ASSESSING THE ECONOMIC VIABILITY OF THE SLASH AND CHAR SYSTEM FOR CARBON SEQUESTRATION AND AGRICULTURAL PRODUCTIVITY: A CASE OF SMALLHOLDER MAIZE FARMERS IN GHANA

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By

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BSc.Agriculture (Hons.)

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Faculty of Agriculture

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DECLARATION

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

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DEDICATION

This work is dedicated to my hardworking mother, Mrs. Efua Harrigyah Otabil and the entire members of the Otabil Family

AKNOWLEDGEMENT

The heights so attained by men, are mostly not achieved by their own efforts alone, but theirs in combination with direct or indirect efforts by others. I could not have come thus far without the help of the Almighty God who connected me to the right persons in life, with all the accompanying opportunities and assistances they offered me. Special thanks to my mother, Mrs. Efua Harrigyah Otabil, who has been of great support to me for my entire educational life.

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ABSTRACT

This thesis looked at the viability of the slash-and-char system under smallholder maize production in Ghana, with a particular reference to the slash-and-burn practice which leads to increased Green House Gas emissions. Analysis is made for carbon sequestration using biochar under a maize production system for three locations in Ghana. The study, shows that carbon sequestration through the slash and char system for maize production is not a profitable alternative to the slash and burn system, both in the short term and in the long term from the perspective of the farmer. For both short and long term agricultural decisions, the farmer would not adopt the slash-and-char practice relative to the slash and burn practice. The proposed carbon sequestration practice is only profitable from the farmers' point of view if there is an incentive scheme for maize farmers. However, the slash-and-char system is a profitable alternative to the slash and burn practice from the view point of the society. The study therefore recommends that farmers should be motivated to adopt the carbon sequestration practice since it leads to a net positive impact on the economy in terms of national income and clean environment. It is further recommended that such incentives should at least be more than the farm income forgone as the farmer changes from the slash and burn practice to the slash and char practice.

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LIST OF ABBREVIATIONS

BEP- Black Earth Products

CH_4-Methane

CO_2- Carbon Dioxide

GHG- Green House Gases

IBI- International Biochar Initiative

KNUST- Kwame Nkrumah University of Science and Technology

MIT- Massachusetts Institute of Technology

UNFCCC-United Nations Framework Convention on Climate Change

EDF – Export Development Fund

ECOWAS- Economic Community of West African States

VAT- Value Added Tax

NHIL- National Health Insurance Levy

CEPS- Customs, Exercise and Preventive Services

CSIR- Council for Scientific and Industrial Research

FRI- Forestry Research Institute

KNUST- Kwame Nkrumah University of Science and Technology

IFPRI- International Food Policy Research Institute

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

IPCC (2007) indicates increased levels of total anthropogenic gases in the atmosphere, especially between 1970 and 2004. In terms of carbon dioxide equivalence, these anthropogenic gases have been identified to include emissions from fossil fuel use (which contributes about 56.6% of CO_2), deforestation and decay of biomass (which contributes about 17.3% of the anthropogenic gases), methane (CH_4) emitted into the atmosphere (14.3%), nitrous oxide (7.9%) and other gases (3.9) (Verbist, 2010). In terms of greenhouse gas emissions by sector, agriculture contributes about 13.5%, forestry (17.4%), waste and waste water (2.8%), energy supply (25.9%), transport (13.1%), residential and commercial buildings (7.9%), and industry (19.4%). (IPCC, 2007).

Meanwhile, increased concentration of carbon in the atmosphere is presumed to cause global warming which is a worldwide climatic problem partly due to its adverse effect on survival of living things. IPCC (2007) indicates that the global atmospheric carbon dioxide concentration has risen from 280 ppm from before the start of the Industrial Revolution (1750) to 381ppm in 2006, showing a 36% increase. One major social implication of global warming that is of significant concern in this century is the disappearance of low-lying island nations due to rising sea levels (MIT, 2009). The entire disappearance of island nations lying a few meters above the ocean surface is highly possible, given the rapid annual melting of polar ice.

To rescue the world from the effects of global climate change, a number of suggestions have been made on ways through which emission of greenhouse gases into the atmosphere could be reduced. These according to Verbist (2010) include technological approaches, reduction to fossil fuel energy emissions, reduction to land use change emissions, the use of vegetation and soil as carbon sink among other integrated options, and emission trading (the carbon market). Specific agricultural and forestry strategies suggested identified by Murray (2006) include afforestation, forest management, and agricultural soil sequestration which explores ways such as crop mix change, crop fertilization change and grassland conversion, among other methods to sequester carbon dioxide.

The slash-and-char method practice has been suggested as an alternative to the slash-and-burn which has been in practice for a long time in Ghana due to the former's ability to sequester atmospheric carbon through the use of Biochar, which according to Polya (2011), is a major component of reducing atmospheric CO_2 and global warming. Also, according to Brown *et al.* (2010), it is possible to combat greenhouse gas (GHG) emissions and reinvigorate rural and agricultural communities simultaneously through the use of biochar. Biochar is the name given to charcoal produced for agronomic and other ecosystem applications. "It is produced by heating biomass in the absence of oxygen, a process known as pyrolysis" (Brown *et al.*, 2010).

The name biochar was generated by Peter Reed, a New Zealand energy lecturer in 2005 (Sohi *et al.*, 2009). It is a plant–derived biomass that, by a process of charring, has been converted to a form which is essentially not degradable. According to Collison *et al.* (2009), biochar applied to the soil remains unchanged for a long time unlike other organic biomass like compost which later mineralizes and returns to the atmosphere to increase the atmospheric carbon concentration.

Lehmann *et al*. (2006) cited by Collison *et al.* (2009) indicates that biochar in the soil is very stable and can remain in the soil for hundreds and thousands of years and continue to sequester carbon dioxide. From a research carried out in Australia, Collison *et al.* (2009) reported increased crop yield, improved water-holding capacity, reduced soil fertilization requirement, and improved soil quality through the use of biochar. Biochar was also identified by Brown *et al.* (2010) to help minimize nitrous oxide (N_2O) and methane (CH_4) emissions into the atmosphere.

Due to the potential benefits from the use of biochar, the slash-and-char system is being promoted worldwide, especially in Africa. Trials have so far been made in Brazil, Senegal, DR Congo, UK, England, Tanzania, Ghana and other countries, and a lot of researches are being done to get this system of farming replace the slash-and-burn system seen to have short falls even though it is easy and convenient for farmers.

