	.709

Table 4.9: Model Summary (Pseudo R-Square)

Model 1		**Model 2**	
Cox and Snell	.427	Cox and Snell	.885
Nagelkerke	.456	Nagelkerke	.939
McFadden	.201	McFadden	.759

According to the test of parallel lines results (Table 4.10), there was no significant difference for the corresponding regression coefficients across the response categories, suggesting that model 1 (χ^2=8.634 and p=0.567) and model 2 (χ^2=95.591 and p=0.493) do not violate the assumption of parallel lines (Table 4.10). Thus, both models with the complementary log-log link provide evidence that satisfies the parallel lines assumption.

Table 4.10: Test of Parallel Lines

Model 1	-2 Log Likelihood	Chi-Square	df	Sig.

Null Hypothesis	19.480			
General	10.847	8.634	12	.567
Model 2				
Null Hypothesis	298.434			
General	202.843	95.591	16	.493

4.4 Ranking of management options for established MTS plantations

Respondents ranked fire management (x̄ = 1.81) as the most important management option for the established plantations. This was followed by alternative livelihood (x̄ = 2.98), plantation maintenance (x̄ = 3.37) and illegal logging (x̄ = 3.47). Conflict identification and resolution mechanisms (x̄ = 7.87) and publication of timber revenue accrued (x̄ = 8.02) were ranked eighth and ninth respectively (Table 4.11). The H test showed statistically significant differences amongst communities who ranked fire management and community mobilization and sensitization. However, the other

management options were not statistically significant (Table 4.11).

Table 4.11: Ranking of management options for established MTS plantations

Management Options	Number of	Minimum value in TANF	Maximum	Mean	H test statistics, mean rank, prespondents
Fire management	111	1	9	1.81	**TANF:51,51,57,87 H(3)=15, p=0.002
Alternative livelihoods	111	1	9	2.98	**TANF:59,51,54,68 H(3)=3, p=0.428
Plantation maintenance	111	1	9	3.37	**TANF:58,55,56,50 H(3)=1, p=0.908
Prevent illegal logging	111	1	9	3.47	**TANF:47,64,54,64 H(3)=6, p=0.103

Prevent illegal farming/hunting/ mining	111	1	9	5.24	**TANF:56,66,46,50 H(3)=7, p=0.081
Joint regular monitoring	111	1	9	5.81	**TANF:55,50,66,50 H(3)=5, p=0.180
Community mobilization and sensitization	111	1	9	6.38	**TANF:72,48,50,47 H(3)=14, p=0.003

Table 4.11continued: Ranking of management options for established MTS plantations

Management Options	Number of respondents	Minimum	Maximum	Mean	H test statistics, mean rank, pvalue in TANF
Conflict identification and resolution mechanisms	111	1	9	7.87	**TANF:47,63,60,51 H(3)=6, p=0.122
Publication of timber revenue accrued	111	1	9	8.02	**TANF:58,58,60,33 H(3)=7, p=0.059

* The significance level is .05
** TANF: Twumkrom (T), Abonsrakrom (A), Ntabene (N), Dormaa FSD (F)

For the ranking of fire management, Mann-Whitney U test revealed significant differences between Abonsrakrom-Dormaa FSD (Mean = 20, 35, χ^2(U) = 66, p=0.001), Twumkrom-Dormaa FSD (Mean = 20, 35, χ^2(U) = 68, p=0.001) and Ntabene-Dormaa FSD (Mean = 18, 29, χ^2(U) = 73, p=0.006). For community mobilization and sensitization, significant differences existed between Abonsrakrom-Twumkrom (Mean = 27, 44, χ^2(U) = 326, p=0.001) and Ntabene-Twumkrom (Mean = 26, 39, χ^2(U) = 302, p=0.003). Generally, gender, age, level of formal education attained and annual household income were statistically insignificant with regards to how management options were ranked (Appendix III, Table B).

CHAPTER FIVE DISCUSSIONS

5.1 Socio-demographic characteristics of respondents

A greater number of respondents in this study were females reinforcing the findings of Abugre *et al*., (2010) that, the MTS is gender friendly. It is important to note that majority of respondents were aged between 55-64, with most of them being resident in their communities for over 45 years. This was of great significance as they would have been around long enough to have observed the changes the forest had undergone to make meaningful contribution to the study. The participation of older people has been observed in many sustainable land use interventions or projects. According to Blay *et al.* (2014), older people desire to develop or acquire properties for future generations whereas the youth want engage in activities with quick cash returns. At this age, their social status and power play also influences their ability to get access to degraded land for MTS (Blay *et al.*, 2014).

