COMPLETION REPORT

ITTO project RED-SPD/077 Rev.1 (F)

Rehabilitation of degraded forests for sustainable wood fuel production and climate change mitigation in the forest-savanna transition zone of Ghana

Host Government: The Government of Ghana

Executing agency: CSIR-Forestry Research Institute of Ghana

Project number:	ITTO project RED-SPD 077/12 -Rev.1 (F)
Project title:	Rehabilitation of degraded forests for sustainable wood fuel production and climate change mitigation in the forest-savanna transition zone of Ghana
Starting date:	May 2013
Duration of project:	24 months
Project cost:	Total US$ 169,359.50 ITTO US$121,662.00 Government of Ghana : US$ 47,697.50
Report type:	Completion report
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Place and date of issue:	Kumasi, July 2017

Disclaimer:
The views expressed in this report are those of the authors and do not necessarily reflect the views of ITTO or the Government of Ghana. The materials contained here are based on the authors' knowledge of the subject and how they can contribute to the sustainable management of woodfuel resources and similar project sites in and outside Ghana

ACKNOWLEDGEMENT

We are thankful to the Donors through ITTO for providing the financial support for execution of this project. We appreciate the Staff at ITTO through the Executive Director for the overall coordination and release of funds for susccessful implemtation of this project. We are especially thankful to Dr. MASUPA Kambale of the ITTO is particularly thanked for the field monitoring and guidance in the implementation of this project. The local communities have particularly noted the usefulness of the field monitoring as one exercise that boosted their morals and urged them on during the implementation of the project. The collaborators of this project particularly the Forest Services Division of the Forestry Commission represented by Mr. Emmanuel Opoku-Antwi and his technical staff at the Kintampo Forest District as well as Energy Commission represented by Mr Julius Nkansah-Nyarko are appreciated for their efforts, cooperation and contribution in the execution of the project. We would like to acknowledge the contribution of Dr. Kofi Kwakye-Ameyaw and Mr. Oppong-Sasu, Directors at the Forestry Commission, Accra for successful execution of the project.

LIST OF ABBREVIATIONS AND ACRONYMS

CBO	Community-Based Organizations
CDM	Clean Development Mechanism
CSIR	Council for Scientific and Industrial Research
EC	Energy Commission
FIP	Forest Investment Programme
FORIG	Forestry Research Institute of Ghana
FRA	Forest Resources Assessment
FSD	Forest Services Division
FSTZ	Forest–Savannah Transition zone
GHG	Green House Gas
GOG	Government of Ghana
IPCC	Intergovernmental Panel on Climate Change
ITTO	International Tropical Timber Organization
LPG	Liquefied Petroleum Gas
MARV	Measurement, Assessment, Reporting and Verification
MP	Project Monitoring Protocol
NGO	Non-Governmental Organization
NTFP	Non-Timber Forest Product
PES	Payment For Environment Services
PTC	Project Technical Committee
REDD	Reducing Emissions from Deforestation and Forest Degradation
REDD+	Reduced Emission from Deforestation and Forest Degradation-Plus
REDDES	Reducing Deforestation and Forest Degradation and Enhancing Environmental Services
R-PP	Readiness Preparation Proposal
SFM	Sustainable Forest Management
SPSS	Statistical Package for Social Science
SZ	Savanna Zone
TPD	Thematic Program Document

CONTENTS

EXECUTIVE SUMMARY

Wood fuels account for over 85% of the total energy consumption of West Africa. In Ghana, wood fuel consumption nearly doubled in recent decades in response to population growth and inaccessibility to alternative energies. In rural areas, over 90% of households depend on wood fuel for cooking. Woodfuel (charcoal and firewood) is a primary source of energy accounting for 60% of total energy consumption in Ghana. Over reliance on woodfuel has contributed to accelerating the rate of natural forest depletion particularly in the forest-savanna transition, where the bulk of supplies are produced. The government of Ghana has consequently become increasingly concerned about the need to preserve the country's forest resources while meeting energy needs. Better management of wood fuel supply particularly through on-farm woodlots in agroforestry systems would help meet energy demands and support natural forest conservation. This ITTO project SPD RED/077-12 Rev (1) aimed at contributing to the sustained socio-economic development of forest dependent communities and reduction in forest degradation in the forest savanna transition of Ghana through the promotion of smallholder and commercial tree plantations that could ensure sustainable resource base for charcoal and other wood energy production, marketing and carbon sequestration. Project activities were executed from May 2013 to the end of December 2016. Baseline studies were conducted using PRA tools, household questionnaire interviews and field surveys to assess the nature of dependency on wood resources, vulnerability of livelihoods and gather data for defining subsequent project field and laboratory activities. Woodfuel trial plots were established with preferred highly productive species in tree-crop mixtures using a farmer participatory on-farm experiments, their silvicultural regimes developed and tree growth assessed; energy profiles of test species were determined using standard laboratory tests; biomass and carbon production potential of test species determined; local people's perception of natural regeneration of wood fuel species assessed, economics of woodfuel trials assessed using cost-benefit analysis and a plan for managing woodfuel resources developed using stakeholder dialogue fora.

Major results achieved are:

1. Baseline information documented on woodfuel species, local knowledge on their uses and ecological characteristics, regeneration potential, availability and distribution in community land use systems, nature of supply and value chains, silviculture as well as resource management options
2. Capacity of smallholder farmers built in establishing multipurpose woodfuel woodlots with a mix of native (*Pterocarpus erinaceus, Anogeissus leiocarpus, Khaya segalensis)* and exotic (*Senna siamea, Acacia spp*, and *Azadrachta indica)* species in food crop fields.
3. Fifty test plots of wood fuel species were installed with farmers in six communities in the Kintampo North and Nkoranza Districts. A total of 18,200 seedlings covering 18ha were inter-planted with food crops from 2014-2016 with 70% success. The 30% loss was a result of harsh weather conditions, wildfire, termite and livestock damage
4. Capacity of 3 Ghanaian undergraduate students of the Faculty of Renewable Natural Resources (FRNR), KNUST were built through their involvement in research design, field data collection processing and report preparation to produce 3 dissertation/thesis documents.
5. The biomass and carbon production potential of the wood fuel species on test/trial plots. Results indicate that above ground biomass range between 80 tons/ha for Ptericarpus sp to 160 tons/ha for Acacia sp. Accacia and Cassia though exotic species have the best potential for both biomass and carbon storage ability for a five years rotation plantation. Khaya segalensis and Anogessis spp that are indigenous species were the next with impressive potential for Biomass (136 tons/ha, 132 tons/ha) and carbon storage ability of 2794 and 2873 Net GHG/Tcer respectively.
6. Laboratory tests on the suitability of the woodfuel tree species for either fuelwood or charcoal were conducted. The calorific values of *Azadrachta indica*, *Senna siamea*, *Anogeissus leiocarpus*, *Afzelia*

africana, *Pterocarpus erinaceus* and *Khaya senegalensis* and thier gravimetric or charcoal yields have been determined. Results indicates that *Afzelia africana, Khaya senegalensis, Pterocarpus erinaceus, Azadrachta indica* have the highest green moisture content (mc), volatile matter (vm), ash content and fixed carbon content respectively. *Pterocarpus erinaceus* gave the highest gravimetric yield for charbonization, which correlated very well with green density of the tree species. Of the 6 tree species studied *Afzelia africana* has the highest calorific value of 5.17 kcal/g for fuel wood and *Azadrachta indica*, the highest value of 6.79 kcal/g for charcoal. The indigenous tree species performed very well comparable to the exotic species based on the above properties, the indigenous species will be good species to be combined with the exotic species for use in agroforestry or wood fuel plantation to advance environment and improve biodiversity

7. Economic analysis indicate that wood production from woodlots is profitable returning NPV of GH¢13,000 and B/C ratio of 2.9 at a market discount rate of 25% over 25 year production period

Results from field trials are relevant for the implementation of the Ghana Forest Plantation Development Strategy (GFPDS) 2016-2040. The GFPDS has recommended establishment of woodlots for charcoal and firewood using *Senna siamea*, Acacia and Azadirachta in the savannah and transition zones to meet the high demand for wood energy in the country. Results from field trials indicate that site-species matching will be critical in wide spread promotion of energy woodlots in communities in the savannahs of Ghana due to long drought, high temperatures, wildfire and cattle browsing. Also high costs of weed management is critical to plant growth and would require innovative planting designs based on security of tenure and cropping systems. It is recommended that *Senna siamea, Azadirachta indica* and *Anogeissus leiocarpus* be promoted in this zone since these species can withstand extreme weather conditions and pest incidence. The species grow quite fast with limited rain and are also not susceptible to browsing by cattle. Wider spacing from 4ft x 4ft to 6ft x 6ft to would need to be adopted permit longer integration of food crops such as pepper, maize, millet and sorghum till the wood is harvested for fuel. This allows for maintenance of the plot to enhance tree growth.

1.0 IDENTIFICATION

1.1 Context

The forest-savannah transition belt of Ghana is a predomantly woodfuel (charcoal and firewood) producing zone including Kintampo North and Nkoranza North Districts of the Brong Ahafo Region of Ghana where the project was undertaken. Kintampo North and Nkoransa North Districts are located in the Kintampo Forest District in the Brong Ahafo Region of Ghana (Figure, 1) with population of 96,358 and 65,895 respectively. The districts are charactersized with the Wet-semi equatorial type of climate and mean annual temperature and rainfall of 27^{o} C and 1,800 mm respectively. The vegetation is savanna woodland with scattered trees including *Acacia spp.*, *Anogeissus leiocarpus, Pterocarpus erinaceus* and *Vitellaria paradoxa*. Traditionally the local economy is agrarian based on the production of yams, maize, cassava, groundnuts and woodfuel (charcoal and firewood). Commercial charcoal and firewood production is a culture and a dominant economic livelihood activity that has contributed to deforestation and forest degradation in the area. The aim of the ITTO Small project RED SPD 077/12- Rev (1) was to analyze the socio-economic and agro-ecological contexts of the area and initiate the development of multipurpose woodlots in smallholder systems for sustainable woodfuel production and climate change mitigation on trial basis and wider application in Ghana and beyound.

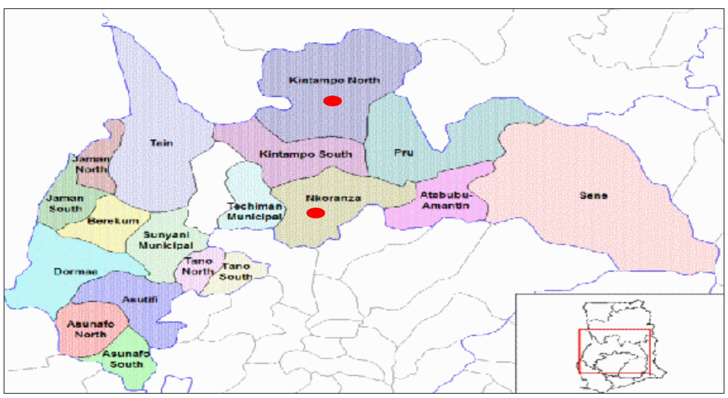

Figure 1: District Map of the Brong Ahafo Region showing project areas

The project contributes to addressing global and national development goals on sustainable use of resources, poverty reduction, and environmental restoration in communities. Specifically, it will contribute directly to the attainment of Goal 15 of the Sustainable Development Goals (SDGs) i.e. *Life on Land - Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss*. Nationally, it addresses nationwide concerns of environmental degradation caused by indescriminate wood harvesting for commercial woodfuel production especially with current decline in agricultural productions as a result of the adverse effects climate. The government of Ghana through the Ghana Forestry Commission has instituted 40 year national plantation development strategy for sustainable supply of wood including fuelwood (FC, 2016). It is anticipated that this would contribute extensively to natural forest conservation and carbon sequestration.

1.2 Origin and problem

The most important product derived from forests and woodland is fuelwood, which accounts for over 85% of the total energy consumption of West African countries and provides most household energy needs. The

Intergovernmental Panel on Climate Change (IPCC) fourth assessment report on mitigation of climate change indicates that fuelwood is the only source of fuel for one third of the world's population with a demand expected to double in the next 50 years. Worldwide harvesting of wood is estimated at 60% industrial round wood and the remaining 40% as wood fuel, primarily charcoal and firewood (IPCC, 2007).

In Ghana wood fuel consumption increased from 18.4 million m3 in 1990 to 33 million m3 in 2006, largely in response to population growth. Wood fuel consumption constitutes 60% of the total energy mix in the country (IEA, 2014). A recent study on forest dependency in the transition zone of Ghana indicates that the most exploited product from natural forest is fuelwood mainly for charcoal and firewood production for sale in high demand urban areas (Obiri et al. 2014a). Commercial charcoal production from natural standing trees in many farming communities and particularly in the transition zone where the project was undertaken is a major livelihood activity in which most households undertake all year round to supplement agricultural income. The over reliance on woody biomass as household and industrial energy generally in the country, has contributed significantly to accelerating the rate of natural forest depletion. It is estimated that, between 1990 and 2010, Ghana lost almost 34 percent of its forest cover, representing about 2.5 million hectares (FRA, 2010). This corresponds to an annual deforestation rate of approximately 2%.

Although, national land use policies acknowledge the sustainability and effective utilization of wood resources, there have not been any concerted efforts to develop and manage forest resources especially for wood fuel purposes until recently. The bio-energy policy of Ghana stresses the need for development of fuelwood plantations for continued supply of wood energy in the country (EC, 2010). Also, although contributes to environmental degradation, fuelwood production from plantations in recent discourses is being considered as a more sustainable forest based enterprise that could offer a leverage for addressing poverty and environmental problems. This is because appropriate species of high calorific values can be produced in woodlots in shorter rotation systems. The coppicing potential of some species if well managed ensures a reliable supply of wood material and thus contributes to arresting deforestation while enhancing climate change mitigation and biodiversity conservation.