1.2 Problem Statement

The slash-and-burn system has been the main method adopted by smallholder farmers in Ghana for the production of annual food and perennial crops. In spatial terms, this agricultural practice results in the creation of a mosaic landscape, characterized by a spatial aggregation of land used as fallow (for variable durations of fields used for food crops and various perennial crop plantations) and quick removal of virgin forest. Though the system was previously seen as sustainable for under-populated tropical regions, it is now considered as one of the main causes of deforestation, soil degradation and spatial expansion of the transitional zone to the detriment of the tropical rainforest. According to Brown (1997), the slash-and-burn system leads to a significant release of carbon in the form of CO_2 to the atmosphere and major variations in soil characteristics.

Due to the problems with the slash-and-burn system, many studies continue to focus on environmentally sound alternatives to the slash-and-burn system of agriculture in the tropics (Brady, 1996). These include biochar systems. Claims and projections made so far on the relevance and potential impact of the use of biochar, particularly as a mechanism for sequestering carbon, are impressive (Lal, 2009; Woolf *et al.*, 2010). Given the potential benefits, the Slash -and-char system has been proposed as an alternative system to the unsustainable slash-and-burn system (Lehman *et al.*, 2006).

But it is not certain whether the slash and char practice is economically viable, and there is limited information on quantitative costs to its implementation. There are also questions pertaining to the amount and economic implications of carbon sequestered, fertilizer use forgone and what measures could be put in place to overcome possible barriers to the adoption of biochar.

The study aims at evaluating the economic viability of the use of biochar as soil amendment for agricultural productivity and as a tool that provides climate change mitigation services. With smallholder farmers in mind, what are the costs of the proposed carbon sequestration practice in Ghana?

1.3 Research Questions

The following questions then arise

1. What are the operational costs with the use of biochar in Ghana?
2. What is the profitability of the change from the slash and burn system to the slash and char system in the short term for maize production?
3. What is the profitability of the slash and char system under maize production in the long term from the view point of the farmer?
4. What is the profitability of the slash and char system under maize production in the long term from the view point of the society?

1.4 Objectives of the Study

1.4.1 Main Objective

The main objective of the research was to assess the economic viability of the Slash-and- Char system for carbon sequestration and agricultural productivity for smallholder maize farmers in Ghana.

1.4.2 Specific Objectives

To help realization of the main objective, the study considered the following specific objectives:

1. To determine the costs and returns per hectare for maize production under the slash and char system
2. To determine the costs and returns per tonne of biochar
3. To determine the profitability of the change from the slash and burn system to the slash and char system under maize production if the farmer buys the biochar in the short term
4. To determine the profitability of the change from the slash and burn system to the slash and char system if the farmer produces the biochar himself in the short term
5. To determine the profitability of the change from the slash and burn system to the slash and char system under maize production if the farmer buys the biochar in the long term
6. To determine the profitability of the change from the slash and burn system to the slash and char system if the farmer produces the biochar himself in the long term
7. To determine the profitability of the change from the slash and burn system to the slash and char system under maize production from the viewpoint of the society

1.5 Hypothesis

Table 1.5: Hypothesis and Theoretical basis for the Hypothesis

Hypothesis	Theoretical Basis for the Hypothesis
The slash and char system is a feasible alternative to slash and burn system.	A farmer's decision to change to a new production technology depends on the relative profitability of the two technologies (Horton, 1982). If the slash and char system is to be adopted, it should lead to a higher net return to the farmer relative to the slash and burn. Also, for the slash and char practice to be successful, the quantity of biochar applied must at least be produced from the same area of land that is to be cropped or the slash and char technique must work with the same resources as other conventional methods (Lehmann *et al.*, 2002)

1.6 Justification for the Study

Climate change has become an issue of global concern. As various ways are being sought in the combat of greenhouse gas emissions into the atmosphere, this study contributes to the development of a new agricultural practice, 'slash-and-char' system of land use in Ghana. The study helps to develop concepts on the possible adoption of the use of biochar in Ghana. The study helps to know quantitatively, the farm opportunity cost of biochar adoption both in the short term and in the long term. As with many investments, an investment which is not profitable to the private person may have a net positive impact on the economy.

This study therefore pinpoints the real impact of the slash and char practice on the farmers' income and on the national income. Farm practices that offer clean environment, interventions could be put in place by government and non-governmental organizations to encourage its adoption. This study contributes to the development of incentive packages that could be put in place to encourage farmers adopt the practice in the case where incentive is required for adoption to occur. This study will also help the development of theory on biochar and climate change mitigation.

1.7 Organization of the Study

This study is organized into five chapters. Chapter one presents an introduction to the study. Chapter two presents a review of relevant information on the topic. Chapter three discusses the methodology employed for the study. Chapter four presents results and discussions for the various objectives the study set out to accomplish, and Chapter five summarizes the findings, and makes recommendations for policy, research and development.

1.8 The Scope of the Study

The study was conducted in three agro-ecological zones, selecting one district from each ecological zone where some agronomic work on biochar had already begun. Two districts from the semi-deciduous forest zone (one with a Peri-Urban setting and the other with a rural setting) and one district from the Guinea Savanna zone were used for the study. The motive was to enable site-specific viability analysis across the ecological zones for maize production with and without biochar.

The first profitability analysis considered maize production for short term agricultural decisions, assuming that the farmers purchases two tonnes of biochar for application on the field. The next analysis assumed that the farmer owns a biochar reactor and produces biochar for application. The study then considered various incentive systems and their viability. Analysis was also done for maize production with and without biochar for long term agricultural decisions from the view point of the farmer and from the view point of the economy. In doing this, it was first assumed that the biochar for application is purchased by the farmer before analyzing with the assumption that the farmer produces biochar himself.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Theoretical Framework

Farmers are rational in their production decisions (Horton, 1982). They therefore seek to maximize their farm income (Antle *et al., 2001)* by choosing farm production technologies which leads to increased farm income relative to the next alternative technology in its best use. Given the slash and burn and the slash and char systems, farmers in Ghana will choose the system that maximizes their net income. They will therefore choose the option which cost them less and pays them more in terms of farm income (Antle *et al.,* 2001). Given that a farmer is currently producing with an existing technology, the change in net income that results from the change in the production technology will be: Change in Net income= [(Additional income + Reduced cost)-(Reduced income+ Additional cost] > 0 ………………(1); and the change in net income should be positive if the change to the new technology should occur.