The involvement of young farmers (18-35 years) was cardinal. These were mostly people who had inherited plots under the MTS due to the demise or migration of a relative who was involved in the scheme. Tripp (1993) reported that younger farmers have the penchant to adopt new initiatives and the rate of unemployment in these communities makes the MTS an attractive option.

Most of the respondents had completed middle school (10 years of schooling) and as such, had some form of knowledge about plantation forest services. Owubah *et al*., (2001) argue that the level of education of farmers influences their ability to engage in sustainable forest management. On the contrary, Ardayfio-Schandorf *et al*., (2007) believe that although secular education may be important, it is not the only determinant for people to engage in forestry but factors such as indigenous knowledge of trees by people also play a critical role. This was what farmers who had no formal education depended on in answering the survey questions. In general, respondents had large family sizes to provide labour on farms.

5.2 Ranking of environmental services of MTS plantation forests

The ranking of water regulation as the most essential environmental service was unanimous amongst the study communities. The sources of water for domestic and agricultural use in these communities are rainwater, boreholes and dug-out wells owned by individuals. This has been the case since the degradation of the Pamu-Berekum forest reserve led to the loss of the watershed protection function of the forest ecosystem which in turn affected their streams and catchment areas (Blay *et al.*, 2008). In reaction to this development, new sources of water had to be provided. The main challenge with these new sources of water is that they are very far from the farms and as such, huge cost has to be incurred in carrying out irrigation activities. Since respondents to the study were mostly peasant farmers, they lacked the capacity to improve productivity through irrigation on a large scale. However, with the rehabilitation of the degraded areas, farmers have lauded the change in their ecosystem. They cited instances where the plantation forest had improved water yield and storage in artificial dams, helping them irrigate their farms and also, raise nurseries to reforest other areas. Farmers in Ntabene and Abonsrakrom communities reiterated the fact that streams which used to dry up during the dry season can be accessed all year round owing to the protection that the established plantation offers (Willis, 2002; Dyck, 2003).

Respondents applauded the stability the plantation forest had brought to their soils through the control of run-off erosion corroborating the findings of Krieger (2001) and Dyck (2003). This was more pronounced in Twumkrom because, the open and undulating nature of their land made it easy for loose topsoil to be carried off anytime it rained. This phenomenon had also resulted in the siltation and drying up of most of their streams and artificial dams.

Aside erosion control, respondents also testified of improvement in soil moisture retention (Kumar, 2005). Again, respondents commended the contribution the plantation forest had made towards improving soil nutrient. This is in accordance with the findings of Pimentel and Wilson (1997) who found that through the fall of litter, plantation forests are able to improve fertility of soil. The FSD staff had more technical knowledge about the contribution of trees to soil fertility. They mentioned that the trees with their roots are able to dig up leached nutrients, making them available for shallow rooted crops (Nair, 1993). The farmers revealed that the plantation forest had reduced their cost of improving nutrient of agricultural lands with chemical fertilizers.

Both farmers and FSD staff agreed on how the plantation forest had improved the diversity of flora and fauna in the study communities. They were of the view that the plantation forest had provided habitat for resident and transient species, pollinators and other non-timber forest products to thrive, curbing biodiversity decline in the area (Adamowicz *et al*., 1998; Dyck, 2003). According to Oduro (2002), NTFPs contribute immensely to the livelihoods and welfare of populations living in and adjacent to forests. Farmers were pleased they could once again collect snails, harvest mushrooms and hunt bush meat to supplement their dietary needs. They could also harvest creeping vines or forest climbers to bind firewood or foodstuffs gathered for transportation (Falconer, 1992). A section of respondents said the fauna enriches soil with their faeces. In addition, some were pleased with the aesthetic view the plantation forest provides and also, knowing that the flora and fauna would continue to exist for future generations because of the habitat that the plantation forest has provided.

The results indicated that the FSD staff had a significantly stronger preference for carbon sequestration than the communities. This demonstrates the prominence of climate change issues in the forestry sector as this development has taken centre stage in global discussions (Marfo *et al*., 2012). In another breadth, the awareness of communities about the carbon sequestration function of forest might have influenced how they ranked this service.