2.0 PROJECT OBJECTIVES AND IMPLEMENTATION STRATEGY

2.1 Rationale

2.1.1 Conformity with ITTO objectives

The project is in accordance with Article 1 of the International Tropical Timber Agreement, 2006, in particular the objective of:

- Encouraging members to support and develop tropical timber reforestation, as well as rehabilitation and restoration of degraded forest land, with due regard for the interests of local communities dependent on forest resources;
- Encouraging members to develop national policies aimed at sustainable utilization and conservation of timber producing forests, and maintaining ecological balance, in the context of the tropical timber trade;
- Encouraging members to recognize the role of forest dependent indigenous and local communities in achieving sustainable forest management and develop strategies to enhance the capacity of these communities to sustainably manage tropical timber producing forests

It is also in accordance with REDDES programme objectives and in particular the general objective of reducing deforestation and forest degradation and enhancing environmental services through the sustainable management of tropical forests, forest restoration, afforestation, reforestation and other related activities. More specifically under demonstration activities:

(a) Restoration of degraded forests and rehabilitation of degraded forest lands

(c) Sustainable forest management planning and implementation activities within the context of multiple use and environmental services (e.g. reduced impact logging, silvicultural measures, etc.)

(d) Participatory approaches involving indigenous and other local groups in planning and implementing forest management including benefit sharing from compensation schemes for forest environmental services.

(g) Other measures to reduce emissions from deforestation and forest degradation and to enhance environmental services from tropical forests (e.g. development of alternative livelihoods schemes, agroforestry systems, etc.)

2.1.2. Relevance to Ghana Forestry and Energy Sector Policies

2.1.2.1 Ghana Energy Sector Policies on Wood Fuel

The project is relevant to Ghana's energy sector policies on wood fuel which seeks to promote and ensure sound management and expansion of the country's natural forest for sustainable supply of wood fuel.

The policy strategies include:

- Support for Non-Governmental Organizations (NGOs) and Community-Based Organizations (CBOs) to create awareness for the development and management of suitable wood fuel species.
- Identification and provision of incentives (financial and non-financial) for the development of woodlots in savannah and transitional zones under international funding protocols such as the Desertification Fund and Clean Development Mechanism (CDM) Fund
- It also encourages the collaboration between the District Assemblies and Traditional Authorities to educate and release land to prospective individuals (especially women) and groups for wood fuel woodlots and plantation establishment.

2.1.2.2 Ghana Sectoral Policies on Forest and Wildlife

The objectives of this project are in conformity with the overall goal of Ghana's New Forest and Wildlife Policy and the Forestry Department master programme (1996). This is to conserve and sustainably develop the nation's forest and wildlife resources while maintaining environmental quality and perpetual flow of benefits to all segments of society. Specifically, the priority objectives of the Forest and Wildlife Policy include:

- Manage and enhance Ghana's permanent forest estate for conservation of biological diversity and sustainable production of domestic and commercial produce; and
- Promote research-based and technology-led forestry and wildlife management, utilization and development to ensure resource availability, socio-economic growth and environmental stability.

Strategies outlined in the Forestry and Wildlife Policy and supported by the proposed project are:

- Emphasis will be placed on reforestation initiatives towards restoring a significant proportion of the country's original forest cover;
- The dedication of various land categories with potential for nature protection and production of timber and other products;
- Revision of resource management standard and techniques for preparation, detailed prescriptions and plans to guide the sustainable management of forest reserves;
- Promotion of resource development programmes aimed at reforesting suitable harvested sites;
- Regulation of utilization and trade in highly valued and endangered species in order to eliminate the threat of extinction, encourage regeneration and ensure future supplies.

2.1.2.3 Key programs on Climate Change in Ghana

According to Ghana's REDD+ Readiness Preparation Proposal (R-PP) development, the creation of an expert working group on charcoal and fuelwood production will seek to establish an authoritative knowledge base on charcoal and fuelwood, which is able to discriminate between different production systems, and which takes into account livelihoods dimensions and alternatives (or their lack). It will aim to provide recommendations for potential pilot projects for substitute fuels and means of production. This small project will also contribute to existing interventions and recommendations for REDD+ in Ghana. The project has also been executed in synergy with other ongoing ITTO-Supported Projects on forest and climate change mitigation including:

- Reducing Emissions from Deforestation and Forest Degradation through Collaborative Management with Local Communities which seek to contribute to sustainable management and conservation of Ankasa Conservation area to improve the provision of environmental services and reduce GHG emissions. The project specifically developed and implemented participatory, good governance and management system for the Ankasa conservation area, determine the financial value of the environmental services as well as methods for measurement, assessment, reporting and verification (MARV) for forest carbon

- Capacity building for CDM forestry in the framework of SFM emphasizing community forests and poverty alleviation in Ghana seeks to develop the capacity for CDM forestry in Ghana via a community rehabilitation of Ghana's degraded forests targeted at poverty alleviation in conjunction with sustainable forest management (SFM). Specifically the project aims at improving capacity for CDM forestry in Ghana via a community forest targeted at poverty alleviation in conjunction with SFM.

2.2 Development objective

The development objective of the project is to contribute to the sustained socio-economic development of forest dependent communities and reduction in forest degradation in the forest savanna transition zone of Ghana through the promotion of smallholder and commercial tree plantations that could ensure sustainable resource base for charcoal and other wood energy production, marketing and carbon sequestration.

2.3 Specific objective

To initiate a process for establishing wood fuel plantations in collaboration with local communities and entrepreneurs through reforestation of degraded lands in the forest savanna transition zone of Ghana for sustainable charcoal/wood energy production and enhancement of above and below ground carbon stock

Expected project outcomes

1. Build local capacity in nursery management and wood lot establishment
2. Demonstration plots of highly productive wood fuel species established in selected communities
3. Technical information on silviculture, energy characteristics of wood fuel test species, biomass and carbon potential, economics of woodfuel plantations, potential impact on livelihoods
4. Wood fuel resource management plan
5. Publications for dessemination of project rsults

2.4 Implementation strategy

Project activities were executed from project inception in 2013 to 2016 following the execution of 4 work packages outlined in Figure 2. Baseline studies were conducted using PRA tools, household questionnaire interviews and field surveys to assess the nature of dependency on wood resources, indigenous ecological knowledge of woodfuel species on their phenology and availability, ecological assessment of priority woodfuel species, vulnerability of livelihoods to gather data for defining subsequent project field and laboratory activities.

Woodfuel trial plots were established with preferred highly productive species in tree-crop mixtures using a farmer participatory on-farm experiments, their silcultural regimes developed and tree growth assessed; energy profiles of test species were determined using standard laboratory tests; biomass and carbon production potential of test species determined; local people's perception of natural regeneration of wood fuel species assessed, economics of woodfuel trials assessed using cost-benefit analysis and a plan for managing woodfuel resources Developed using stakeholder dialogue fora.

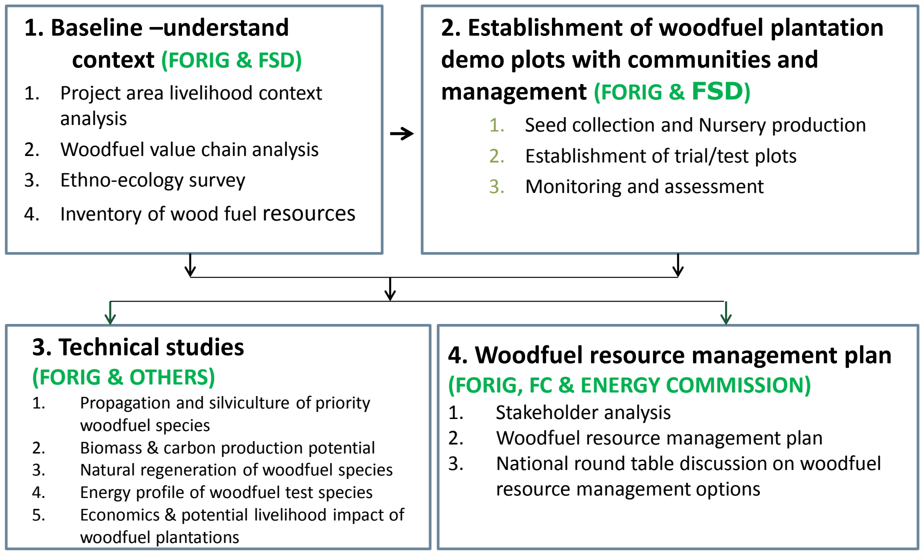

Figure 2: Project execution framework

Major project activities and methodologies applied under each of the work packages are outlined below:

2.4.1 Baseline studies

I. Participatory and quantitative questionnaire survey methods were used for characterizing local livelihoods context including their vulnerability to climate change and value chain analysis of the associated wood fuel economy in the project areas. The data collected has been analyzed descriptively.

II. Wood fuel tree resource inventories were conducted with communities using 1 hectare sized plots to determine species abundance/richness and description of characteristics of dominant and key species. The data collected has been analyzed descriptively.

III. An ethno-botanical survey of woodfuel species used in the project areas was also conducted using key informant interviews, open-ended questionnaires and and field observations to assess their availability, use trends, ecological and phenological characteristics among others. The data collected has been analyzed descriptively.

IV. Questionnaire surveys was conducted to document local knowledge on natural regeneration of wood fuel species from the perspective of respondents in selected communities in project districts as well as identify socio-economic and environmental factors affecting the successful regeneration of woodfuel species and management of coppice growth. The data was analyzed descriptively and differences in responses between sites were tested using Mann Whitney U test.

2.4.2 Field experimentation and evaluation

I. Preparatory stakeholder dialogue meetings
   - Local level workshops of communities and technical experts in forestry and wood energy sectors was organized to thoroughly discuss and screen options for sustainable wood fuel resource development

II. Prioritized wood fuel development options were planted on demonstrations plots to be managed by volunteer experimenters on their privately owned lands

III. Scientists and FSD technical experts assisted experimenters with technical knowledge to plant and manage their test plots using appropriate rotation strategies and planting (block and mixed) patterns. Farmers were also supported with material incentives including quality fast growing planting materials, to enhance survival and growth as wellas cutlasses and wellington boots to support their farm operations particularly weeding and general maintenance of the planted fields. Wood fuel species planted were determined by stakeholders and comprised a mix of both indigenous and well researched and tested exotics species that could easily be managed by both smallholder and larger scale experimenters. Consideration was given to fire tolerance and nitrogen fixing species and also planting regimes that would ensure compatible agri-silvicultural or tree-agricultural crop mixes in temporal and/or spatial sequences.

IV. Monitoring and evaluation of test plots

- A monthly monitoring schedule was followed after establishment of the trial plots and necessary technical backstopping provided to maintain test plots. During this period, data was collected for the following analyses:

  ✓ Tree performance i.e. survival and growth (vegetative, stem and girth) for estimating biomass production potential of trial wood fuel species.

2.4.3 Technical studies

2.4.3.1 Biomass and carbon production potential of woodfuel species in test/trial plots

Carbon dynamics and vegetation carbon cycle modeling approaches was employed for potential biomass and carbon stock assessment. Data on height and diameter was collected on the test species on 4 well established farmer plots in 2 communities i.e. and Babatokuma in the Kintampo North District 2 years after planting. Each farmer plot had five subplots; of which subplots represent the treatments (tree species) with a planting distance of 4 m×4 m. Average planting densities were 858.7, 965.7, 965.7, 795.0 and 927.6 trees/ha for *Acacia mangium*, *Anogeissus leiocarpus*, *Azadirachta indica*, *Khaya senegalensis* and *Senna siamea* respectively. Silvicultural practices for tending included regular weeding, beating up and watering. Ten trees of each species were randomly sampled on each subplot, making up 50 sampled trees per plot and a total of 200 trees for measurements of diameter (mm) at 0.1m (10 cm) aboveground and total height (cm) using a caliper and steel tape respectively . Mean diameter, mean height, aboveground tree biomass and carbon sequestered were calculated for each plot. Aboveground tree biomass was estimated using the equations:

$Y = \exp[-1.996 + 2.32 \ln(DBH)]$ (Brown *et al*., 1989).

$Y = 0.153\,(DBH)^{2.382}$ (IPCC, 2003) and $M = A\,(DBH)^{B}$ (Yeboah, 2011) Where; Y and M are tree biomass in kilograms, DBH is the diameter in centimeters,

ln is natural logarithm.
A=0.051 and B=2.47 are scaling coefficients.

Carbon was estimated on the assumption that 50% of a tree‟s biomass is carbon (Nair, 2011).
Tree density per hectare was estimated as:

$$\text{Tree density} = \frac{\text{number of individuals} \times 10000}{\text{subplot area } (m^2)}$$ (Opuni-Frimpong *et al*., 2013).

The calculated density per hectare was multiplied by the individual tree average for above ground biomass and carbon stock.

2.4.3.2 Silvicultural management prescriptions for woodfuel species

Information on silvicultural management regimes for species in woodfuel test plots was compiled through field observations, literature and knowledge from the PROTA database. The information has been synthesized into a handbook

2.4.3.3 Laboratory chemical analysis of wood fuel species on test plots using standard tests

Laboratory studies were conducted to determine the biomass and energy content of six (6) tree species comprising of two (2) exotic tree species *Azadrachta indica* and *Senna siamea* and four (4) indigenous tree species of *Anogeissus leiocarpus*, *Afzelia africana*, *Pterocarpus erinaceus* and *Khaya senegalensis* used for wood fuel production planted in test plots. The tree species are among the most common species employed in wood fuel production in the forest transition zone of Ghana. Small size log samples of the species were collected from the Kintampo North District of Ghana for the analysis. The wood fuel products, fuel wood and charcoal were characterized for their suitability as fuel based on Moisture Content (MC), Volatile Matter (VM), Ash Content (AC) and Fixed Carbon (FC).

2.4.3.4 Cost and benefits of wood fuel plantations
Ex-ante economic analyses of the options experimented to access viability using the cost benefit methodology. Profitability indicators estimated are the Benefit Cost Ratio (BCR) and Net Present Values (NPV)

2.4.3.5 Potential impact of woodfuel plantations on livelihoods and environment
Questionnaire survey of 100 participants/registered volunteer farmers involved establishing woodfuel woodlot trials was conducted to determine the potential social, economic and environmental impacts of wood fuel plantations on local livelihoods. The data was analyzed descriptively.

2.4.4 Policy and stakeholder dialogue for development of woodfuel resource management plan
- Local, district and national level workshops of stakeholders in the wood energy, environment and forest sectors have been engaged to thoroughly discuss, design and draft a plan for wood fuel resource development and management.

3.0 PROJECT RESULTS/ OUTCOMES
3.1 Baseline studies
Baseline socio-economic, value chain, ethnobotany and ecological studies were conducted to provide information for the establishment of nursery and field trials, technical studies, policy and institutional analyses for development of woodfuel resurce management plan. Key results are detailed in the sections that follow.