The benefits of carbon sequestration is measurable in terms of contributions toward yield improvement, value of fertilizer application forgone (Collison *et al*., 2009), the cost of burning of biomass forgone (in terms of Ghana Cedis), and benefits from the carbon market (Cameron, 2010). The study assumes that the net emission reduction with the slash and char system is additional to the reference situation. For environmentally sound practice, the slash and char is to be preferred. However, the farmers' aim is not a clean environment. As business men, the objective is profit maximization. Therefore, regardless of the net positive environmental impact that the slash and char offers, the farmer will choose the practice which maximizes his net farm income.

Although the slash and char system will reduce emissions into the atmosphere, improve crop yield, and supplement fertilizer application, yielding tremendous savings in cost and therefore leads to improvement in the smallholder maize farmer's farm income, the slash and char system introduces additional cost to farmers (such as gathering of biomass, charring of biomass where the farmer produces the biochar himself, transportation of biochar to the field for application, and the incorporation of biochar into the soil).and this could be offset by the gains in yield, fertilizer application forgone, cost of burning forgone, and or payments from the carbon market.

Payment from the carbon market is not included in the financial analysis but is rather included in the economic analysis because this is an environmental benefit the society gets for sequestering carbon dioxide. If there is an incentive, the farmer's net income situation will improve. His choice between the two production practices will still be based on which option costs him less Ghana Cedis and pays him more in terms of net income. Therefore, such incentive packages could be structured such that it would be enough to cushion farmers for the reduction in revenue resulting from maize production under a desired production practice. Such incentive systems would be necessary in the event that the carbon sequestration option is financially less attractive to farmers. These incentive schemes could be from carbon payments or other incentive systems. However, to qualify the financial additionality criteria for carbon payment, the net present value of the best mitigation option should be less than that of the most profitable alternative, without carbon payment.

The slash and char system is assumed to be a viable alternative to slash and burn system on the basis that a farmer's decision to change to a new technology depends on the relative profitability of the two technologies (Horton, 1982).

2.2 Conceptual framework

2.2.1 Slash and Burn to Slash and Char

Figure 2.2.1 below gives a pictorial representation of the practices involved in the slash and char system and its alternative. As can be seen from the Figure, in the existing slash and burn practice, clearing of thrash is followed by burning of biomass on-site under open oxygen conditions but in the slash and char practice, there is no burning of biomass on-site under open oxygen conditions. Though the slash and burn practice is labour-saving, it leads to the release of CO_2 into the atmosphere. It also leads to destruction of soil microbes and therefore fast depletion of soil nutrients and destruction of the natural rain forest. The practice also involves application of copious amounts of fertilizer and this further contributes to Green House Gas emissions in the form of nitrous oxide. A farmer who applies the slash and burn practice obtains farm income from maize production activities under this practice which is the motivating factor for his continual use of this practice or otherwise.

Conversely, in the slash and char practice, initial vegetative clearing is followed by gathering and charring of biomass and the biochar obtained is applied to the soil with some fertilizer application, the rate being lesser than the rate used for maize cultivation under the slash and burn practice. Environmental benefits of the slash and char method may be improvement in air quality, improvement of soil easiness for tillage, reduced smoke from traditional hearths (through the use of improved household hearths), and improvement in soil water holding capacity (Lehmann and Joseph, 2009). Biochar also improves crop yield, and reduces soil fertilization requirement. However, the same system poses a threat of increasing extraction of wood from the forest for biochar production, and biochar could be detrimental to soil conditions if biochar is not well prepared. There is also the possibility of conflict over the distribution of carbon credits. With the slash and char system, extra time is needed to learn new skills (Lehmann & Joseph, 2009) and any increase in time for the performance of any extra activity incidental to the slash and char system may pose a threat to food security if this is not commensurate with the gains in yield improvement caused by those activities. The threat to food security also applies if biochar has a net negative effect on crop performance. Apart from the shortfalls outlined above, successful biochar deployment could improve socio-economic lives of farmers through employment creation and introduction of new governmental, non-governmental and quasi-governmental organizations to the community (Lehmann & Joseph, 2009).

Despite the environmental benefits, the farmer's decision on which practice to employ would still be motivated by financial gains resulting from maize production under that method so that in the end, the father chooses between the slash and burn and the slash and char based on financial gains and not necessarily the environmental benefits or convenience.