Though some of them mentioned that forests are able to remove harmful substances from the atmosphere, they could not explain the mechanisms behind it. Those who made these remarks were taungya heads (leaders of participating farmer groups) or individuals who by virtue of their positions have attended workshops or seminars where the roles of forest in climate issues were discussed. The other farmers had very little to say on the carbon sequestration service of the forest plantation. Moreover, the significant difference between the responses of FSD staff and farmers is an indication of the communication gap that exists between these stakeholders (Marfo, 2010).

In general, it was observed that farmers were more interested in environmental services which had direct impact on their agricultural activities whilst the FSD officials were more concerned about those which ensured ecological stability.

5.3 Willingness to accept compensation for planting trees

Each step of the research leading to the estimation of WTA was built on the perspectives of respondents who were also participants in the selection of plantation forest environmental services. The aim of adopting a participatory approach for the valuation process was to integrate respondent's perspectives into policies and management actions (Harrison and Qureshi, 2000). Participants in this study reported that water regulation was the most influential attribute in ranking of the profiles. This finding reinforces study results obtained for the first objective of the present study. The high relative importance that respondents placed on water regulation revealed how they appreciate the watershed protection role of plantation forests, in the absence of which farmers incur huge cost in carrying out irrigation activities. Contrary to the result in this study, most conjoint studies (Hardy *et al.*, 2000; Behe *et al*., 2005; Mason, 2007), found price (money) to be the most important factor. However, in this study, increasing monetary values had no effect on the ranking of choice profiles. The increasing money variables rather produced negative utilities

(Behe *et al*., 2005).

Respondents perceived nutrient cycling as the least important factor. This could be attributed to the difficulty encountered by respondents in judging between the factors presented in the study (Hardy *et al.*, 2000). It could also be that respondents placed themselves in a realistic situation where they have to leave established plots when tree canopy closes (Agyeman *et al.*, 2003) and thus, gain no direct benefit from soil enrichment in situ. Nonetheless, respondents attested to the fact that plantation forests are able to improve soil nutrient (Nair, 1993; Pimentel and Wilson, 1997). The improvement in soil nutrient translated into bumper crop harvest corroborating the findings of Kalame (2009), Kalame *et al*., (2011) and Ros-Tonen *et al*., (2013) that MTS plantation forests contribute significantly to food security. In this study, higher crop output corresponded to a higher utility as anticipated. Again, higher levels of habitat provision for NTFPs produced high utilities. Respondents however, expected species diversity to increase over time as forest composition becomes more developed (Oliver and Larson, 1996). Biodiversity within a plantation forest is influenced by stand age, species and forest management practices. Considering the young nature of the plantation forest under study, high biodiversity levels would be realised as the forest cycle advances. The indigenous species (*Terminalia superba*, *Entandrophragma spp, Khaya spp*) used in the plantation would also enhance biodiversity (Blay *et al.*, 2008).

The amount of money respondents were willing to accept as compensation for improving environmental services of plantation forest was calculated by converting utility values into monetary values. Orme (2001) suggests that converting utility values into monetary values enhances the interpretation of conjoint data. The utility to monetary value calculations in this study were done strictly for the purpose of interpretation. The results revealed that respondents were willing to accept GH¢400/hectare/year as compensation in addition to future proceeds from sale of timber per the benefit sharing agreement of MTS

(Agyeman *et al.,* 2003). A study by Shaikh *et al.,* (2007) corroborates this finding. In their study, farmers were also willing to accept compensation for planting trees on their agricultural lands to sequester carbon aside future benefits from the trees. In a similar study by van Beukering *et al.,* (2008), farmers were willing to accept compensation in the form of agricultural inputs (seedlings, fertilizers and pesticides) aside the most preferred type of compensation (money, grants or subsidies). In addition to the credibility of the payment vehicle chosen for the survey, respondents also agreed with the importance of the topics they were asked about in the questionnaire.

The ordinal logistic result revealed that characteristics of respondents had more influence on ranking of choice profiles compared to attribute levels. The finding that respondents from Abonsrakrom community are more likely to be in higher categories of choice profiles with higher utilities was not surprising. This community has the highest reforested total area of 76.208ha compared to Twumkrom (26.558ha) and Ntabene (24.774ha) (Damnyag *et al.,* 2015). As a result, their expectation is to derive the maximum benefit accruing from the plantation. Again, the likelihood of respondents with no formal, primary and middle school education to be in the higher categories of choice profile with the highest utility is understandable. Respondents with university education had employment in the civil or public sector and as such, have diversified sources of income compared to those with no formal, primary and middle school education whose occupation is only farming. Odds ratios were not computed for the ordered logistic regression models because of the complicated nature of the clog-log link function (Chan, 2005) which places limitations on the direct interpretation of parameter estimates. As such, only the direction of the coefficients were explained.