3.1.1Socio-economic study
The objective of the socio-economic study was to understand the local context with respect to the agro-ecosystem in the project area to facilitate execution of other project activities. Specifically, it was also to help understand the agro-ecological production - consumption system, identify and analyze constraints and opportunities associated with the woodfuel sector and the extent of vulnerability of wood fuel dependent livelihoods to climate change effects. Results from the questionnaire survey of household heads are as follows:

3.1.1.1 Socio-demographic profile of respondents/households

Generally most households are headed by males in Ghana. The random sample of respondents interviewed was in both Kintampo North (KN) and Nkoranza North (NN) was dominated by male household heads. Ninety-one percent of the respondents in KN were male household heads while male constituted 87% of respondents in NN. The mean household sizes are about eight in both districts (Table 1).

Table 1: Household size in project communities

DISTRICT	MIN	MAX	MEAN
KINTAMPO NORTH (KN)	1	23	8.4
NKORANZA NORTH (NN)	1	16	8.2

In the Kintampo North district, primary education level was about twenty one percent and about thirty-nine percent was recorded for middle and no education. However in Nkoranza North, secondary and primary was about four percent, middle school dominated with seventy-nine percent and no education had approximately thirteen percent (Figure 5).

About half of the people in KN and three quarters of the people from NN are natives. Migrant population is about seventeen in both districts. However the settlers, had thirty one percent for KN and about eight for NN. The mean number of years respondents from KN and NN have lived in their community is 35.2 years and 34.8 years respectively. The minimum and maximum number of years lived in communities in KN are 5 and 75 years respectively and that from NN are 13 and 55 years respectively.


Plate 1: Socio-economic interviews

With respect to occupation, both districts had seventy one percent for farming as the main occupation. Figure 3 shows the trend in secondary occupation in both districts. Majority of the people were engaged in charcoal production in KN and NN districts. Other economic activities undertaken by respondents from KN District are firewood production (5.7%), charcoal trading (14.3%), artisanal jobs (2.9%), petty trading (2.9%) and chainsaw operation (2.9%). Respondents from NN District are also engaged in trading (4.2%), dealing in charcoal (4.2%), artisanal jobs (8.3%), government work (4.2%) and chainsaw operation (8.3%) (Figure 3).

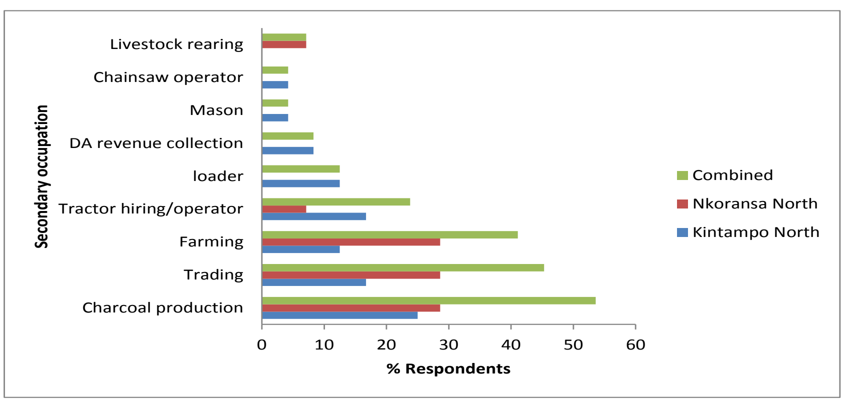

Figure 3: Secondary occupation pursued by respondents in KN and NN

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Table 2: Sources of monthly income

	Farming	charcoal production	Tractor hiring/operator	Livestock rearing	Artisan	District Assembly revenue collection	Trading	Chainsaw operator	Charcoal loading	Driving
Kintampo North	x	x	x	x	x	x	x	x	x	
Nkoransa North	x	x	x	x	x		x	-	-	x

Average monthly income of respondents from KN is 423.44 Ghana cedis with the minimum and maximum income being 30 and 3000 Ghana cedis respectively. Respondents from NN earn an average of 672.27 Ghana cedis with the minimum and maximum salary being 100 and 3000 Ghana cedis respectively.

3.1.1.2 Land resources and mangement

Land availability

Land tenure

Land size

Land use

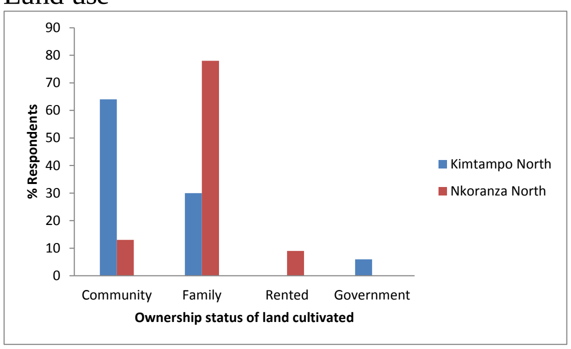
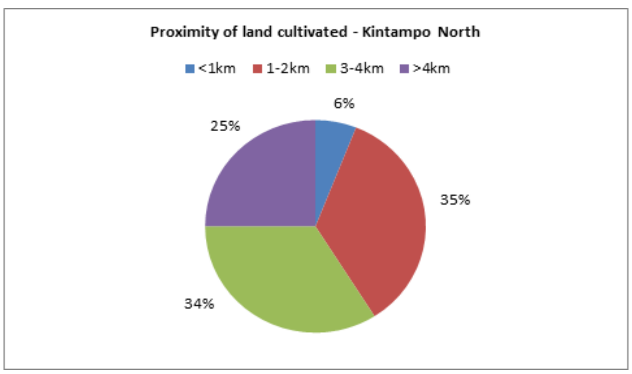


Figure 4: Tenure to land used by respondents

Figure 5: Farm land sizes cultivated



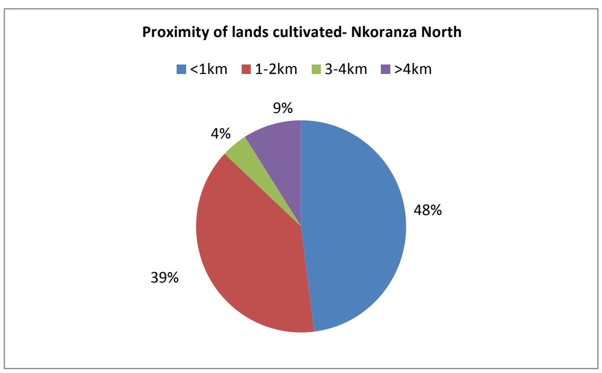


Figure 6: Proximity of land cultivated in KN

Figure 7: Proximity of land cultivated in NN

3.1.1.3 Agricultural production

Crop production

Livestock production

Production constraints

Crop production

Cropping pattern

Majority of the respondents do not practice mixed farming in the KN (87%) and NN (96%) districts

Table 3: Crops cultivated in Kintampo North and Nkoransa North Districts

District	**Food Crop**	**Average Annual Yield**	**Average Proportion sold (%)**	**Average Proportion consumed (%)**
Kintampo North	Yam (N=26)	973 pieces	59.6	49.2
	Maize (N=30)	9.8 bags	62.2	56.3
	Okro(N=4)	22bags/baskets	96.5	4.7
	Cassava (N=18)	6.8 tracks/bags	81.3	55.6
	Rice (N=14)	11.7 bags	69.5	43.5
	Groundnut (N=6)	9.3 bags	88.0	26.7
	Pepper (N=2)	1.5 bags	86.0	14.0
	Beans/Cowpea (N=3)	7.3 bags	83.3	25.0
Nkoranza North	Yam (N=19)	1150 pieces	59.5	67.4
	Maize (N=19)	18.4 bags	80.7	21.0
	Okro (N=1)	25 baskets	95.0	5.0
	Cassava (N=6)	2.2 bags/tracks?		
	Groundnut (N=4)	6 bags	85.0	15.0
	Pepper (N=4)	20.8 bags	99.3	1.5
	Beans/Cowpea (N=2)	5 bags	87.5	12.5
District	**Cash crop**	**Average Annual Yield**	**Average Proportion sold (%)**	**Average Proportion consumed (%)**
Nkoranza North	Cashew (N=9)	10 bags	100.0	0.0

Majority of the households' rear animals in both districts (77% Kintampo and 70% Nkoranza)

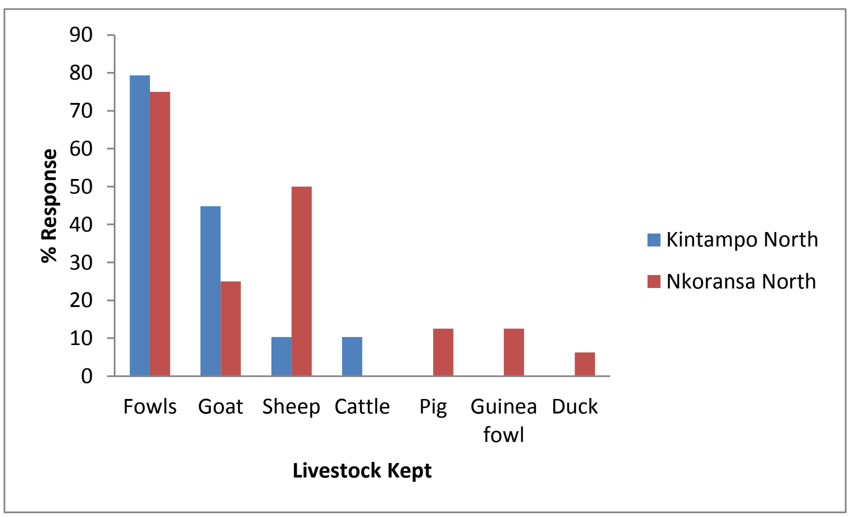


Figure 8: Livestock types reared

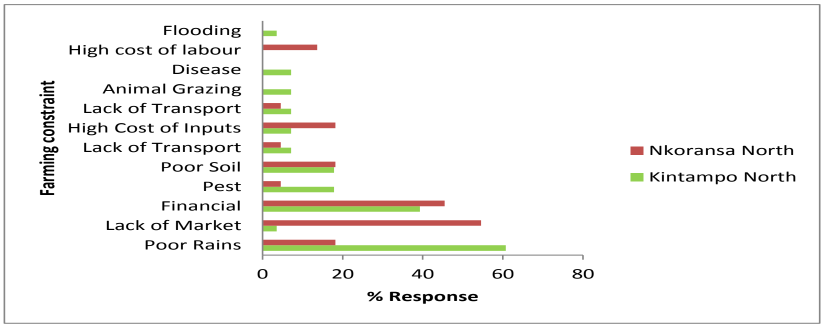


Figure 9: Contraints to crop production in the KN and NN districts

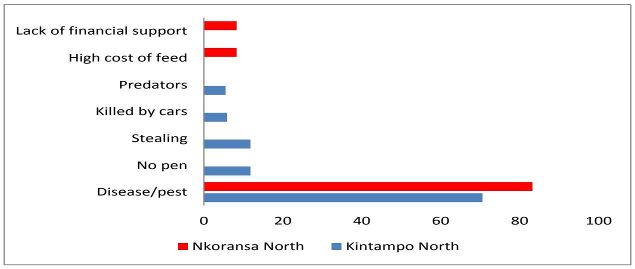


Figure 10: Contraints to livestock rearing in the KN and NN districts

3.1.1.4 Woodfuel resources, management and utilization
Tree/forest resources
Tree tenure
Sources of woodfuel
Wood fuel species and their characteristics
Species availability and management
Challeges in woodfuel resource management
Determinants of woodfuel dependency
Charcoal and firewood production

Over 90 % of respondents in both districts have trees on their farms. The most frequently mentioned include Krayie (*Pterocarpus erinaceus*), Kane (*Anogeissus leiocarpus*), Senya (*Daniellia oliveri*), Kranku (*Vitellaria paradoxa*) Dawadawa (*Parkia biglobosa*), Potrodom (*Erythrophleum africanum*), Papao (*Afzelia Africana*) and kerekekye (*Hymenocardia acida*) (Figure 11). Nearly all, these species are commonly used for woodfuel, particularly charcoal production in both districts.

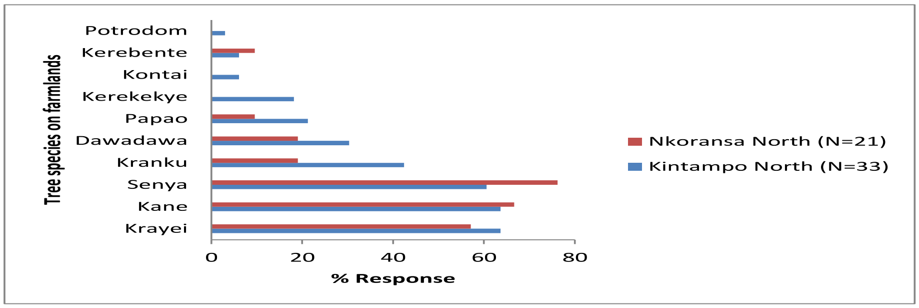


Figure 11: Tree species found on farms of respondents
Note: Percentages are based on multiple responses

3.1.1.5 Vulnerability context

3.1.1.6 Conclusion and implications for research and policy/development

3.1.2 Woodfuel value chain survey

3.1.2.1 Overview of the woodfuel value chain

A value chain is a set of activities that a firm operating in a specific industry performs in order to deliver a valuable product or service for the market. As a product moves from the producer to the consumer, a number of transformations and transactions take place along a chain of interrelated activities, and value is added successively at each stage. Value chain analysis (VCA) focuses on all categories of key actors and their relations at all levels and their often-complex networks that influence value creation along the chain. According to Kaplinsky and Morris (2001), VCA offers a framework to analyze the activities and processes involved in taking a product from the forest, eventual production, transformation and processing to delivery to final consumers and ultimately disposal. Value chains do adapt and respond to local conditions, policy and institutional environment, market power and consumer preferences, among other things. Some of these factors shaping value chain evolution may not be optimal from a social welfare standpoint. The aim of value chain analysis, therefore, is to analyze the organization and behavior of all the participants and their respective activities in the value chain, to diagnose the constraints and problems that they face, estiamte profit distribution along the chain, and to identify public actions that may enhance the performance of the value chain and contribute to national policy objectives. The basic elements, transactions, etc. of the woodfuel (charcoal and firewood) in the Kintampo Forest District are presented in the sections that follow.