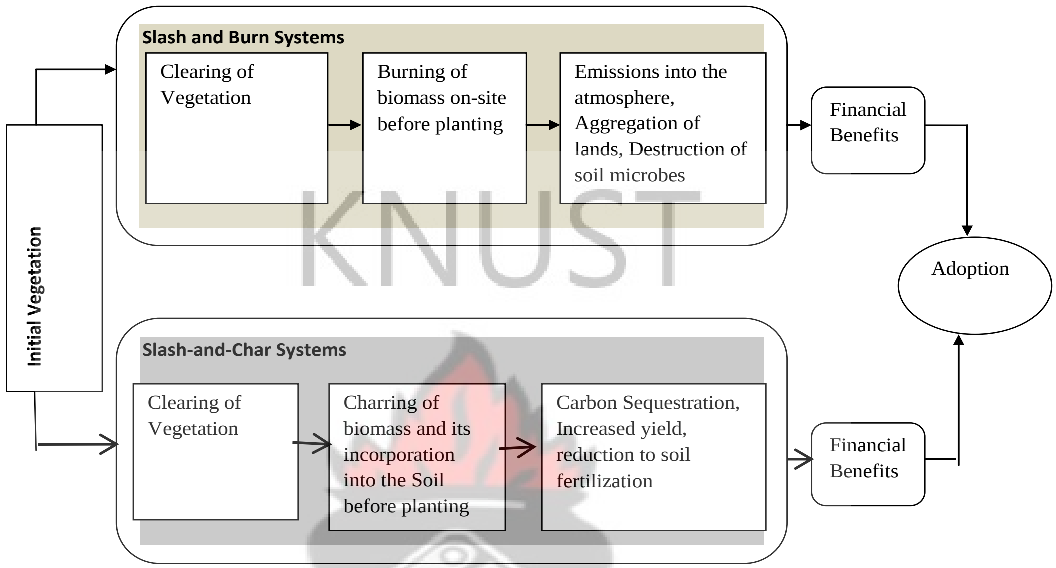

Fig 2.2.1 Conceptual Framework for Slash and Char Adoption

Source: Author's Design based on Literature

2.2.2 Relationship between Barriers to Adoption and Climate Change Mitigation

Figure 2.2.2 below illustrates the relationship between Climate Change mitigation and barriers to the adoption of the slash and char system of land use. As can be seen, the use of biochar offers a good alternative for climate change mitigation. Yet there may be some institutional, socio-cultural, technical, economic, and other factors limiting its adoption. In some situations with environmental projects, a production technique promises sound environmental benefits but this gain is not commensurate with financial benefits to farmers. At other times there might be reduction in farm profits from an adoption of a mitigation option due to yield reduction. Under both circumstances, provision of special incentives to farmers and the continuing commitment by governments and supportive organizations to achieve the environmental benefits of the mitigation practice have a role to play in the project's viability and hence adoption. But incentives alone cannot help overcome the barriers to adoption. Some of the limiting factors could be overcome by promotion of the technology, and providing technical know-how.

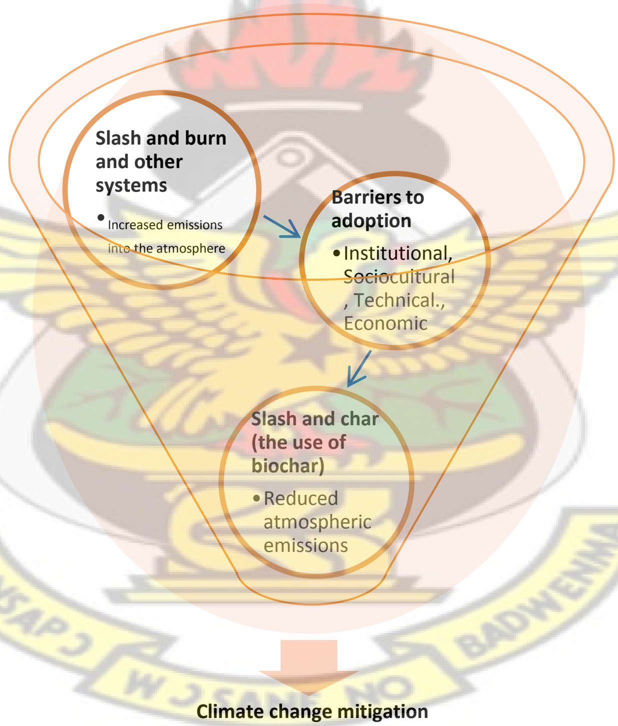

Fig. 2.2.2 Relationship between Barriers to Adoption and Climate Change Mitigation
Source: Author's Design

2.3 Biochar

Scientific literature define biochar as a carbon-rich product which remains when biomass is heated to a high temperature under reduced or no oxygen conditions through a process called pyrolysis. According to Collison *et al.* (2009), an amount of carbon remains in this charred material which remains after pyrolysis. This brings the difference between burning under reduced oxygen and combustion or incineration in oxygen-rich environment, where the carbon oxidizes to atmospheric carbon. This charred material, according to Collison *et al.* (2009), exhibits similar characteristics with charcoal. Apart from the use of forest biomass intended to be burnt on-site, biochar can also be obtained from yard, orchard and urban forest trimmings, agricultural crop waste, wood processing waste, processing waste from food stuffs, manure and poultry litter in excess of manure, and spoiled hay or straw (Miedema, 2011).

2.3.1 Biochar Production

Biochar is a carbonaceous material produced for application as part of agronomic or environmental management Brown (2009). The process through which biochar is produced is called pyrolysis (fast pyrolysis, slow pyrolysis or gasification depending on the temperature and the conditions of production). Fast pyrolysis gives more of bio-oil and less of biochar. However, slow pyrolysis produces more of biochar and less of bio-oil (bio-fuel). Table 2.3.1 below summarizes the conditions for classification of pyrolysis and the possible products of pyrolysis adapted from Duku *et al.* (2011). The main products of the pyrolysis process are biochar, bio-oil and syngas. The syngas produced is combustible and could be used as a source of fuel (Talberg, 2009). The bio- oil produced could also be an alternative to diesel. Biochar on the other hand is used as filtration medium in addition to its agronomic benefits. Poultry farmers also use biochar to enhance egg production and prevent diseases outbreak. The proportion of biochar and bio-oil produced from the pyrolysis of biomass depends on the intent of production- whether to produce biochar or bio-diesel. For agricultural purposes, the objective of production would be to produce more biochar and less or no bio-diesel. In that case, the temperature of the pyrolysis plant could be adjusted as such. However, for energy generation, more of bio-oil would be produced relative to biochar. This study does not explore the relative profitability of the alternative objectives of pyrolysis of biomass. Work on the relative profitability of two biochar systems (fast and slow pyrolysis) was done by Brown *et al*. (2010), and it was revealed that both scenarios were not profitable activities given the assumptions made.

Table 2.3.1 Modes of Pyrolysis and Possible Yields

Mode	Condition	Liquid(bio-oil)	Biochar	Syngas
Fast pyrolysis	Moderate temperature (up to about 650 º C)	75%(25% water)	12%	13%
Intermediate pyrolysis	Low moderate temperature. Moderate hot vapour residence time	50% (50% water)	25%	25%
Slow pyrolysis	Low moderate temperature (430 º C to 500 º C)	30%(70% water)	35%	35%
Gasification	High temperature (>800 º C). Long vapour resident time	5% tar (55% water)	10%	85%

Source: Amended from Duku *et al.* (2011)

2.3.2 The Pyrolysis Process

Pyrolysis is a thermal decomposition of organic substances at high temperatures without the use of oxygen. It differs from combustion and hydrolysis because the pyrolysis process does not involve reactions with oxygen, water or any other reagent. To produce biochar, the biomass is fed into the pyrolysis kiln (pyrolyser) - that is a furnace (Talberg, 2009). This produces biochar with or without bio-oil depending on the technology being used and the objective of the pyrolysis process. Depending on the technology being used, the first stage produces biochar and bio-fuel (bio-oil) as described by Figure 2.3.2 below. These can then be gasified at higher temperatures to produce syngas in addition to the primary products. Syngas can be used as fuel. Currently, pyrolysis plants available in Ghana do not produce bio-oils: only biochar is produced.