A higher Pearson's R value would have been obtained for the study if the orthogonal array used in generating study profiles was balanced (i.e. equal number of attribute levels across selected attributes/factors). According to Sanko (2001), an unbalanced orthogonal array reduces the value of the Pearson R but gives variety to profiles generated. The three levels selected for the money attribute rendered the design unbalanced since the levels for the other attributes were two each. The choice experiment technique allowed respondents to indicate the relative value that they place on various environmental services of small holder MTS plantations.

5.4 Governance of established MTS plantations

The findings on the value of plantation forest environmental services have important implications for their management. Careful management is required to prevent degradation of the forest plantation which would result in the loss or reduction in volume of environmental services produced. Toward this end, the study asked respondents to suggest strategies to manage their established plantations.

The findings suggest that fire management strategies are very vital to the sustenance of the established forest plantations. Respondents mentioned that most of the wildfires which have destroyed forests, farms and plantation nurseries were as a result of the use of fire in land clearing and preparation in the dry season, fire related hunting, on-farm cooking and careless disposal of lighted cigarettes, corroborating the findings of Appiah *et al.*, (2010). As a result of the widespread incidences of fire in the area, some prevention and mitigation strategies have been implemented. These include traditional rules and regulations which are mostly centred on prohibition of the use of fire, acquiring permits for fire related hunting, wildfire prevention at the community level (fire volunteers and harmattan patrols) and the establishment of fire belts or rides (Appiah *et al.*, 2010; Blay *et al.*, 2014). Even with these strategies in place, occasional incidences of fire were experienced.

An analysis of the situation brings to fore the need to strengthen governance and institutional arrangements with respect to the implementation of fire management strategies. For instance, respondents bemoaned the lack of financial assistance and logistics pertinent to the prevention or mitigation of wildfires. It was revealed that the fire volunteers used to receive some monthly allowance from GNFS and Unit Committee (under the Dormaa Municipal Assembly) but for a long while, the money had not been forthcoming. This has become a major disincentive to the implementation of fire management strategies. North *et al*., (2015) posit that sustaining incentives for fire management in fire-prone areas is essential for achieving the objectives of wildfire policies or reforms.

To effectively deal with the incidences of fire, respondents again suggested that awareness creation and sensitization in nearby communities during fire prone seasons be carried out. The respondents reported that current fire occurrence have their source from Nkyekyema, Botokrom and other neighbouring villages. It then becomes necessary to extend fire sensitization and education strategies to all communities fringing established plantations (Appiah *et al.*, 2010; Blay *et al*., 2014).

From the results of the study, preventing illegal logging is also vital to the management of established plantations. Issues of lumber theft especially from plots established twelve (12) years ago has been a major source of worry for farmers. The act is fuelled by the fact that farmers have to move to new plots when the tree canopy of old plots closes. Farmers in Twumkrom community have their new plots of plantation forest close to the old site but their counterparts in Ntabene and Abonsrakrom communities have their new plots far away from the old sites, making it difficult for them to monitor illegal activities. Whilst a few of them blamed the issue on the connivance of FSD staff with illegal chainsaw operators (Marfo, 2010), others made some suggestions to curb the development. Suggestions made included building the capacity of communities to arrest offenders (Omoro and Glover, 2013), creating checkpoints (similar to that of TIDD) to ensure the transportation of only legally harvested logs, carrying out periodic patrols in the plantations, curbing corruption and coming up with local by-laws to deal with the illegality. With the exception of creating a barrier, respondents were of the view the aforementioned strategies could also help tackle illegal farming, hunting and mining in the established plantations.

It was against the backdrop of leaving closed canopy plots unmonitored, making them conducive for illegalities that respondents came up with the idea of incorporating less intensive alternative livelihoods into established plots. Livelihood activities suggested in this regard included bee-keeping, mushroom cultivation (where spawns are scattered on the forest floor), snail-rearing (where eggs are scattered on forest floor), ginger (because of its ability to thrive under shaded conditions), *Piper guineense* (suro-wisa), *Aframomum melegueta* (fam-wisa), and *Xylopia aethiopica* (hwentia) cultivation (Oduro, 2002; Rao *et al.*, 2004). Respondents were of the view that this strategy would enable them visit old plots periodically and that their presence could serve as a deterrent to perpetrators of illegal activities.