3.1.2.2 Charcoal value chain

3.1.2.2.1 Socio-demographic characteristics of actors

Gender and Age Distribution of Respondents

From the study 85.5% of the charcoal producers were males while the remaining 14.5% were females. On the other hand 44% of the charcoal marketers are males while the remaining 56% are females. With the charcoal transportation, it wholly dedicated to the males as they dominate that particular sector of the chain. The study indicates that charcoal production is male dominated whiles marketing is reserved for females. Male dominance in charcoal production is associated with the very tedious operations and intimate practical knowledge of the principles of combustion. More so charcoal production activities are labor intensive and muscular in nature therefore difficult for the females to undertake such activities. All the respondents involved along the charcoal chain are above the age of eighteen for the producer, although there were some young ones understudying the trade for the elderly. The mean age of charcoal producers was 26 years, with maximum age of 65.

Educational status

Figure 12 shows that greater proportion of the charcoal producers have no formal education compared to the marketers and transporters. About 51% of the charcoal transporters have attained education to the middle/JSS level, this is associated with the need for one been able to read and/or write before handling a driver licenses. None the charcoal producers and marketers have attained education to the SHS level.

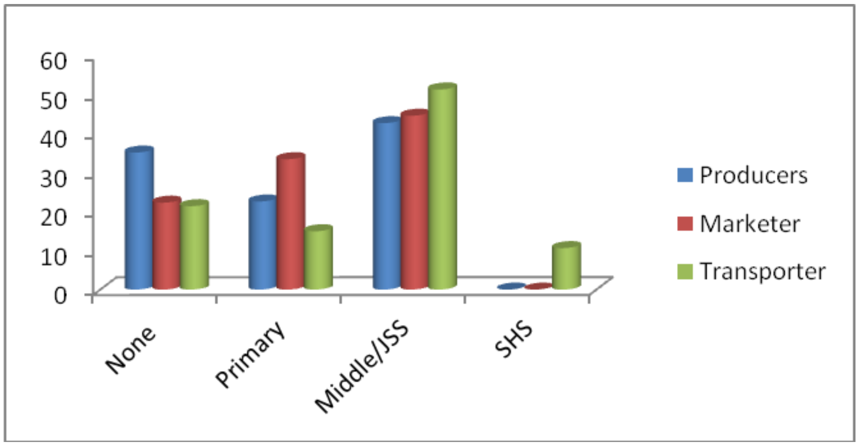


Figure 12: Level of formal education
Source: Field Survey, 2013

3.1.2.2.2 Charcoal value chain activities and transactions

The charcoal value chain in Ghana is quite well established with distinct production, transportation and retail line although the charcoal value chain is informal. Results indicate that the charcoal value chain is not linear but a web with many actors overlapping from one stage of the chain to the next. The basic elements, actors and activities they perform and relationships in the form of transactions undertaken to acquire wood, process into charcoal, distribute to traders and consumers in the study districts is illustrated in Figure 13

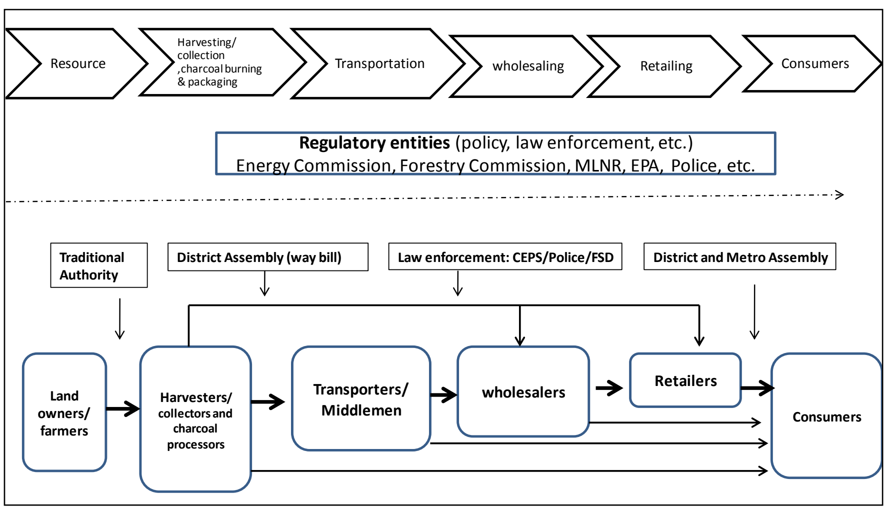


Figure 13: Map of the Charcoal Value Chain in Kintampo Forest District
Source: Field Survey, 2013

Wood is secured from farmlands owned by producers and often has to be acquired at a fee except in cases where the producer or supplier owns the farmland. Labourers including chainsaw operators are engaged in preparing the wood for burning by cutting into chunks for bigger diameter logs. The supply/value chain involves three categories of traders i.e. the roadside dealers (usually in production areas), truck dealers/transporter middlemen and traders usually women in consuming areas. Supplies are usually collected and sold at the producing points where there is access route or hauled to the road side and sold to a truck dealer or transporter/middleman. The truck dealer/transporter/middlemen may either deliver to traders in markets for wholesaling/retailing to consumers (food processors or households, institutions, exporters) or deliver directly from the truck to the consumer (Figure 13). Direct supply from producer to the trader at sale points on urban markets prevails.

The activities of several regulatory entities also influence the performance of the charcoal value chain. At the resource or producing areas traditional authority particularly the chiefs may give out community lands to be harvested at a fee or may impose regulations on species and quantities of wood to be harvested to protect the resource. The Forest Services Division (FSD) regulates harvesting of wood from legal sources and also issue paid permits as conveyance certificates for charcoal enroute to market. The police and customs officers check authenticity of conveynance certificates from the FSD accompanying charcoal being transported to market. The District Assembly collects tolls at the farm gate/loading point in the producing communities on each load of charcoal transported to the market. The distict and metropolitan assemblies also collect tolls on deliveries on markets.

According to Sepp and Mann, (2009) the value of wood used for charcoal production is not reflected in the value of the charcoal. From the study most of the charcoal is made from indigenous wood species, which are either cleared for farm-land extension or as an income generating activity on government land or on individual farms. In other cases, charcoal producers are contracted to make charcoal from other people's farms after which they share the charcoal with the owners.

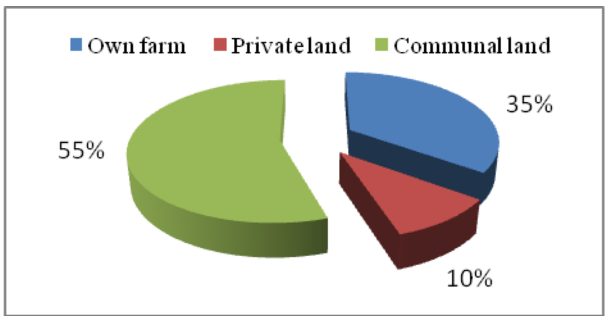


Figure 14: Source of wood for producing charcoal
Source: Filed Survey, 2013

Fifty-five percent (55%) of the charcoal producers interviewed obtain wood for charcoal from their communal land which comes at no cost. With the remaining obtaining it from their private (10%) and own (35%) land (Figure 14). In the charcoal production, wood harvesting is done by the producers, who cut the wood and stack it systematically in a pile into an earth mound kiln. Piled wood in is then covered with grass and sand. The kiln is then fired and left for between seven and fourteen days for the charcoal to be ready depending on the quantity of wood fed into the kiln. After cooling, the charcoal is offloaded from the kiln and packed into bags which range from 35 to 50 kilograms with 40kg being the average. The charcoaling process, from tree felling to packing takes between 10-21 days depending on the quantity of wood fed into the kiln.

Plate 2: Charcoal awaiting conveyance at the roadside   Plate 3: A truck load of charcoal ready to be transported

The packed charcoal is sold to the transporters at the charcoaling site or transported to the roadside, mostly using human labour tractor or donkey carts, awaiting customers who are either transporters to the urban centers or consumers who directly procure their charcoal from the charcoalers. The transporters or wholesalers who assemble charcoal mostly come with their packing bags which they give to the charcoalers after getting a packed bag of charcoal. Charcoal at other times transported to the market with the aid of humans, bicycles, donkey carts, pickups and trucks. Human, donkey carts and bicycles cannot be used for long distance transport and are mostly limited in capacity. Pickups and trucks are the most commonly used means of transporting the charcoal by transporters (Plates 2 and 3). A truck can carry anything between 200 and 250 sacks of charcoal depending on the tonnage.

The transporters interviewed reported of frequent police harassment enroute to markets in the urban centers. The police normally detain charcoal trucks even though transporters acquire transport permit to allow passage of goods to destined markets. Haulage may be done at night to evade the police harassment, although one can hardly make one trip without paying bribes, not less than GH¢50. Other challenges reported by the transporters include lack of finance to acquire appropriate trucks to facilitate haulage, poor road infrastructure constraining traction particularly during the rainy season.

The traders are the last in the charcoal value chain and sell directly to the final consumers. There is limited transcation between charcoal wholesalers or retailers and their clients (households, food vendors, restaurants, educational institutions, etc), since most traders sell their charcoal in sacks to other retailers and final consumers. Most of the retailers operate in open yards or tin-sheds in government or private plots where they pay little or no rent. The major challenge constraining retailers is price hikes often resulting from exhorbitant infomal payments/bribes paid to security officers such as the police and customs at check points or during delivery of supplies to the localities or markets. This may discourage suppliers who divert to less cumbersome supply areas which sometimes create charcoal scarcity.

3.1.2.2.3 Cost and benefits along the charcoal value chain

The costs and revenue streams per the unit of sale i.e. 50kg bag of charcoal along the charcoal value chain during the survey period in 2013 is presented in Table 4. A summary of the profit distribution along the chain indicates that wholesalers earn the highest income or profit of GH¢ 3.5 representing 45% share of total profit along the chain (Figure, 15).

Table 4: Actors revenues and expenses in the charcoal value chain

Actors	Variable costs per 50kg bag of charcoal (GH₵)	Revenue (Selling price/ 50kg bag (GH₵)	Gross profit (Revenue – costs) GH₵
Charcoal Producer			
Wood	2.50		
Labour	2.00		
Permits	0.50		
Sub-total			
Sales	5.00	6.30	
			1.30
Middle men			
Charcoal	6.30		
Labour	0.20		
Sub-total	6.50		
Sales		7.00	
			0.50
Transporter			
Charcoal	7.00		
Vehicle hire	4.00		

Labor (On loading)	0.50		
Transport permit	0.20		
Illegal payments	0.30		
Sub-total	13.00		
Sales		13.50	0.50
Traders (Wholesalers)			
Charcoal	13.50		
Labour (Off loading)	0.50		
Charcoal sack	0.50		
Sub-total	14.50		
Sales		17.00	2.50
Traders (Retailers)			
Charcoal	17.0		
Labour (Packaging)	0.50		
Sub-total	17.50		
Sales		18.00	
			0.50

Figure 15: Costs and benefits along the charcoal value chain

3.1.2.3 The firewood value chain

Actors and transactions along the firewood value chain

In Ghana the fuelwood value chain is quite informal and poorly developed. This is mainly because firewood is mostly used in the rural areas, where it is collected for free or paid in kind reducing its economic value. Trade in fuelwood in the producing areas is on a small scale. Institutions that rely on firewood like schools have transporters who buy the wood from the source and sell it directly to the school. The traders also indicated that they buy their wood from transporters by normally placing an order to the transporters for a certain amount of wood and this is delivered in to their vending site.

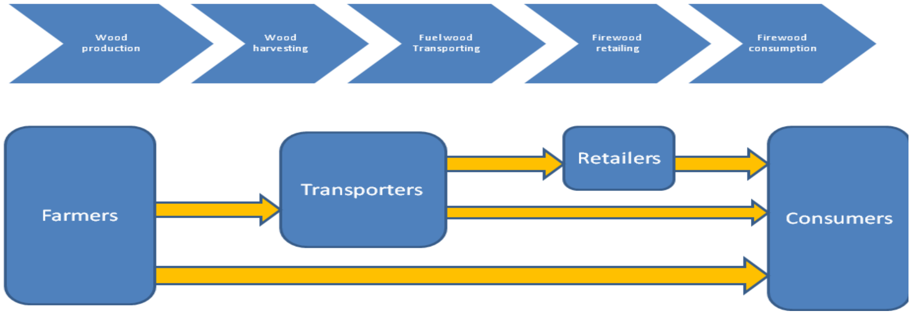


Figure 16: Map of Firewood Chain in Ghana
Source: Field Survey, 2013

Tree parts used for firewood production

Observations from the survey showed that all parts of the tree were used as fuelwood throughout the study areas, everything from the tree branches, to the trunk and cut timber. In the urban areas cut timber is what is predominately sold at the market place and the most commonly used fuelwood source. The cut timber refers to the wood split for purchase. This is not usually available widely in the rural areas but urban.


Plate 4: Piles of fuelwood for sale in project communities

Characteristics of good fuelwood trees

The characteristics of fuelwood species were soughted from the respondents. Vast majority (85%) said that calorific value was the single most important attribute necessary in fuelwood species. In accordance with the cooking habits of the respondent 60% of the respondents cited that they preferred burning smokeless fuelwood. Interestingly other attributes which were of interest to respondents were wood density, long-lasting flame and the effect of the tree on the food while cooking.

Collection techniques

The collection of fuelwood whether done at daily or weekly interval was an important and time-consuming activity for the majority of respondent in the study area. Collection is mainly male dominated. However, the people involved in fuelwood collection varied with regards to the household's economic standing. The study observed that in rural areas female adults were equally responsible along with adult males for fuelwood collection. Furthermore in the rural areas, wood is collected from the bush or forest for free and therefore children, in particular male children are required to assist.

Table 5: Reasons given for an increase or a decrease in fuelwood supplies

Increase	Decrease
Always available	Increase in population
Plenty still in the bush	People are not replanting
More trees are dying, hence available for fuel	Trees are being cut down
People are replanting	Vegetation is dwindling
Demarcating Community Forests for future	No management of trees
More trees are growing	Increase in bush fires
	Rainy season is shorter

The fuelwood sector is quite complex and not linearly organized as presented in the map above. The price of wood varies greatly depending on the buyer and the intended market. For the purpose of this analysis, farm-gate prices paid by transporters to a farmer which is about GHC 2 per sterm were used. The transporters have to negotiate the final price with the farmers and this depends on the distance from the source of fuelwood and final destination of delivery. They then harvest the wood and transport it to the institutions or vendors in the urban centers. The main challenges they face are; harassment by corrupt police and city council officials who demand bribes, limited finances for business expansion and lack of a vibrant market in the city. The transporters indicated that most of the institutions normally issue them with a tender for wood supply and they get paid after delivering the wood an arrangement which requires a huge investment outlay.