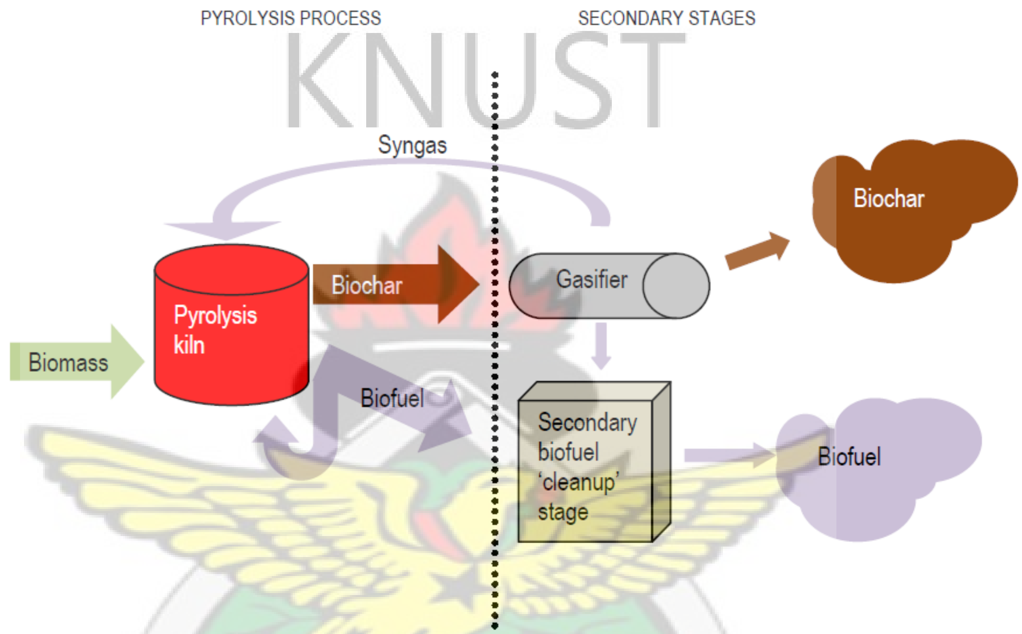

Fig. 2.3.2: Simplified Flow of the Pyrolysis Process; Source: Adapted from Talberg (2009)

2.4 Slash and Burn versus Slash and Char

The slash and burn system of land use is the cultivation method where the biomass slashed during land preparation is burnt on-site under full oxygen to clear the land of trash. In the slash and char system, the forest biomass is not burnt on-field under open oxygen condition. It is rather gathered, and burnt in a kiln under reduced oxygen conditions in a process called pyrolysis. The product obtained from the pyrolysis (called biochar) is then incorporated into the soil as soil conditioner. The slash and burn is believed to increase carbon dioxide concentration in the atmosphere and it depletes soil fertility (through the destruction of soil microbes) whereas the slash and char system sequesters carbon and improves soil conditions. According to Duku *et al*. (2011), the use of biochar mitigates climate change, reduces poverty through increased farm income, minimizes the impact on environmental resources, stabilizes organic carbon, and reduces emission of greenhouse gases into the atmosphere.

2.5 Biochar and Agriculture

Citing from Coomes and Burt (1999), Swani *et al*. (nd) report that the use of charcoal as soil amendment tool for agricultural purposes is common in Brazil and widespread in Asia. Studies show that carbonized materials are formalized for use as soil amendment in Japan, and 30.6% of its national charcoal production is used on agriculture. Yeboah *et al.* (2009) reports that there are benefits for maize crop production with application of biochar than with cattle manure. Report from Collison *et al.* (2009) and other available literature indicate that biochar application to the soil has long term benefits on the biophysical properties of the soil and hence improved soil productivity. Some of these benefits cited include improvement in the water holding capacity of the soil and therefore reduced percolation, improvement in the soil structure and soil pH (Cameron, 2010).

2.5.1 Benefit from Increased Yield

According Fruth and Ponzi (2010), using biochar as soil amendment improves crop productivity. They also cited that the productivity of crops in *terra preta* (Amazonia Dark Earth) may be twice that of crops grown in nearby soils, and that the use of biochar plus chemical amendments has demonstrated the ability to double grain yields over the use of fertilizer alone. Productivity, however, according to the same authors, depends on a number of factors including the type of soil, the type of crop, biochar concentrations and nutrient levels. Collison *et al.* (2009) also reports that gains in yield of 100% or more have been achieved on poor soils for some countries. Biochar is reported to have no influence on productivity to as much as 151% yield increment with soya bean (Talberg, 2009).

2.5.2 Benefits from Fertilizer Application Forgone

Cameron (2010) reports that nitrogen fertilizer usage can be reduced by 100% through the use of manure-based biochar and possibly, 50% through the use of wood-based biochar. The amount of money that would have been spent on fertilizer as well as the cost of its carriage and application becomes benefits.

2.5.3 Benefits from Carbon Price (Carbon Payment)

Though the use of biochar is currently not included in the carbon market, its inclusion in the future is highly possible. For farmers to adopt the carbon sequestration practice, agronomic benefits from the use of biochar should be high enough to cover its investment costs, or payment from the carbon market should at least be high enough to cover the possible reduction in revenue incurred by the farmer for committing resources into the carbon sequestration practice. However, since carbon credit buyers would also incur administrative expenses, the final price the farmer receives per tonne of carbon sequestered is reduced by such expenses. Therefore, carbon payments should be high enough so that it would be able to cushion farmers for the charges that would be applied by carbon emission traders for their supply of marketing services

Kulyk (2012) reported carbon price of $37 to $200/tonne (giving a preferred estimate of $118.5/tonne). Where carbon payment exists, the revenue gained by the farmer from carbon payment is the carbon sequestration rate, multiplied by the CO_2 offset price per ton of carbon equivalence.

2.6 Carbon Sequestration Potential of Biochar

Every tonne of biochar applied to the soil contains 0.61-0.8 tonne of carbon (Kulyk, 2012). This, in relation to the molecular weight of carbon, translates into a CO_2 equivalence of 2.2-2.93 tonnes that can be sequestered by each tonne of biochar applied to the soil (Kulyk, 2012). Therefore the average carbon sequestration potential of biochar per tonne is 2.565 tonnes of carbon dioxide equivalence (t CO_2 eq). This implies that, for the biochar application rate of two (2) tonnes per hectare considered for this study, 5.13 tonnes of CO_2eq could be sequestered per hectare by biochar applications to the soil. It is however not clear as to whether this value is the same for all biochars, and across all regional soils.