Both FSD staff and farmers agreed on the significance of putting in place conflict identification and resolution mechanisms. One potential conflict scenario identified during the study was the activities of Fulani herdsmen. Farmers complained that the herdsmen were grazing cattle on their farms destroying tree seedlings and food crops. A section of the farmers had threatened to take matters into their own hands since attempts to call on both traditional authorities and FSD to address the issue had proved futile. To this end, institutionalizing and formalizing structures to address conflict episodes as and when they develop is pivotal to the management of established plantations (Derkyi *et al.*, 2014).

The finding on community mobilization is worth discussing. In communities where farmers are well organized, they work together to ensure the protection of established plantations (Damnyag *et al.*, 2015). This was more evident in Ntabene and Abonsrakrom where participating farmers show enthusiasm, are more responsive and cooperative towards forest practices such fire management and plantation maintenance as compared to their counterparts in Twumkrom who exhibit lackadaisical attitude towards forestry activities.

Placing the survey results on management options for the established plantations within the context of the governance study of Robledo, (2014) brings to the fore more issues of governance and institutional arrangements which need to be given attention. For instance, to ensure compliance and effectiveness of the identified strategies, there is a need to involve all stakeholders (local communities, traditional authorities, FSD, environmental NGOs, scientific community/academia, donor agencies and CSOs) in the implementation (Wily, 2001; Blay *et al*., 2008). Delineating each actor's role in the management of established plantation is also critical. With changing trends in global forestry and climate change issues taking centre stage of multilateral discussions (Marfo *et al*., 2012), there is a need to draft managements plans to capture the provision and protection of environmental services although the primary target of the MTS is to expand timber resource base (Agyeman *et al.*, 2003). The management plan should again state the source of funding for forestry practices in the plantations. For example, if the services of fire volunteers would be required, there is a need to set aside a budget to sustain their activities. A way forward is to consider how the suggested alternative livelihood activities could be used as an incentive to fund the operations of fire volunteers. Again, if environmental services or carbon credit become a part of the objectives of the plantations, there is a need to address issues of ownership of the carbon. Although, a benefit sharing agreement exists for the future sale of timber, there should be further documentation detailing ownership of carbon credit from such plantation forests. This would prevent conflicts and also ensure equitable distribution of revenue (Robledo, 2014). Contemplating carbon trading requires effective tackling of potential sources of carbon leakages such wildfires, lumber theft and other illegalities.

Additionally, a transparent, understandable and feasible monitoring system should be in place to promote accountability. Hopefully, the emergence of forest governance initiatives such as Forest Law Enforcement, Governance and Trade (FLEGT) and Reducing Emissions from Deforestation and Forest Degradation (REDD+) (Nketia *et al.*, 2009) could contribute to the management of such forest estates.

CHAPTER SIX CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This study investigated environmental values from MTS forest plantations in the Dormaa forest district and how these values could be protected from further degradation. From literature and focus group discussions, environmental services of plantation forests were identified. Respondents were asked to determine the significance of these services. Results of the study revealed that water regulation was the most essential environmental service for stakeholders. Other services identified were nutrient cycling, biodiversity promotion, protection against windstorm, air quality, carbon sequestration and soil erosion control. In general, it was observed that farmers were more interested in environmental services which had direct impact on their agricultural activities whilst FSD officials were more concerned about those which ensured ecological stability.

The environmental value of plantation forests were estimated through choice modelling. This non-market valuation method was selected because it allows multiplechoice options and attributes. It also allows the integration of respondent's characteristics to elicit their environmental preferences. It was discovered that water regulation was the most influential attribute in the ranking of choice profiles. This finding was consistent with the result of the first study objective of the present study. Increasing money values had no effect on how choice profiles were ranked but rather produced negative utilities. The empirical results revealed that those who are not married, respondents from Abonsrakrom community, those with no formal, primary and middle school education placed higher value on choice profiles made up of higher attribute levels. Farmers were willing to accept

GH¢400/hectare/year as compensation for improving environmental services in addition to future benefits from sale of trees.

Careful management is required to ensure the continuous provision and flow of plantation forest environmental services. Paramount amongst identified management options was fire management strategies. It was found that incentivising farmers is critical to making fire prevention/mitigation strategies effective. Alternative livelihood, plantation maintenance and tackling illegal logging were amongst the most important management options for the established plantations. The study also highlighted the need to include more stakeholders in the implementation of management options. The need to delineate each stakeholder's role in management of these forest plantations was also deemed very necessary. Including the management of plantation forest environmental services in management plans and defining ownership of these services were seen as ways of avoiding future conflicts. Based on the implication of the study results, useful information are provided for forest managers to evaluate actions, plans and policies to ensure sustainable forest management in Ghana.