The retailers interviewed during the study complained of limited market, lack of credit facilities, and lack of support from the government. The producers do not fully engage in the wood selling business but rather sell the wood when in need of money for school fees, medical or other urgent needs thus it is not easy to quantify how much they make per month from selling wood. During the research, it was further observed that vendors sell their wood in small bundles of two or three pieces of wood (depending on the size of split wood) each retailing rage of GHC 0.50 – GHC 2.0. Table gives a summary of the expenses and income distribution between different actors in the firewood supply chain per KIA load of wood.

Table 6: Expenses and Income from Firewood Supply Chain

Actors	**Variable costs (GHC)**	**Revenue (Selling price)**	**Gross profit (Revenue – costs)**
Farmer (farm-gate)			
Harvesting	-		
Sales		40	
			40
Transporter			
Wood buying price	40		
Vehicle hire	110		
Labour	10		
Transport permit	5		
Illegal payment	20		
Sub-total	185		
Sales		250	
			65
Retailer			
Wood buying price	250		
Rent	3		
Labour for splitting wood	30		
Taxes	2		

Sub-total	285		
Sales		320	
			35

Source: Field Survey, 2013

From the table, the transporters seem to make the highest profit per KIA load of wood sold compared to the retailers and the farmers. The retailers interviewed said that they sell about one full KIA load of firewood per week, translating to a profit of GHC 260 per month. Though transporter scavenge for the firewood from farmer, the farmers do not engage in firewood as their full time business but rather sell the wood when there is urgent need of money like school fees, medical or others.

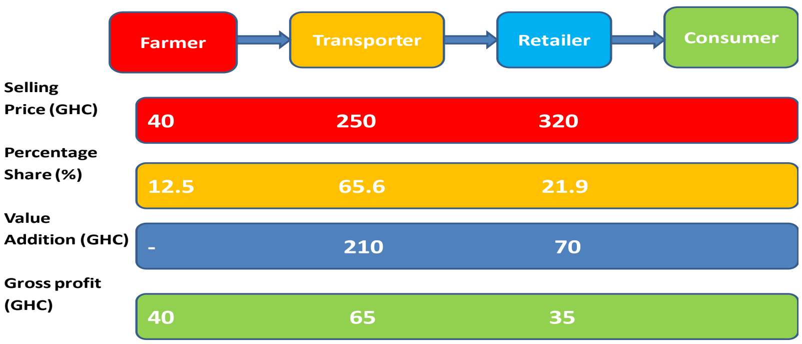


Figure 17: Cost and benefits among actors along firewood value chain
Source: Field Survey, 2013

Table 7: Common challenges characterizing the fuelwood value chain

	Producers	***Transporters***	***Wholesalers/Retailers***	***Consumers***
Challenges 1	Corruption	Corruption	Corruption	Health risk from emissions
Challenges 2	Finances	Finances	Finances	

Source: Filed Survey, 2013

3.1.2.4 Conclusions and implications for research and policy

In Ghana the woodfuel sector is very important not only for energy supply but also as a source of employment if properly managed. The firewood markets are poorly developed because it is mostly consumed in the rural areas where it is freely accessible or residents use agricultural residues. The charcoal chain has well established structures from production, transport and trade but still continue to be hampered by lack of a proper operational legal framework. This has enabled corruption and unfairness against the actors (producers, transporters and traders). The woodfuel chain is profitable among all the actors but greater proportion of the income is earned by the transporters.

Recommendations

With the increase scarcity and dwindling state of forests and trees stands in Ghana. These recommendations are made following the results of the Woodfuel study.

- Increase awareness of the benefits of woodlots as a renewable woodfuel resource through existing extension services and NGO's,

- Increase research on multi-purpose tree species in Ghana specifically for the production of woodfuel but with the ability to increase soil fertility, fodder production and establish live fencing,
- Increase extension on agroforestry practices such as woodlot management on an individual basis, live fencing, fodder production, boundary planting, orchard and fruit tree management,
- Increase research on practical fuel efficient stoves and alternatives to fuelwood
- Increase dissemination of information regarding the decline in forest resources via NGO and government extension to farmers, thereby increasing farmer's incentive to establish woodlots.
- Increase the promotion of alternate fuels, i.e. kerosene and natural gas, until woodfuel production becomes sustainable

3.1.3 Ethno-ecological study

The Forest-Savannah Transition Zone of Ghana is one of the major sources of wood fuel supply in Ghana. Communities are predominantly involved in farming but have actively engaged in wood fuel production from natural vegetation stands over centuries. Communities are thus, quite knowledgeable of wood fuel species, their energy and ecological characteristics, availability, etc. This aspect of the project baseline studies involved an ethno-botanical survey of indigenous knowledge on important wood fuel species and their ecological characteristics in the Kintampo North Forest District. The objectives of the survey were:

- Identify tree species used for charcoal production in transition zone target communities
- Plan for seed collection of preferred species for establishment in the test plots
- To guide inventory of stocks to ascertain distribution and availability of important charcoal wood species in the transition zone target communities

3.1.3.1Communities surveyed, data collection and analysis

The study covered 8 communities in the Kintampo Forest District reported to be the intensive charcoal producing communities as follows:

- Kintampo: Potor, Atakura, Gulumpe, Babatokuma and Tahiru
- Nkoranza: Busunya/Bomini, Nkranka, and Dromankuma

Data was collected from focus group interaction with charcoal burners and key informants including a Forestry Officer who works with the communities. Field observations of important wood fuel species were also made. Data collected has been summarized in tables.

3.1.3.2 Findings

Figure 18 shows the most frequently reported wood fuel species used for charcoal production over the years in order of importance. Respondents gave their perceptions about their availability and other benefits derived from them. Generally most species are on the decline and could be harvested only from 10 to 20 km from the various communities. Trees nearer the communities are of very small sizes. Charcoal producers think that their harvesting methods do not destroy trees as they mostly coppice after felling. They contend that it is farmers who destroy trees by actually burning them to clear land for their activities.

Data indicates that most wood fuel species have multiple uses for fuel, timber for construction and furniture, medicine, utensils, etc. Majority of the species are currently harvested from secondary forests but have declined in stocks with no traditional conservation measures. The Species are also highly susceptible to wildfire. Most of the species also flower between September and December, fruiting thereafter with the seeds maturing between January and March in the dry season

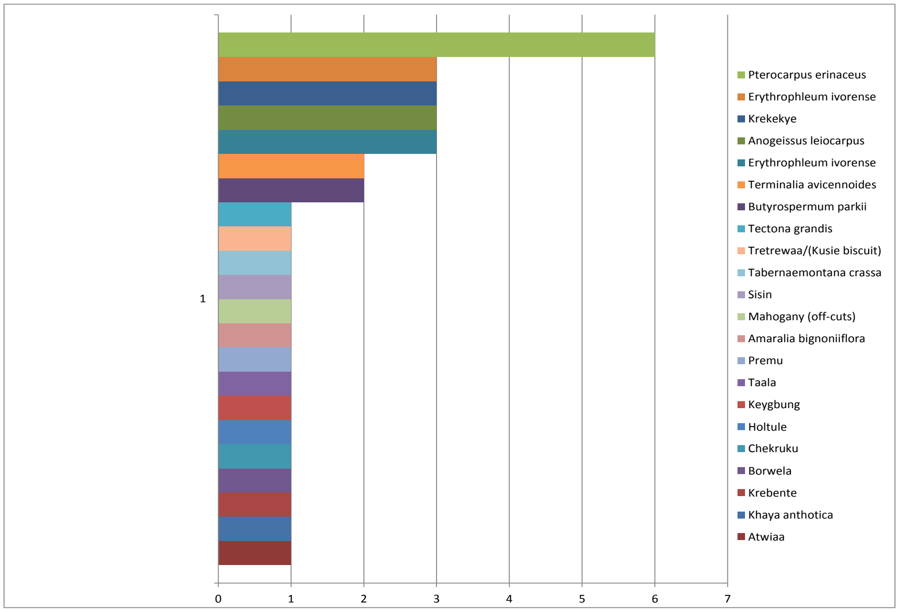


Figure 18: Important wood fuel species in the Kintampo North Forest District

3.1.4 Ecological study

3.1.4.**1 Introduction**

Wood-fuel production is a major commercial activity in the forest-transitional zone of Ghana. However, deforestation through excessive timber exploitation, uncontrolled wood-fuel tree species harvesting and annual fires are threatening the resource with future consequenses on local people who depend on woodfuel production for livelihood. One of the efforts to curb this alarming threat is managing forest sustainably. However, there is plimited knowledge on stocks with respect to the diversity of species, their distribution, availability and current management strategies to guide management options for ensuring sustainability in use while reducing vulnerability of local livelihoods to negative quensequences of mitigate climate. To achieve one key activity on the project which is to take inventory of the wood fuel tree species in the project areas, a team of five (5) men was mandated to kick-start this paramount activity in Attakura, a community within the Kintampo North District. The field inventory exercise was a follow up to confirm species the socio-economic survey which quizzed the local people on desired wood fuel species and those currently being used.

3.1.4.2 **The inventory methodology**

A total of thirteen (13) 50m x 50m temporal sample plots were randomly laid around the community and within each plot was a 10m x 10m subplot. Five (5) plots on each sides of the community and three (3) plots in the Buru Forest reserve to serve as control plots. On each side of the community, access route were traced with the help of local community members for a distances of over two (2) kilometers before putting first plot after which four others followed at 300m interval. GPS coordinates of plot corners as well as reference point within the community were taken for mapping purposes. Tree species above 5cm diameter at breast height within each plot were measured and identified by a botanist with local and scientific names. In the subplots, saplings below and equal to 5cm diameter at breast height were identified and counted.

Plate 5: Enumeration of sample plots to assess distribution and avilability of major woofuel species

Remarks on trees such as coppice shoots, forked and multiple stems were indicated and convenient point of measurement taken. Pictures to proof evidence of charcoal production were also captured.

3.1.4.3 Results

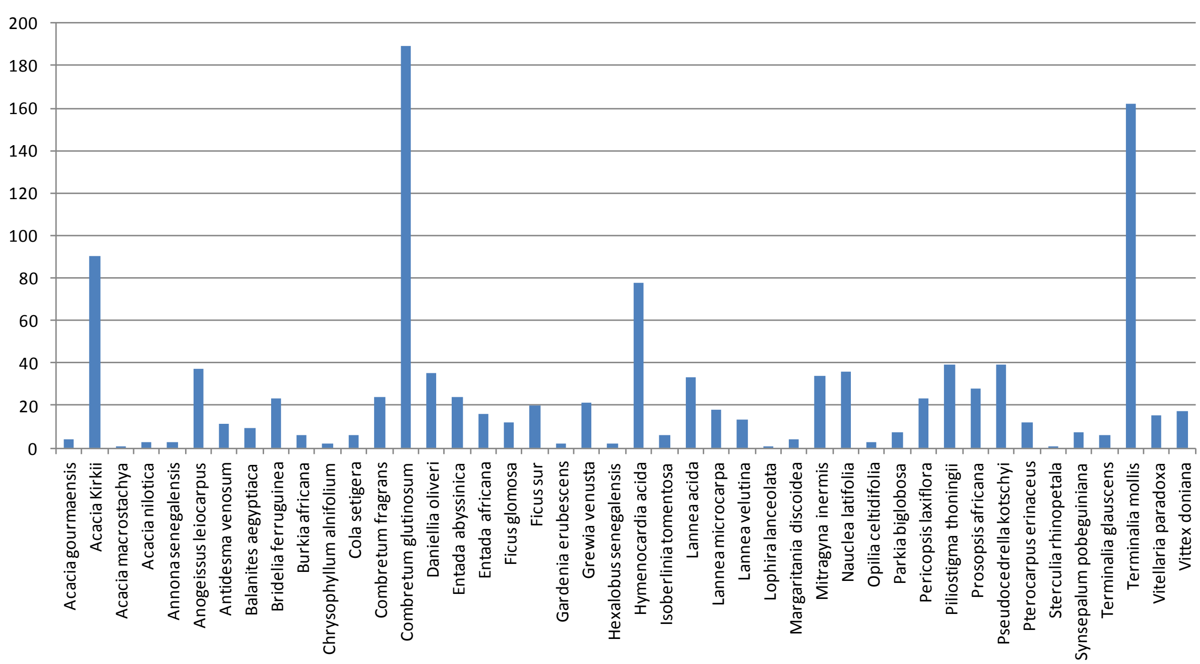


Figure 19: Frequency of Tree Species Spotted in Survey plots

Some of the endemic species found are *Pterocarpus erinaceus*, *Anogeissus leoicarpus*, *Terminalia mollis*, *Combretum glutinosum*, *vitellaria paradoxa and Daniellia oliveri* but the most utilized species were *Pterocarpus erinaceus* and *Anogeissus leoicarpus*. There was also community ban on cutting of *Vitellaria paradoxa* according to reports from the local people.