2.7 Cost of Climate Change Mitigation

Potential elements of cost for climate change mitigation services in general, from economic viewpoint (De Pinto *et al.*, 2010), include farm opportunity costs (the value of alternative farm income forgone from the best alternative profit generating activities) and the cost associated with implementation of contracts for the provision of environmental services.

At the micro-level such as with the focus of this study, transaction cost would not apply. With the inclusion of the carbon market, transaction costs become important for discussion since the amount the farmer finally receives as carbon payment depends also on the transaction cost. In the carbon market especially for small-scale farmers, there would be provision of marketing services by marketing participants plus a margin charged on the farmers by players for the provision of carbon payment services to the farmer. These services include Search and Negotiations, Project Approval fees, Project monitoring cost, Verification, and Insurance (Cacho *et al.*, 2008). Fig.2.7 is a schematic representation of farm opportunity costs and transactions costs of climate change mitigation services.

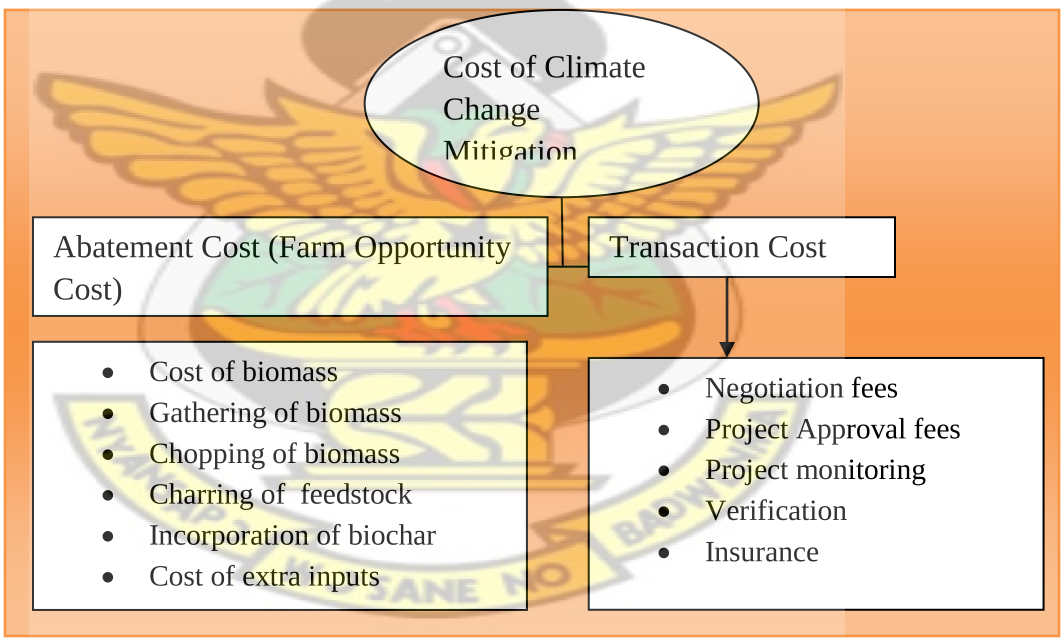

Fig 2.7: Schematic Representation of Costs of Climate Change Mitigation

Source: Author's Sketch, 2012

2.8 Abatement Cost (Farm Opportunity Cost)

Abatement costs are defined by Cacho *et al*. (2008) as the cost of producing a unit of uncertified carbon sequestration services or the cost of producing one unit of biomass carbon. It is the opportunity cost of undertaking climate change mitigation services. That is; the value of the profit from the most lucrative alternative land preparation practices forgone. For small-scale maize production in Ghana, the opportunity cost of the use of biochar is the value of the profit from the next alternative land preparation practice in its best use. This could be quantified in terms of how much the farmers would have earned from the best alternative employment in the area in the absence of the increased production operations induced by the use of biochar or the profit forgone by switching from the current production practice to the carbon sequestration practice. New elements of cost with the use of biochar under a subsistence maize production in Ghana include:

2.8.1 Cost of Biochar

Farmers can obtain biochar by purchasing from biochar sellers, by making it themselves, through community or group biochar making, or by share burning arrangements where the trash from the field is turned into biochar by someone other than the farmer so that the biochar is shared between the farmer and the biochar producer. Cameron (2010) puts the expected price of agrichar (biochar) at $122.50 per tonne. Where the farmer purchases the biochar, the total cost of biochar required is the price multiplied by the application rate. The minimum application rate of biochar has been estimated at 1 tonne (1000kg) per hectare by the Black Earth Products (BEP). Application rates up to 78 tonnes per hectare have been found in literature but this study explores an application rate of 2 tonnes Ha^{-1}

In the event where the farmer chars the biomass himself, the cost of biomass (if imported or trucked in from elsewhere), the cost of gathering the biomass, the cost of transporting the biomass to the production site, the cost of chopping it into pieces suitable for charring as well as the cost of charring the biomass become the cost elements of consideration apart from some fixed costs.

2.8.1.1 Gathering of biomass

This activity may be done manually or through the use of a machine specially designed for that purpose. A machine for gathering biomass could be designed to chop it into pieces as it gathers. The cost of gathering biomass would differ with vegetation type and the type of weeds cleared on the field. Thorny bushes are likely to attract higher charges. In situations where there are a lot of big trees on the field, gathering of biomass may take time. Also, it is difficult to gather biomass that has already dried on the field relative to biomass that has just been cleared. Fig. 2.8.1.1 shows gathering and loading of biomass.

Fig. 2.8.1.1 a: Loading of Biomass to Production Site; Source: Author's Field Work, 2012

2.8.1.2 Loading and off-Loading of Biomass into Truck

This cost arises with a centralized biochar production system where the biomass is cut and trucked in from somewhere else**.** Where purpose trees are grown for biochar production due to biomass deficit like the case of the Guinea Savanna Zone of Ghana, the cost of truck services may not arise. On rather larger plantations, truck services would still be needed for biomass quite distant from the biochar production site. The cost of loading and off-loading of biomass may reduce under a mechanized biomass loading where the biomass is loaded into the truck by a machine specially designed for that purpose.