6.2 Recommendations

Based on the results and findings of the present study, it is recommended that further research be conducted to investigate the value of other environmental services of forests as the present research estimated the value of the four most important environmental services from the study forest plantation.

The issue of lumber theft should be addressed by the FSD. Per the suggestions of farmers, the FSD could mount checkpoints in the various communities to ensure that only legally harvested logs are transported out of the Pamu-Berekum forest reserve. These checkpoints should be jointly manned by the FSD and a representative of participating farmers to ensure transparency and accountability.

Farmers in the study communities did not know how to seek redress when they encounter conflict scenarios such as the Fulani menace. It is therefore recommended that the FSD come out with a clearly laid down procedure for addressing such issues to prevent conflicts from escalating. Although the ultimate objective of MTS is timber, the FSD should consider managing some of these plantation forests for their non-market values. Managing these plantation forests for carbon credits could be a starting point. This would provide income for farmers in the short term as they await future proceeds from sale of timber.

The study brought to the fore issues such as the need to widen the stakeholder bracket for managing established plantations, delineating stakeholder's roles and setting up a feasible monitoring system to promote accountability. It is recommended that, institutional arrangements be strengthened to enhance the governance of established plantations. The accountability aspect should be given special attention as this could dispel the distrust farmers have for FSD officials and also, improve the working relationship between these two stakeholders.

The study further recommends that the FSD should pay attention to mechanisms and institutions used in compensating farmers for their contribution in implementing fire management strategies in the study area. In addition to these, the local communities need to be equipped in terms of capacity and resources to effectively manage the plantations they have established.

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APPENDICES

APPENDIX I

QUESTIONNAIRE FOR VALUING ENVIRONMENTAL SERVICES OF PLANTATION FORESTS (COMMUNITIES)

Thank you for agreeing to participate in this study. I am a graduate student of the Kwame Nkrumah University of Science and Technology carrying out a research on the environmental services of plantation forests. I would like to seek your views on management options which could influence the flow of these services, the most essential environmental service to you and your willingness to accept compensation for your contribution towards improving these services through plantation forests. Your responses are confidential and would be used just for statistical purposes.

Name: __________________ Contact: ______________ Community: ___________

Section A Your preference on the extent of influence of management options

The Modified Taungya System (MTS) plantation forests yields vital environmental services as a result of forest ecosystem functions, properties or processes. These services are of benefit to society. To ensure continuous provision of these services, some plans or activities need to be implemented. It is intended that your response would help understand how you feel about plantations and recommend actions to improve their management.

Kindly indicate the extent to which each management option influences the provision of environmental services. Assign number 1 to the most important and so on for the rank section.

Management Options	***Not Important***	***Slightly Important***	***Important***	***Very Important***	***Overall Rank***
1. Fire management *Creation of fire rides *Planting of firebelt *Harmattan patrols *Fire volunteers *By-laws	1	2	3	4	
2. Prevent illegal logging *Capacity building *Create checkpoints *Periodic patrols *Curbing corruption *By-laws	1	2	3	4	
3. Prevent illegal farming/hunting/ mining *Empower community to fish out perpetrators *Periodic patrols *By-laws	1	2	3	4	

4. Plantation maintenance *Replant patches *Beating up *Regular cleaning of boundary lines and placing signpost at vantage points	1	2	3	4	
5. Alternative livelihoods *Bee-keeping *Mushroom *Snail-rearing *Ginger/surowisa etc.	1	2	3	4	
6. Community mobilization and sensitization on plantation management	1	2	3	4	
7. Joint regular monitoring by Forest Services Division (FSD) and community members *Dealing with Fulani herdsmen	1	2	3	4	
8. Publication of timber revenue accrued and media coverage of MTS success stories	1	2	3	4	
9. Conflict identification and resolution mechanisms	1	2	3	4	

Section B In your perspective which is more important

The MTS plantation forest ecosystems are capable of providing environmental services which are beneficial to people. The table below contains a list of such services.

Rank the environmental services according to their importance to you. The most important should be assigned the number 1 and so on. Kindly refrain from assigning the same number to two or more services.