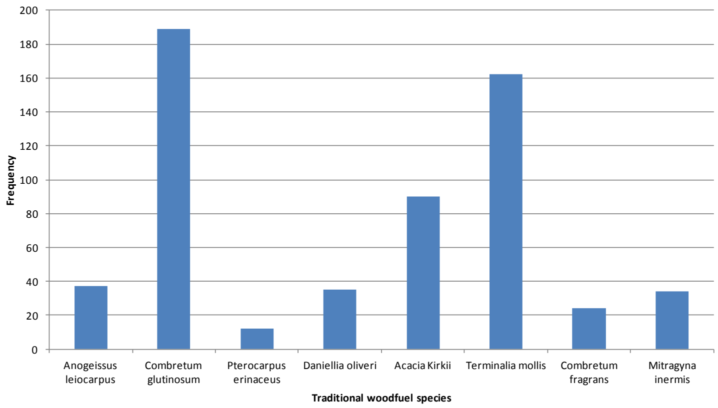


Figure 20: Key Fuel Wood Species Abundance

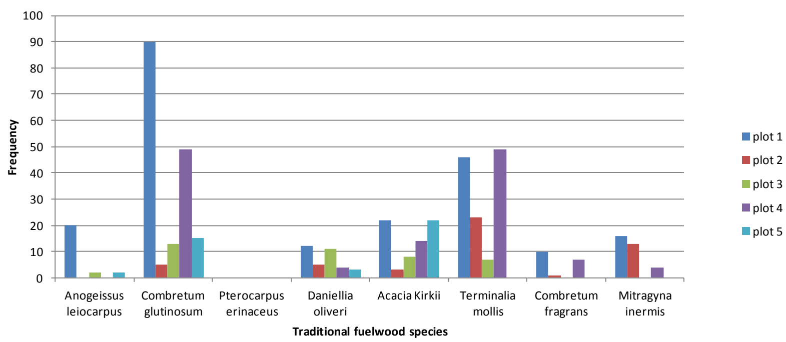


Figure 21: Comparing species abundance between plots

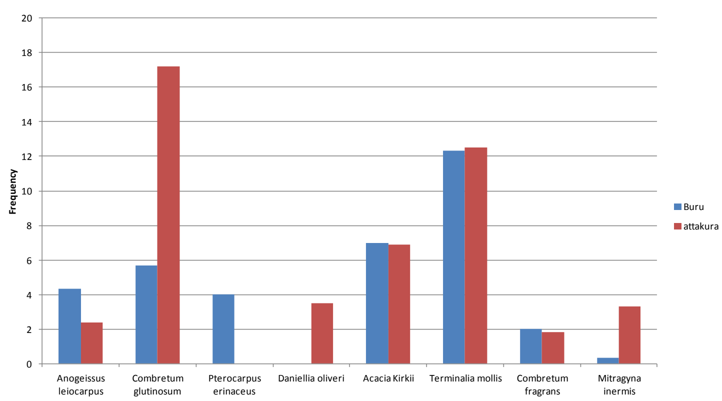


Figure 22: Comparison of key woodfuel species between community land and forest reserve

3.1.4.4 Conclusions

It was evident that within the control plots existed diverse tree species which highlights a negative effects of uncontrolled tree harvesting of wood fuel in the farm land areas. It is laudable that potentially scares trees species should be introduced through plantations by the project to help develop the wood resources base to sustain the local business and increase carbon sequestration.

3.1.5 Community perceptions on natural regeneration of woodfuel species

The objective of this study was to assess the natural regeneration of wood fuel species from the perspective of farmers in charcoal producing districts as well as identify socio-economic and environmental factors affecting the successful regeneration of fuelwood species and management of coppice. Such information is expected to provide baseline data that would be used to establish an ecological study to determine actual and potential yield of fuel wood from natural forest regeneration and coppice growth. Key results are as follows:

3.1.5.1 Socio-demographic profile of respondents interviewed

The target group was farmers, fire wood producers, and charcoal producers living in the selected communities.Of the total respondents 71.9% were males and 28.1% females, 38% of the people surveyed were natives whilst 62% were settlers. The primary occupation of most of the inhabitants in the communities is farming (73.3%), followed by charcoal burning (23.0%) and 3.6% for other occupational activities such as petty trading chairs saw operator. The age categories of the respondents are presented in Figure 23.

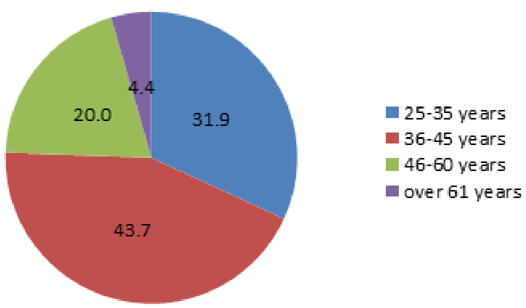


Figure 23: Ages of respondents in surveyed communities: Dromankese, Dromankuma, Atta Akura and Chiranda.

3.1.5.2 Fuel wood species used for charcoal production

Respondents gave a tall list of tree species used for the production of charcoal in the communities. However among the many species, species such as Kane (*Anogeissus leiocarpus*), Krayie (*Pterocarpus erinaceus*), Senya (*Daniellia oliveri*), Potrodom (*Erythrophleum africanum*), Papao (*Afzelia Africana*), Mahogany *(Khaya senegalensis*) and kerekekye (*Hymenocardia acida*) formed 69% of species used for burning charcoal in the communities studied. The details are presented in Table 8.

Table 8: Fuelwood species used in four communities

Species name	**% respondents**
Kane (*Anogeissus leiocarpus*)	18.1
Krayie (*Pterocarpus erinaceus*)	16.0
Kerekekye (*Hymenocardia acida*)	7.4
Senya (*Daniellia oliveri*)	7.3
Potrodom (*Erythrophleum africanum*)	7.1
Papao (*Afzelia Africana*)	6.7
Mahogany (*Khaya senegalensis*)	6.2
Other species	31.1

3.1.5.3 Methods of regeneration and factors impeding regeneration

Most of the respondents (99.3%) were well aware of regeneration capacity of the species used for charcoal production in the communities. Most of the species mentioned regenerate through coppicing and through seeds. However, a majority (85%) of the respondents indicated a lack of sufficient regeneration of the listed species in the natural vegetation. Some of the reasons attributed to the insufficient regeneration were over harvesting (32.2%), farming activities (26.5%) and fire outbreaks (15.9%). Fallow lands provided the majority of fuel wood (99.3%) used by the communities though to many (88.9%) the volume of fuel wood harvested from fallow land are declining due to changes in fallow length that is attributable mostly to inadequate land (67%) and wildfires (14.6%). This pattern has been observed elsewhere in sub Sahara African countries such as Kenya and Uganda where local people depend mostly on fallow lands to meet their energy needs under declining stock in natural forests (Naughton-Treves and Chapman 2001). To alleviate existing pressure on natural forests, management of fallow land for fuel wood production including enhancement of tree regeneration and intensive fire prevention education should be a priority when implementing strategies for sustainable fire wood production.

3.1.5.4 Impact of harvesting techniques on coppicing/regeneration of fuel wood species

Respondents were knowledgeable about the management of coppice. According to most respondent coppice shoot took between 5-7 years to reach the marketable size to be sold as fuel wood (Table 9). Respondents harvest fire wood throughout the year but a majority harvest the fire wood during the wet season whilst a minority harvest during the dry season (Figure 2). There was no significant difference in the period of harvest between the two sites studied (Mann-Whitney U = 2111.5, Z = -0.467, P = 0.64, N =133). Harvesting during the dry season can lead to failure of coppice as there would be insufficient water for the stumps (Brown and Amanor (2006). The heights at which the stumps are cut influence the nature of regeneration (Ref). Farmers were well aware of the effects of cutting height and time on the success of the coppice. There was significant difference in the position at which the stem is cut (Mann-Whitney U= 1312, Z= -5.651, P =0.001, N =133). In the Kintampo North District almost all of the respondents (97%) indicated they cut the stem close to the ground whereas in the Nkoranza North 60.35% of the respondents indicated same. Stems that are cut low to the ground coppice better than those cut about a certain height. For example Brown and Amanor (2006) found that a cut below 50 cm results in development of small trees, while a cut above 50 cm result in the development of branches. The coppice after the stem cut grows normally with little damage from animals though most are damaged in the event of a wildfire. However the ability of a woody plant to coppice and remain vigorous mainly depends on the severity of the disturbance with reference to above ground biomass, availability of water and nutrients (Moyo *et al* 2015). In the face of reduction in dry season rainfall reported for most forest types in Ghana (Fauset et al 2012) farmers need to be trained in harvesting methods as well as the cutting season to ensure establishment of coppice shoots in both the natural forest and fallow lands.

Table 9: Rotation time for coppice shoot to reach marketable sizes

Number of years	**Percentage of respondents**
3 years	11.9%
5 years	37.7%
7 years	22.2%
10 years	17%
Over 15 years	11.1%

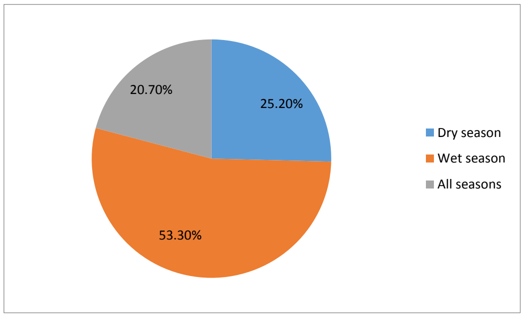


Figure 24: Season during which wood is harvested for fuel wood and charcoal production at Dromankese Dromankuma Atta Akura and Chiranda communities in Kintampo North and Nkoranza North District.

3.1.5.5 Coppice management practices by farmers and best practices

There is currently no system of management of coppice in the natural stands and fallow lands in our study communities though a study (Brown and Amanor 2006) in the Kimtampo area found a somewhat management of stumps and coppice by farmers. This is due to the fact that the community still depends on the limited fuel wood stock in the natural stands and fallow lands. To ensure coppices are well managed for sustainable production of fuel wood there will be the need to train farmers and also support them to establish fuel wood plantation which can be managed. Majority of farmers (78.5%) were therefore willing to use a portion of their farm land to grow short rotation species for use as fire wood and also for charcoal production. A little below half (47.4%) of the respondents were interested to use 15% of their fallow land for the cultivation and management of short rotation fuel wood species that can coppice and mature within 3-7 years. Results reported from studies (ref) in other African countries showed success in fuel wood production in fallow lands.

3.1.5.6 CONCLUSIONS AND RECOMMENDATIONS

From the perspective of community members in the studied district there appears to be insufficient natural regeneration of the species used as fuel wood due to overharvesting, farming activities and wildfire. Additionally there is no management regime for coppice in the natural vegetation, which further exacerbates the scarcity of wood for charcoal and firewood. There exists a potential for the establishment of short rotation plantation of fuel wood species with local community participation if the right incentives such as provision of planting materials, training in coppice management and fire prevention are given. Assessment of coppice stands in fallow lands as well as natural regeneration of fuel wood in forest is needed for the estimation of actual regeneration capacity of fuel wood species used by the communities.

3.2 Establishment of woodfuel trial plots
3.2.1 Planting material production

3.2.1.1 Assessment of flowering and fruiting in priority woodfuel species
Following information produced from ecological knowledge in the ethno-botanical and ecological/inventory studies, field assessment of the status of flowering and fruiting of priority woodfuel species to be planted in the on-farm trials or test plots. This was done to guide collection of mature and viable seeds from species that were in fruiting for germination trials and mass propagation at the nursery.

Plate 6: Field assessment of flowering and fruiting status of woodfuel species

3.2.1.2 Seed collection and processing

Seeds from phenotypically good trees of priority species in the wild were collected and processed (Plate 7) and stored at FORIG. Seeds of Acacia sp. were obtained from the African Plantation for Sustainable Development (APSD) Company at Atebubu for propagation. Seeds from the Acacias were not ready for collection. The seed stocks were used in the germination trials and subsequent nursery production.

Plate 7: Seeds collected and being processed

3.2.1.3 ***Seed germination trials***
Germination trials of selected and preferred wood fuel test species to be planted in wood fuel demonstration plantations were conducted (Plate 2). Data was gathered on the germination requirements on seeds of *Anogeissus leioccarpus* (Kane), *Pterocarpus erinaceus* (Rose wood- Krayie), *Khaya senegalense*, *Azadrachta indica* (Neem), *Senna siamea*, *Acacia mangium*, and *Acacia cracicarpa* (Exotic) to be planted in demostration trials. Results indicate that seeds began germination after 6 days with pre-treatment. However, Kane and Rose wood- Krayie have recalcitrant seeds that are difficult to germinate with pre-treatment media. The exepriment was repeated after the seed of kane (*Anogeissus leioccarpus*) was stored for one year after collection. All test seeds germinated with water pre-treatmnet after 6 days.

Plate 8: Germination trials at the shade house

Establishment and management of nurseries

Nurseries were established at selected sites at Nkranka, Babatokuma, Attakura and FORIG to produce approximately 25,000 seedlings for establishment of wood fuel demonstration plots. Routine monthly monitoring of these nurseries were done to ensure that they are properly maintained for production of healthy seedlings. Additional seedlings have been acquired from a private nursery to augment nursery stocks during the 2015 and 2016 planting seasons.

Plate 9: Community Nursery and FORIG nurseries

3.2.2 Establishment of on-farm woodlot test plots

Seedlings raised at community and FORIG central nurseries were distributed to farmers for establishment of test/demonstration plots. Seedlings of nine woodfuel tree species, namely *Acacia magnium, Acacia cracicarpa, Anogeissus leioccarpus, Pterocarpus erinaceus `Khaya senegalensis, Azadirachta nidica, Senna Siamea, Afzelia africana* and *Terminalia ivorensis* were distributed among volunteer farmers for establishment of test/demonstration plots in 6 project villages namely Babatokuma, Attakura and Potor (Kintampo North District) and Nkranka, Dromakuma and DromaKese (Nkoransa North District) (Table10). Farmers cut their pegs and FORIG technicians and FSD field staff assisted in pegging fields. FORIG and FSD field staff assisted farmers to transplant seedlings at planting distance of 4t x 4ft triangular spacing in blocks intercropped with food crops, mainly Cassava, maize, yam vegetables. At least three or more species were planted per plot depending on the farmer’s preferenceFarmers cut their pegs and FORIG technicians and FSD field staff assisted in pegging fields. FORIG and FSD field staff assisted farmers to transplant seedlings at planting distance of 4t x 4ft triangular spacing in blocks intercropped with food crops, mainly Cassava, maize, yam vegetables. At least three or more species were planted per plot depending on the farmer’s preference.

Table 10: Tree species planted on wood fuel test/demonstration plots

No.	Species local name	Scientific name	Kintampo North district	Nkoransa North District
1	Mahogany	*Khaya senegalensis*	x	x
2	Neem	*Azadirachta indica*	x	-
3	Acacia	*Acacia mangium*	x	x
4	Acacia	*Acacia cracicarpa*	x	x
5	Krayie (rose wood)	*Pterocarpus erinaceus*	x	-
6	Cassia	*Senna siamea*	x	-
7	Papao	*Afzelia africana*	x	-
8	Kane	*Anogeissus leioccarpus*	x	x
9	Ofram	*Terminalia ivorensis*	-	x

50 test plots of wood fuel species have been installed in six communities in the Kintampo North and Nkoranza Districts. A standard plot planted for scientific data collection with all the seven trial species is illustrated (Figure 25). Twenty-three Farmer plots covering 5ha were systematically planted with seedlings in six project villages in 2014. 27 additional fields were been planted in 2015 and 2016. Overall, 50 farmer plots were planted with 18,200 seedlings covering 18ha from 2014-2016 with success rate of 70%. The 30% loss was as results of poor weather conditions particularly the elnino with very high temperatures and prolonged drought, wild fire and livestock browsing especially in the Kintampo North district.