2.8.1.3 Transportation of biomass

Transportation of biomass would be for a system where the biomass is brought in from different fields. The cost of transporting biomass would depend on the quantity carried per trip, distance from the source of biomass to the production premises, the type of biomass, and perhaps, whether the truck is owned by the biochar producer or someone else.

2.8.1.4 Cutting of Biomass into Pieces

With all the technologies available for biochar production in Ghana, the biomass from the field would need to be chopped manually further into smaller sizes appropriate for charring. This is even more necessary since there would be too much air in the kiln if the biomass is not compact. Too much air in the kiln would reduce biochar output by burning biomass to ashes, and it may also increase emissions into the atmosphere if the air is not tapped. With more advanced kilns like the rotary kiln, the biomass could be chopped into smaller pieces by the kiln as it combusts the biomass.

2.8.1.5 Loading of Biomass into the Kiln

The cost of loading biomass into the kiln would depend on the type of kiln, and the processes involved in filling the kiln with the biomass. With the metal kiln available in Ghana, the biomass is fed into the kiln through an opening at the side. Additions are then made by the help of an opening at the top to fill the kiln in full with the biomass. For light weight biomass, it may be easy to do this. For heavy biomass, it would have to be carried in bits and this would take some time.

2.8.1.6 Charring of biomass

The metal kiln available in Ghana has two compartments: a smaller lower chamber into which the starter (fuel wood) is feed and a bigger upper chamber where the biomass is fed. The two chambers are separated by a metal plate with small perforations. Charring of biomass begins after filling the upper chamber with the biomass. A starter (fuel wood) is put into the lower chamber and ignited. It is allowed to burn under oxygen conditions until the metal plate (separator) heats enough to enable burning of biomass. The lower chamber is then closed together with the closure of all openings to the kiln to allow burning under zero oxygen conditions.

Fig. 2.8.1.6: A Metal Kiln in Ghana for Biochar Production at CSIR-Soil Research Institute, Kumasi: (March 20, 2013)

2.8.1.7 Monitoring of the Burning Process

Regulation of the temperature is very important since biochar output and the resident time depend on the temperature. In the course of the burning process, the temperature can go down. In that case, new fire has to be set to the lower chamber to restart the process of charring. Successful charring process has three stages: a) Blue smoke to start the process. b) Yellowish smoke indicating that the biomass is still charring and c) White (grey) smoke to indicate that the process is completed. Labour for monitoring of the burning process is a cost item for consideration.

2.8.1.8 Removal from the Kiln, Weighing and Bagging

After biomass is successfully charred, they are then collected from the kiln. It is good to pour water on biochar which still has fire in it otherwise it would burn into ashes if collected from the kiln. Where water is poured on the biochar, sun-drying it becomes necessary before it is weighed and bagged.

2.8.2 Biochar Application Cost

The cost of incorporating biochar into the soil is also captured under the cost of land preparation. This cost depends on the method of application. Methods of application found in literature include broadcast-and-disk method, trench-and-fill method (Williams & Amott, 2010), and side placement suggested by other researchers. However, the best application method and rate of application as well as the right time of application are not yet known. Theoretical gaps also exist as to whether biochar application should be one off or with subsequent applications, and with what year intervals. The method of application considered for this study is that of broadcast-and hoe method, comparable with the broadcast-and-disk method studied by Williams & Amott (2010). The possible cost per hectare could be compared with the cost of spreading the biochar plus that of hoeing or plowing a hectare of land.

2.9 Revenues

The main source of revenue for the farmer is the output of maize per hectare, multiplied by the price of maize per bag in the area. Increase/decrease in total revenue between the two technologies would be from the contribution of biochar to yield (whether positive or negative) due probably to field specific conditions. Where a payment scheme exists, the total revenue for a farmer per production season are the revenues from the sale of maize plus the carbon sequestration rate per hectare times carbon price per tonne of CO_2 equivalent (tCO_2eq). There may be instances where the farmer also produces surplus biochar from farm operations and this also sold and added to the revenues per hectare.

2.10 Viability Analysis of Farm Production Technology Adoption

2.10.1 Partial Budgeting Approach

The partial budget does not provide data on the cost of a whole system but calculates the extra profits of an improved measure in terms of additional money spent and gained. The advantage is that only data on costs and returns of measurements that are different from the conventional system are needed to compare the two systems (Joenje, 1996). From Horton (1982), data on quantities of inputs which vary between alternative technologies, prices of these variable inputs, yields resulting from the two technologies as well as prices of harvested produce are needed to do an accurate partial budgeting.

That is, this budgeting approach does not include all production costs but only those which vary between the current production practice and the proposed one (Horton, 1982). From theory, it helps to assess the impact of the change in the production system on the farmer's net income without knowing all costs incidental to the production process. That is, the partial budget explores the change in the farmer's net income that results from the change from one technology to another. The selection criteria for the partial budget, according to Horton (1982) are to:

a. Reject the new technology if net income remains the same or decreases. This means the new technology is not profitable relative to the existing one.
b. Accept the new technology if net income increases and variable cost remain the same or decrease, which means the new technology is profitable than the old one known to farmers.
c. If both the net income and variable cost increase, the rate of return should be used for a decision. The greater the increase in net income and the higher the rate of return, the more economically attractive an alternative technology is.

However, for a change in technology that requires high capital investments like that of biochar, partial budgeting is not an appropriate tool for assessing its economic viability as it fails to take into account what happens over time but at least what happens in the short term is also very important. Economic models that explore the present values of the alternative technologies become appropriate. For a technology like the slash-and-char system, biochar amendments to the soil in one year have agronomic relevance in the subsequent years.

Therefore, just evaluating its profitability in the short term might be an under-estimation of its full economic potential.

210.1.1 The Rate of Return

Rate of return is useful in evaluating the economics of a new production technology in that, in addition to a change in net income, the rate of return measures the increase in net income which is generated by each additional unit of expenditure (Horton, 1982). It measures the net return on additional labour, capital and management. It becomes necessary if the new technology costs more than the farmers' old technology. That is if the new technology is costly, then the rate of return must be higher than those of other possible investments, and higher also enough to cover risks associated with adoption. In some cases, the rate of return could be negative, meaning the investment is not profitable. Where it is also lower than those of old and other alternative investments, the new technology should be rejected.