Forest environmental services	*Rank*	*Reason (why you think they are important or not so important)*
1. Nutrient cycling (increasing output of crops)		

2. Water Regulation (improving water yield in watercourses and storages)		
3. Soil erosion control (regulate run-off)		
4. Protection against windstorms		
5. Biodiversity promotion (provision of habitat for NTFPs)		
6. Carbon sequestration (capture airborne pollutants)		
7. Air quality (modification of the microclimate)		

Section C Your willingness to accept compensation

The Pamu-Berekum forest is one of the oldest and first reserves to be gazetted in the country. However, it is also one of the most degraded. Degradation of forest has adverse impact on the provisioning of environmental services such as air quality, carbon sequestration, protection against windstorm, erosion control, water regulation, biodiversity and nutrient cycling. Humans and activities related to forest ecosystem processes suffer as a result.

However, forest plantation programmes have the potential to restore or improve the flow of these environmental services. The Modified Taungya System of which you are a participant is one of such plantation schemes. I would like to know your willingness to accept compensation for your contribution towards the improvement of environmental services as part of your effort in reforesting the degraded Pamu-Berekum forest reserve.

In this section, scenarios based on the attributes of environmental services discussed previously have been created. Eight options are presented in addition to the previous situation or 'baseline' which explains how the situation used to be. The options (alternatives) are a distinctive combination of the environmental services attributes. Carefully compare the options presented and allot ranks to them. The most important should be assigned the number 1 and so on.

	Baseline	Alternative A	Alternative B

Increasing output of crops	 Low output	 Moderate output	 High output
Water yield and storage	 No retention	 Moderate retention	 High retention
Protection against windstorm	 No protection	 Low protection	 High protection
Biodiversity promotion	 10% NTFP habitat	 40% NTFP habitat	 70% NTFP habitat
Money	Gh¢0/year/ha	Gh¢400/year/ha	Gh¢400/year/ha
Rank			

	Alternative C	**Alternative D**	**Alternative E**

Increasing output of crops	 High output	 Moderate output	 Moderate output
Water yield and storage	 High retention	 High retention	 High retention
Protection against windstorm	 Low protection	 High protection	 Low protection
Biodiversity promotion	 40% NTFP habitat	 40% NTFP habitat	 70% NTFP habitat
Money	Gh¢400/year/ha	Gh¢500/year/ha	Gh¢450/year/ha
Rank	☐	☐	☐

	Alternative F	**Alternative G**	**Alternative H**

Increasing output of crops	 High output	 Moderate output	 High output
Water yield and storage	 Moderate retention	 Moderate retention	 Moderate retention
Protection against windstorm	 High protection	 High protection	 Low protection
Biodiversity promotion	 40% NTFP habitat	 70% NTFP habitat	 70% NTFP habitat
Money	Gh¢450/year/ha	Gh¢400/year/ha	Gh¢500/year/ha
Rank	☐	☐	☐

Section D

Demographics

In this last section, I would like to ask some questions about you.

1. Are you: Male ☐ Female ☐

2. Are you: Single ☐ ☐ Married ☐

   Separated Widowed ☐

3. What is your age?

18-24 ☐ 25-34 ☐ 35-44 ☐ 45-54 ☐ 55-64 ☐ +65 ☐

4. What is the highest level of formal education have you attained?

No formal education ☐ Primary ☐ Junior High ☐ Senior High

Middle ☐ School ☐ University Other (state) ☐

____

5. Have you received any training or gained knowledge about plantation forest services?

Yes ☐ No ☐

If yes, give details: ____

6. How many hectares of degraded forest have you restored?

26.558ha ☐ 76.208ha ☐ 24.774ha ☐

7. How long have you been a resident of this community? _______ year(s).

8. Do you have any other occupation(s) aside farming? Yes ☐ No ☐

If yes, kindly state your other occupation(s) ________________________

9. Including yourself, how many people live in this household? _______

10. Excluding yourself (and your spouse), how many people in your household are gainfully employed? ________

11. What is your annual household income from all sources?

Under GhȻ100 ☐ GhȻ101-500 ☐ GhȻ501-1000 ☐

GhȻ1001-1500 ☐ GhȻ1501-2000 ☐ GhȻ2000 and above ☐

12. Do you have any other comments? ____

Thank you for your participation!

APPENDIX II

QUESTIONNAIRE FOR VALUING ENVIRONMENTAL SERVICES OF PLANTATION FORESTS (FSD STAFF)

Thank you for agreeing to participate in this study. I am a graduate student of the Kwame Nkrumah University of Science and Technology carrying out a research on the environmental services of plantation forests. I would like to seek your views on management options which could influence the flow of these services and the most essential environmental service to you. Your responses are confidential and would be used just for statistical purposes.