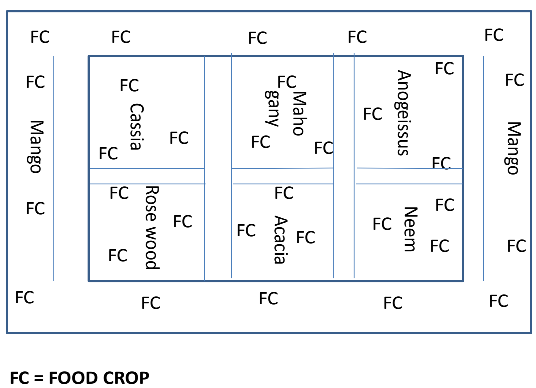


Figure 25: Farmer woodlot plot design and tree-food crop-mix

Plate 10: Distribution of seedlings for planting on the field

Plate 11: Planting seedlings in test plots on farmer fields

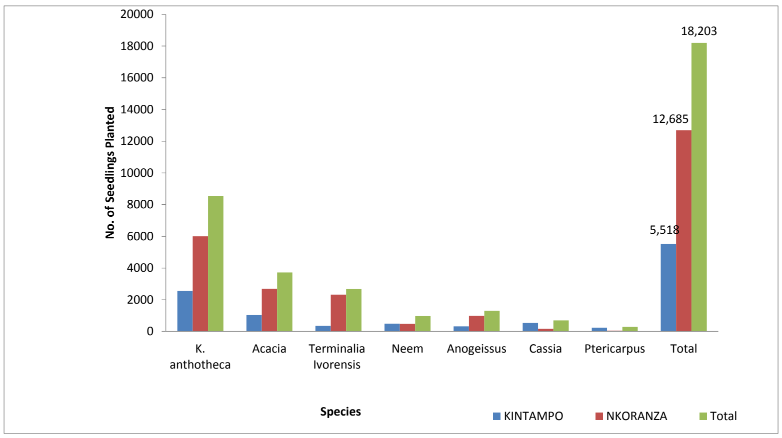


Figure 26: Distribution of seedlings planted in project districts

Table 11: Farmer plot characteristics

Field Charateristics	**KINTAMPO NORTH**	**NKORANSA NORTH**	**TOTAL**
No. fields	19	31	50
Field size per farmer (AV.) HA	0.3	0.4	0.3
Total acreage (HA) @ 4 x 4 m	7.5	10.6	18.1
No. seedlings	5,500	12,700	18,200
Tree species	*K. anthotheca* *Acacia spp* *Senna siamea* *Anogeissus* *Ptericarpus* *Neem* *Afzelia africana*	*K. anthotheca* *Acacia* *Terminalia* *Anogeissus*	*K. anthotheca* *Acacia spp* *S. siamea* *Anogeissus* *Ptericarpus* *Neem* *Terminalia* *Afzelia africana*
Food intercrops	Maize, yams, millet, pepper	Cassava, maize, yam vegetables	Cassava, maize, millet, yam, pepper, vegetables

Table 12: Tree-crop mixtures planted on farmer test plots

District	Tree-crop woodlot model	Reason for choice	Expected products
Kintampo North	*Senna siamea-Azadirachta indica*-Yam-Maize-Millet	All species browsed by livestock and suceptible to wild fire dmamage except *Senna siamea and A. Indica*	Food crops Leave biomass improve soil fertility Wood for charcoal Poles for construction Stakes for trailing yam vines
Kintampo North	*Senna siamea-Khaya senegalensis-Anogeissus leioccarpus- Acacia sp*. –Yam-Maize-Pepper	Where livestock browsing and wildfire can be controlled	Food crops Leave biomass improve soil fertility Wood for charcoal Timber for sawing Poles for construction Stakes for trailing yam vines
Nkoransa	*Khaya senegalensis- Acacia sp. Terminalia ivorensis* –Yam-Maize-Millet	Preference for multipurpose woodlots that can produce wood for both timber and charcoal	Food crops Leave biomass improve soil fertility Wood for charcoal Timber for sawing Poles for construction Stakes for trailing yam vines

3.2.3 Evaluation of on-farm test/trial plots

3.2.3.1 Biological assessment

As part of periodic monitoring and evaluation schedule, follow up visits were made to all wood fuel trial plots to assess performance/survival of seedlings planted. Generally, seedling survival was over 95% on all fields visited. Some fields need weeding for the seedlings to be protected against wild fire, especially those established on fallow land.

Plate 12: Farmer woodfuel trial plots at Kintampo

The status of the species in the plots is presented in Plate 12. Tree species survival in the plots was 80% despite the prolong drought during the establishment period. Average growth in tree height of test species over three years indicates that the exotic species (*S. siamea, Acacia sp*. and *A. indica*) grow faster than indigenous species (Anogeissus, Khaya and Pterocarpus). *S. siamea* recorded the heighest mean growth in height of 532 cm compared with 58 cm for *P. erinaceus* in the third year (Figure 27).

Plate 13: Status of some species in woodlots 3 years (2014-2016) after planting –Kintampo District

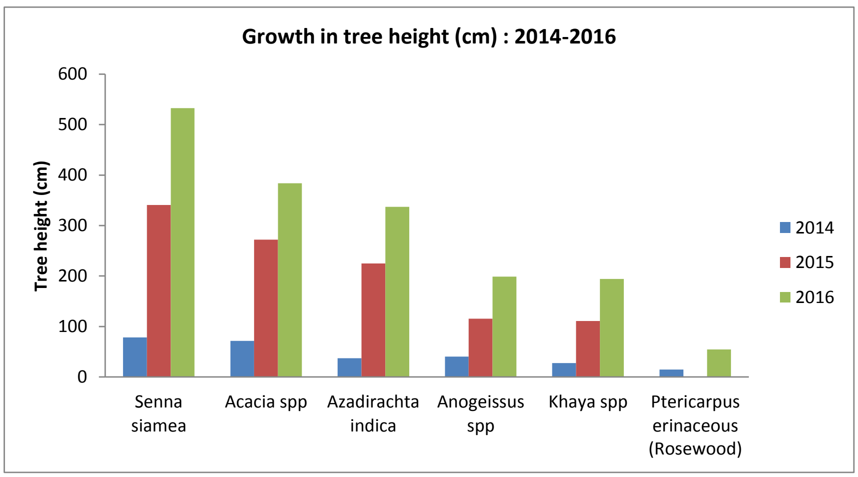


Figure 27: Mean height (cm) of test species (2014-2016)

3.2.3.2 Economic assessment of test plots

Ex-ante analysis of the wood fuel test plots was conducted to assess the profitability of wood production from on-farm smallholder woodlots of mixed native and exotic species (Acacia-Neem-Cassia-Anogeissus) integrated with food crops mainly for fuelwood production. Input-output data was collected and subjected to financial cost-benefit analysis. Results indicate that fuelwood production from woodlots was profitable returning a NPV of GH¢2,500 and B/C ratio of 1.3 at a market discount rate of 22% over a 20 year rotation. Profitability is quite sensitive to increases in production costs. The NPV declined to GH¢550 at 50% increase in production cost.

Economic assessment of wood production from the trial plots was undertaken. This involved an ex-ante analysis of the profitability of fuelwood production from multipurpose woodlots, comprising mixed native and exotic species (Acacia-Neem-Cassia-Anogeissus-Mahogany) integrated with food crops in a 5-year rotation system, based on coppice management over 25 years. Input-output data was collected and subjected to financial cost-benefit analysis at 25% discount rate. Benefit-Cost Ratio (BCR) and Net Precent Values (NPV) were computed to determine the profitability of the woodlots using the formulae in Table 13.

Table 13: Profitability indicators

Profitability indicator	Formula	Decision criteria
B/C Ratio	$\frac{\sum B_t}{(1+r)^t} \div \frac{\sum C_t}{(1+r)^t}$	BCR ≥ 1.0
NPV	$\sum_{t=0}^{t=n} \frac{(B_t - C_t)}{(1+r)^t}$	NPV ≥ 0

B=benefit, C=cost, t=time in years or rotation/production period, r =discount rate, n= rotation length in years

Results from the economic analysis indicate that wood production from woodlots was profitable returning NPV of GH¢13,000 and B/C ratio of 2.9 at a market discount rate of 25% over the 25 year production period (Table 14). Profitability is quite stable to increases in production costs and decline in wood yield up to 50%. Profitability is enhanced over one and half times at lower discount rate of 10% (Table 15). It was observed that with wider spacing, pepper a biennial crop could be cultivated twice in the woodlot to increase revenue over the 5 year rotation. Also income from mahogany timber at the end of the 25th year significantly enhanced overall profitability of the woodlot and increased product diversity. The 5 cycles of 5 year rotation for fuelwood permitted integration of food crops for 3 years for intermittent income during each rotation. This enhanced the overall profitability. Studies conducted by Current *et al.*, 1995; Franzel 2004 and Duguma 2013, confirm that smallholder woodlots are highly profitable from 10% to over 20% discount rates but has to be designed to fit into the socio-cultural and economic constraints of such systems.

Table 14: Discounted cash flow of profitability of multipurpose woodlot

Discount rate	Benefit Cost Ratio (BCR)	Net Present Value (NPV) (GHC)
Base scenario at 25%	2.87	13,000.00
Decrease discount rate @10%	3.74	21,950.00

Table 15: Sensitivity of profitability to changes in increases in costs and decrease in wood yield

Scenarios	Benefit/cost ratio	Net Present Value (NPV) (GHC)
Base scenario @ 25%	2.87	13,000.00
Increase total cost at 50%	1.93	9,547.00
Decrease in wood yield by 50%	1.81	8,371.00

3.2.3.3 Potential Impact on livelihoods and environment

A literature review was done to develop a framework for analysing the feasibility of wood fuel plantation PES in forest-savanna transition of Ghana. The review covered i) identification of a working definition and conditions where PES work, ii) determination of the focus of PES scheme, iii) identification of the justification or need for a PES scheme, vi) how to organize farmers for PES project, v) how PES and carbon sequestration is organized on agricultural landscape drawing on lessons from existing projects, vi) identification of the challenges and strategies used to overcome such challenges. Questionnaires were also used to collect data analyzed to determine the potential impact of wood fuel plantations on the livelihood and environment of households. Results indicate that households expect to gain mainly extra incomes and ecosystem services from integrating woodfuel species in agricultural landscapes.

3.4 Silvicultural prescriptions for establishing and managing woodlots

Information on silvicultural prescriptions on species planted on test plots have been compiled into a handbook. Contents of the handbook is illustrated in Figure 28.

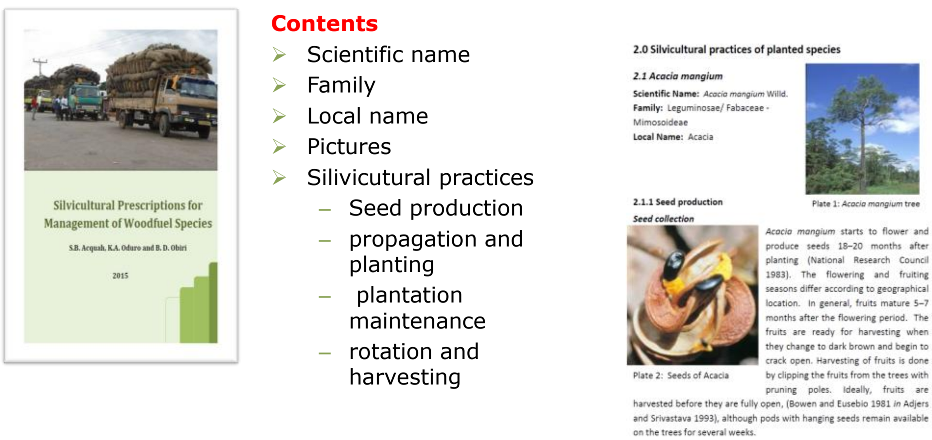


Figure 28: Contents of handbook on silvicultural prescriptions of woodfuel test species

3.5 Biomass and carbon production potential

Two BSc. students from the Agroforestry Department of the Faculty of Renewable Natural Resources, KNUST were recruited to conduct studies on biomass and carbon stock production potential of the woodfuel test plots and evaluated the effect of farmer silvicultural practices on seedling survival and growth on their plots. These studies have been completed and theses published and uploaded on the POLM in 2016.

The biomass and carbon production potential of the wood fuel species on test/trial plots have been estimated. Results indicate that above ground biomass range between 80 tons/ha for *Ptericarpus sp* to 160 tons/ha for *Acacia sp*. *Accacia* and *Senna siamea* although exotic species have the best potential for both biomass and carbon storage ability for a five years rotation plantation. *Khaya segalensis* and *Anogessis spp* that are indigenous species were the next with impressive potential for Biomass (136 tons/ha, 132 tons/ha) and carbon storage ability of 2794 and 2873 Net GHG/Tcer respectively.

Results from carbon estimation indicates that carbon sequestered varied among 4 plots after 1 year of planting due to differences in plot management behaviour of farmers and site characteristics. Total carbon sequestered by each tree species (*Acacia mangium, Anogeissus leiocarpus, Azadirachta indica, Khaya senegalensis and Senna siamea) were 10.14, 4.35, 6.13, 3.14 and 18.23 kg C/tree/yr (equivalent to 8.75, 4.22, 6.02, 2.45 and* 16.40 Mg C/ha/yr) respectively. Overall, Cassia (*senna siamea*) has the highest carbon sequestration potential in woodlots.