Name: ______________________ Contact: ______________ Position: ___________

Section A

Your preference on the extent of influence of management options

The Modified Taungya System (MTS) plantation forests yields vital environmental services as a result of forest ecosystem functions, properties or processes. These services are of benefit to society. To ensure continuous provision of these services, some plans or activities need to be implemented. It is intended that your response would help understand how you feel about plantations and recommend actions to improve their management.

Kindly indicate the extent to which each management option influences the provision of environmental services. Assign number 1 to the most important and so on for the rank section.

Management Options	***Not Important***	***Slightly Important***	***Important***	***Very Important***	***Overall Rank***
1. Fire management *Creation of fire rides *Planting of firebelt *Harmattan patrols *Fire volunteers *By-laws	1	2	3	4	
2. Prevent illegal logging *Capacity building *Create checkpoints *Periodic patrols *****Curbing corruption *By-laws	1	2	3	4	

3. Prevent illegal farming/hunting/ mining *Empower community to fish out perpetrators *Periodic patrols *By-laws	1	2	3	4	
4. Plantation maintenance *Replant patches *Beating up *Regular cleaning of boundary lines and placing signpost at vantage points	1	2	3	4	
5. Alternative livelihoods *Bee-keeping *Mushroom *Snail-rearing *Ginger/surowisa etc.	1	2	3	4	
6. Community mobilization and sensitization on plantation management	1	2	3	4	
7. Joint regular monitoring by Forest Services Division (FSD) and community members *Dealing with Fulani herdsmen	1	2	3	4	
8. Publication of timber revenue accrued and media coverage of MTS success stories	1	2	3	4	
9. Conflict identification and resolution mechanisms	1	2	3	4	

Section B

In your perspective which is more important

The MTS plantation forest ecosystems are capable of providing environmental services which are beneficial to people. The table below contains a list of such services.

Rank the environmental services according to their importance to you. The most important should be assigned the number 1 and so on. Kindly refrain from assigning the same number to two or more services.

Forest environmental services	***Rank***	***Reason (why you think they are important or not so important)***
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2. Water Regulation (improving water yield in watercourses and storages)		
3. Soil erosion control (regulate run-off)		
4. Protection against windstorms		
5. Biodiversity promotion (provision of habitat for NTFPs)		
6. Carbon sequestration (capture airborne pollutants)		
7. Air quality (modification of the microclimate)		

Do you have any other comments? ____

Thank you for your participation!

APPENDIX III

Kruskal Wallis H test results for other grouping variables

Table A. Ranking of environmental services

Forest environmental services	Variable	p-value for H test
Water regulation	Gender	0.335
	Age	0.078
	Level of education	0.060
	Household income	0.554
Nutrient cycling	Gender	0.088
	Age	0.563
	Level of education	0.122
	Household income	0.097
Biodiversity promotion	Gender	0.149
	Age	0.797
	Level of education	0.778
	Household income	0.118
Protection against windstorm	Gender	0.177
	Age	0.618
	Level of education	0.282
	Household income	0.615
Air quality	Gender	0.943
	Age	0.611
	Level of education	0.432
	Household income	0.883
Carbon sequestration	Gender	0.698
	Age	0.715
	Level of education	0.272
	Household income	0.420
Soil erosion control	Gender	0.988
	Age	0.539
	Level of education	0.105
	Household income	0.872

Table B. Ranking of management options

Management Options	Variable	p-value for H test
Fire management	Gender	0.358
	Age	0.575
	Level of education	0.560
	Household income	0.961
Alternative livelihoods	Gender	0.059
	Age	0.462
	Level of education	0.061
	Household income	0.181
Plantation maintenance	Gender	0.434
	Age	0.568
	Level of education	0.736

	Household income	0.059
Prevent illegal logging	Gender	0.116
	Age	0.628
	Level of education	0.428
	Household income	0.317
Prevent illegal farming/hunting/mining	Gender	0.076
	Age	0.645
	Level of education	0.059
	Household income	0.204
Joint regular monitoring	Gender	0.269
	Age	0.951
	Level of education	0.107
	Household income	0.458
Community mobilization and sensitization	Gender	0.728
	Age	0.096
	Level of education	0.058
	Household income	0.059
Conflict identification and resolution mechanisms	Gender	0.962
	Age	0.316
	Level of education	0.194
	Household income	0.108
Publication of timber revenue accrued	Gender	0.096
	Age	0.317
	Level of education	0.740
	Household income	0.184