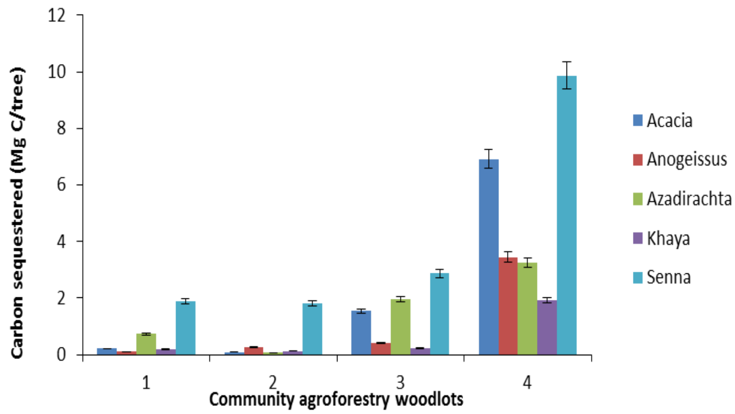


Figure 29: Carbon sequestration potential of woodfuel species on trial plots

3.6 Enery characteristics of woodfuel species in test plots

Samples of species planted in the test plots were collected from the wild to determine their energy values at the laboratory. Moisture contents of the samples were determined followed by determination of their calorific values, charcoal yielding potential and carbonization characteristics (Table 16).

Calorific value (CV) is the most important fuel property (Telmo *et al*., 2011). It depends on the chemical composition and moisture content. The CV of both fuel wood and charcoal were very high for the species investigated. The gross calorific value of the six (6) wood species studied ranged from 3.39 - 5.17 kcal/g for fuelwood and for charcoal it ranges between 6.07 and 6.79 kcal/g. The average gravimetric (charcoal) yield was about 30.93% with *Pterocarpus erinaceus* having the highest of 33.30% and *Khaya senegalensis* with the lowest of 29.20%. The Ash content is the total inorganic component of the woodfuel.

Table 16: Moisture content, volatile matter (VM), ash, fixed carbon (FC), Gravimetric yield, and gross calorific value (GCV) of charcoal from the species studied

Scientific names	Local Names	MC (%)	VM (%)	Ash (%)	FC (%)	Gravimetric Yield (%)	GCV (kcal/g)
Azadrachta indica	Neem	3.56	22.6	0.600	76.8	29.90	6.79
Senna siamea	Cassia	1.61	30.2	2.75	67.0	29.20	6.48
Anogeissus leiocarpus	Kane	2.26	26.2	6.78	67.0	34.10	6.38
Afzelia africana	Papao	1.71	26.7	6.44	66.8	29.90	6.07
Pterocarpus erinaceus	Krayie (Rosewood)	8.00	24.1	5.63	70.2	33.30	6.69
Khaya senegalensis	Mahogany	0.970	19.3	6.05	74.6	29.20	6.53

The Ash content is an important factor for determining the quality of wood fuel since ash is non-combustible and wood fuels with low ash content are preferred to fuel with high ash content. The higher the ash content of wood fuel, the lower the calorific value (Pereira *et al*., 2013). The ranking of the six tree species for their suitability for either fuel wood or charcoal was determined with FVI as the indicator. The *Anogeissus leiocarpus* gave the best fuel wood and the worst was Azadrachta indica according to their FVI's ratios. The ranking was significantly different for the charcoal, the FVI for *Khaya senegalensis* was the first and the sixth was *Pterocarpus erinaceus***.** The suitability of the tree species fort either fuelwood or charcoal indicate for fuelwood *Anogeissus leiocarpus* is the best and the worse is *Azadrachta indica* whilst for charcoal *Khaya senegalensis* and *Pterocarpus erinaceus* are the best and worse respectively.

3.3 Potential of community organization for PES schemes

A literature review has done to develop a framework for analysing the feasibility of wood fuel plantation PES in forest-savanna transition of Ghana. The review covered i) identification of a working definition and conditions where PES work, ii) determination of the focus of PES scheme, iii) identification of the justification or need for a PES scheme, vi) how to organize farmers for PES project, v) how PES and carbon sequestration is organized on agricultural landscape drawing on lessons from existing projects, vi) identification of the challenges and strategies used to overcome such challenges

3.4 Woodfuel resource management plan

District and national stakeholder dialogue meetings were held to discuss and prepare a wood fuel resource management plan (Figure 30).

DRAFT

MANAGEMENT PLAN FOR SUSTAINABLE WOODFUEL RESOURCES IN GHANA

Kwame A. Oduro[1], Julius Nkansah-Nyarko[2], Angella Adjei-Darko[3] and Beatrice Darko Obiri[1]

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[3]Faculty of Renewable Natural Resources, KNUST.

JULY, 2014

Figure 30: Stakeholder fora and plan for sustainable woodfuel resource management

4.0 OUTPUTS AND DELIVERABLES PRODUCED

1. 50 farmer woodlot trial plots covering 18ha with 70% success in Kintampo and Nkoransa Districts
2. Publications

i. Korang, J.K., Obiri, D. B., Awuku, S. and Appiah, H. 2015**.** Calorific values and gravimetric yield of six wood fuel tree species in the forest transition of Ghana. Ghana Journal of Forestry, 31: 51-61

ii. Obiri, D. B., Peprah, T., Nunoo, I., Obeng, E. A. and Opuni-Frimpong, E. 2017. Financial analysis of fuelwood production from woodlots in the savannah transition of Ghana. In review, Ghana Journal of Forestry

iii. Obiri, D. B., Dumenu, W. K., Quartey, R. K., Dawoe, E. L. K, Opuni-Frimpong, E. Oduro, K. A. and Twintoh, J.J., 2017. Rosewood (*Pterocarpus erinaceus*) governance and livelihoods in the Savannah's of Ghana (Draft manuscript)

iv. Obiri, D. B., Dumenu, W. K., Quartey, R. K., Dawoe, E. L. K, Opuni-Frimpong, E. Oduro, K. A. and Twintoh, J.J., 2017. Rosewood (*Pterocarpus erinaceus*) governance and livelihoods in the Savannah's of Ghana (Coneference Poster printed)

v. Dissemination of results at Conferences

- Obiri, D. B., Peprah, T., Nunoo, I., Obeng, E. A., Aguilar, F. X. and Opuni-Frimpong, E. 2016. Financial analysis of fuelwood production from woodlots in the savannah transition of Ghana. Paper presented at the annual meeting of FLARE Network, 2-5 December, U.K.

- Obiri, D. B., Quartey, R. K., Dawoe, E. L. K, Opuni-Frimpong, E. and Oduro, *K. B*. 2016. Rosewood (*Pterocarpus erinaceus*) governance and livelihoods in the Savannah's of Ghana. Poster presented at the annual meeting of FLARE Network, 2-5 December, U.K.

- Obiri, D. B., Owusu-Afriyie, K and Opuni-Frimpong, E. 2015. Production and Marketing of Woody Biomass for Energy in Ghana. Paper presented at ECOWAS Capacity Building Workshop on Sustainable Management of Forest (SMF) with a focus on REDD+ 27-29 April 2015 in Niamey, Niger

vi. 3 BSc theses (uploaded on the POLM)

- Carbon & biomass production potential of woodlots
- Farmer management effect on plot performance
- Role of rosewood in farming system and livelihoods

vii. Silviculture handbook (uploaded on the POLM)

viii. Woodfuel resource management plan (uploaded on the POLM)

ix. Reports produced (uploaded on the POLM)

- Value chain
- Ethono-ecology
- Ecological assessment
- Potential PES & livelihood impact
- Natural regeneration

5.0 SUSTAINABILITY OF THE PROJECT AFTER COMPLETION

The Executing agency for the ITTO woodfuel project RED-SPD/077-12 Rev.1 (F) has established strong collaboration with various stakeholders including community farmers, energy experts, foresters, range officers, academic professionals and undergraduates in restoration of degraded forest lands with both indigenous and exotic woodfuel species. The project implementation involved capacity building for community farmers. This ensured that technology for restoration of degraded forest lands with woodfuel species developed were transferred to them as a sustainability strategy for the project. In the communities, knowledge and techniques in nursery and woodlot establishment and management were transferred to the farmers. They gained experience in establishing tree nurseries as some of them were familiar with establishing nurseries of cashew and other cash crops for commercial purposes especially in the Nkoranza District. The draft silviculture toolkit on woodfuel test species on farmer's plots developed from this project will be simplified to a manual to facilitate participating farmers manage their woodlots after project completion. The EA also collaborated with African Plantations for Sustainable Development (APSD), a private company in energy plantations on off-reserve community lands in the Atebubu forest District which supplied Acacia seeds for establishment of farmer test plots and also to share in the results of the project for promoting smallholder woodlots for woodfuel production.

At the recommendation of the Project Technical Committee at a meeting on 21st January 2016, a second phase of the project will be submitted to ITTO for funding to among other objectives refine the silvilculture toolkit for woodfuel plantation development and management as well as up-scale success results in this small project phase to selected communities including educational institutions across all ecological zones of Ghana. Knowledge gained from the RED-SPD/077-12 Rev.1 (F) and its second phase or follow-up project will serve as practical guide for nationwide sustainable woodfuel woodlot development in support of the National Forest Plantation Development Strategy (GFPDS) earmarked up to 2040 in Ghana. The GFPDS will benefit from the initial results of the RED-SPD/077-12 Rev.1 (F) for especially savannah areas where woodfuel is a major product harvested from forests and farmlands and vast expanse of woodlands are degraded to provide alternative household income from charcoal burning. Species recommended for woodfuel development under the GFPDS include those that have been tested on farmer fields under RED-SPD/077-12 Rev.1 (F) including *Acacia auriculiformis, Acacia mangium, Senna siamea and Azadirachta indica.* The GFPDS will also guide the restoration of degraded community landscapes with trees and agroforests under the Ghana Forest Investment Program (FIP). Results from the farmer field trials under RED-SPD/077-12 Rev.1 (F) have shown that under prevailing socio-economic and agro-ecological conditions species such as *Acacia auriculiformis, Acacia mangium, Senna siamea, Azadirachta indica, Anogeissus leioccarpus and Khaya senegalensis* will thrive in woodfuel woodlots with limited rainfall and prolonged drought periods. However, termite damage and livestock browsing may threaten the survival of seedlings or tree stands in woodlots in drier or savannah ecological zones during periods of extended drought.

In addition to the silvicultural manual, the resource management plan also developed from RED-SPD/077-12 Rev.1 (F) will be useful in guiding sustainable woodlot development and management in Ghana and will also facilitate future applications by local communities and other stakeholders at small, medium and large scale levels. The knowledge generated from the energy studies on calorific values and gravimetric yield of the test species as well as their biomass and carbon production potential will also be of immense use in validating candidate species for woodfuel woodlot or plantation development nationwide.

6.0 LESSONS LEARNT

Plate 14: High weed incidence on woodlots   Plate 15: termites, fire and livestock damage on woodlots

7.0 CONCLUSION AND RECOMMENDATIONS

This ITTO small project, RED-SPD/077 Rev.1 (F) is aimed at testing and promoting the establishment of woodlots for woodfuel i.e. wood biomass energy production with communities in Ghana. This is anticipated to contribute to securing woodfuel dependent livelihoods particularly in the forest-savannah transition zone of Ghana which is the hub for charcoal production for supply to domestic and export markets. Baseline socio-economic and ecological studies, field trials, laboratory energy analysis, bio-physical/silvicultural, economic and potential impact studies were conducted from 2013-2016.

The ethno-ecological study indicated that wood fuel species have multiple uses - fuel, timber for construction and furniture, medicine, utensils, etc. Majority of the species are currently harvested from secondary forests and fallow lands. Species have declined in stocks. There is erosion of traditional conservation measures in communities, hence wood fuel resources are hardly managed /regulated while the species are highly susceptible to wildfire.

This project established 50 trial plots comprising a mix of indigenous and exotic tree species on smallholder fields to demonstrate the possibility of integrating wood energy production in agricultural landscapes. Results indicate that multipurpose woodlots of *Senna siamea, Acacia spp, Azadrachta indica, Anogeissus leiocarpus* and *Khaya segalensis* can be planted for energy and other uses in small holdings. In establishment of the trials, farmers preferred multipurpose woodlots for woodfuel, timber and fruit production for short, medium and long term benefits and also for income diversification. Although *Pterocarpus erinaceus* (rosewood) is slow growing, the species is in high demand for timber. Further trials with fertilizers and other soil amendments are required to enhance growth on the field. Farmers need to be trained in managing fields as five year rotational woodlots. Wider spacing from 4ft x 4ft - 6ft x 6ft permit longer integration of food crops such as pepper, maize, millet and sorghum till the wood is harvested for fuel. This allows for maintenance of the plot to enhance tree growth.

The results from field trials are relevant for the implementation of the Ghana Forest Plantation Development Strategy (GFPDS) 2016-2040 developed the Forestry Commission. The GFPDS has recommended establishment of woodlots for charcoal and firewood using Senna siamea, Acacia and Azadirachta in the savannah and transtion zones to meet the high demand for wood energy in the country. However, site-species matching will be critical in wide spread promotion of energy woodlots in communities in the savannahs of Ghana. Critical risk factors to woodlot establishment particuarly in the drier forest and savannah zones are annual wildfires, high weed incidence and prolonged drought leading to moisture stress or plant dessication and necrosis in both leaves and stem as prevalent in the Acacia spp., insect/pest attack and livestock browsing and wildfire during El Nino periods. Also high costs of weed management is critical to plant growth and would require innovative planting designs based on security of tenure and cropping systems. It is recommended that *Senna siamea, Azadirachta indica* and *Anogeissus leiocarpus* be promoted in this zone since these species can withstand extreme conditions. Rosewood (*Pterocarpus erinaceus)* is in high demand on the timber market particularly for export to China and for socio-economic and agro-ecological needs of communities, it is recommended that a research program is commissioned to research into all aspects of the species to aid its domestication and integration into farming systems for sustainable production and conservation in its endermic areas in the savannahs of Ghana. Research results also indicate that it is economically feasible to integrate fuelwood woodlots into farming systems. It is profitable at 25% market discount rate. Profitability is stable to upward changes in cost and decreased wood yield up to 50%. It was observed that shorter rotations of 5 years for fuelwood production from fast growing tree species increases the frequency of food crop integration enhancing income from the woodlot production system. Integration of fast growing timber producing species diversifies income sources. A program to support smallholders in fuelwood production may provide loans at lower interest rates at least 10% or less to encourage widespread adoption. However, it is imperative that woodlots are desgined to appropriately fit into smallholder production sytems and within their resource constraints.

APPENDIX: ATTACHMENTS

1. Socio-economic survey report
2. Value chain report
3. Natural regeneration study report
4. Management plan
5. Poster
6. Silviculture hand book
7. Energy paper
8. Financial analysis paper
9. BSC theses
10. Conference presentations (Ecree Niger and Flare 2016)
11. Financial statement
12. Gantt chart