Horton (1982) computed rate of return on capital as $R = \frac{\Delta NI}{\Delta VC} \dots\dots\dots\dots\dots\dots..(2)$.

Where

ΔNI = change in net income and ΔVC = change in variable cost. The change in net income is the difference between the change in total returns and the change in fixed costs and variable costs (Horton, 1982). The fixed costs are the costs that do not vary across the slash-and-burn and the slash-and-char technologies. Variable cost here is the cost of investment that varies between the two technologies. Therefore, since the fixed costs are the same for both technologies, they cancel out.

2.10.2 Net Farm Income

Net farm income is a measure of return to the equity capital, unpaid labour, and management contributed by the owner/operator to the farm business (Kay & Edwards, 1999). The net farm income is influenced by the profitability of the farm business, and the proportion of the total resources utilized in the farm business contributed by the farmer. Replacing borrowed capital with equity capital, rented land with own land, or hired labour with operator labour can all increase net farm income (Kay & Edwards, 1999). Apart from the farmer, other resource contributors to maize production under the slash and char system include money lenders, landlords, employees, and input suppliers such as suppliers of biochar and fertilizer. After the deduction of payments to the suppliers of inputs, interest to lenders of borrowed money, rent to owner for rented land, and wages to employees, what is left over is the net farm income. The size of the net income to the farmer depends on how many of the resources he contributes. It is argued that the net farm income should be a starting point for analyzing profitability than as a good measure of profitability by itself since it is an absolute cedi amount, making it difficult to use net farm income by itself as a measure of profitability.

2.10.2.1 Return on Capital

Return to capital (also called return on assets or return on investment) measures profitability with a ratio obtained by dividing the cedi return to assets by the average farm asset value for the year (Kay & Edwards, 1999). By this approach, return on assets is calculated by finding the *adjusted net farm income*, subtracting the returns to labour and management and then expressing the remaining amount as a percentage of the adjusted net farm income. This percentage obtained is the cedi value of all capital invested in the farm business. Expressing it as a percentage allows for comparison with other values obtained from the different farms. The adjusted net farm income is the net farm income plus any money accruing from the interest expense due to the amount and the type of financing for the business. The net farm income is adjusted because the return to capital also measures the cedi return to both debt and equity capital. Therefore, the adjusted net income equals the actual net farm income in the absence of debt and thus there is no payment of interest.

2.10.2.2 Return on Labour

Return to labour is the cedi amount that represents the part of net farm income from operations that remains to pay for operator labour after all capital and management are paid returns equal to their opportunity cost. That is what remains after subtracting the opportunity cost of unpaid management and the opportunity cost of farm investment in total farm assets from the adjusted net farm income.

2.10.2.3 Return on management

Return to management is the portion of adjusted net farm income that remains after the opportunity cost of both unpaid labour and equity capital have been subtracted (Kay & Edwards, 1999). It represents the return to the farmer for the management of input. Return to management can be negative. Negative return to management means that the net farm income was not sufficient to provide a return to capital, labour and management equal to or higher than their opportunity costs (Kay & Edwards, 1999).

2.10.2.4 Return on Farm Equity

Return to equity is the return to the owner's share of the invested capital. That is the return on equity capital. Equity capital is the capital that would be available to the farm for alternative investment if the business is liquidated and liabilities are paid off (Kay & Edwards, 1999). In computing the return to equity, no adjustment to the net farm income is needed. The net income from operations without adding back the payments on interest is used. Return on labour and management are deducted from the net farm income from operations to arrive at the return on equity and then expressed as a percentage.

2.11 Biochar Systems

There are three broad biochar (pyrolysis) systems identified in literature. Of these are a centralized pyrolysis plant, low –tech pyrolysis kilns for individual farmers or a small group of farmers and mobile on-farm pyrolysis truck system powered by syngas (Talberg, 2009).

2.11.1 Large-scale Centralized Biochar System

This biochar production system is proposed to be a centralized system, charring all the biomass (producing 1tonne of biochar in 3days) in a particular region (Talberg, 2009). The main motivation for this biochar system is large-scale biochar production and the production of bio-energy for sale through commercial distributors in regional or even international level (Joseph &Watts, 2009). For this study, a kiln which produces only biochar is assumed. This kiln is assumed to produce one (1) tonne of biochar in three days with a biochar recovery rate of 20%, making a total biochar output of 121tonnes per year. In this case, biomass is trucked in from fields around a production premise sited in the community. Apart from a building to store biomass and biochar as well as other equipment, wood cutter is needed to help chop woody biomass into pieces. All labour requirements are also assumed to be met by wage labour, the cost of labour being GHc 10 per man hour for both Ayuom and Afiaso and GHc 5 per man/person hour for Nyankpala. Each hired labour uses four (4) hours for the GHc10 and GHc 5 charges.

2.11.2 Household-Scale Biochar System.

This system is proposed by Joseph & Watts (2009) to produce both household cooking energy and biochar for soil amendments. The system seeks to integrate biochar preparation into the household cooking system so that the farmer prepares biochar with household level cooking stoves. The system is proposed to either operate solely on on-farm residues or in combination with wood as potential sources of energy for biochar production in a sustainable manner. This low tech individual or group household reactor system may not include secondary processes such as gasification.

The stove is found to be capable of producing 1.6kg of biochar a day. With this production capacity, it would take 1250 days for a farmer to get two tonnes of biochar for application. The stove system could therefore be for backyard farms of small sizes. In Ghana, some biochar stoves have been provided to farmers at Afiaso for domestic cooking and small-scale biochar production at the household level. However, most of the farmers stopped using the stoves because according to them, the stove does not cook their food fast enough for them. Apart from that, the feedstock used burns so fast whiles the stove becomes heated that they are often unable to stock it with new feedstock again.

2.11.3 Mobile On-Farm Biochar System.

Under this system (shown in fig. 2.5.3), biomass on the field is processed by a pyrolysis truck. The pyrolysis truck is powered by syngas and could be driven around for processing of biomass (Talberg, 2009). It is proposed to make use of biomass from field for the production of biochar and bio-oil. The biochar and bio-oil produced could therefore be transported back to the community for farmers and customers. It is assumed that the truck produces only biochar with a recovery rate of 20%. The cost of the mobile pyrolysis truck is estimated between GHc192,000 and GHc 500,000 and can process 1 tonne of biomass per hour in a continuous process. This leads to the processing of 8tonnes of biomass per day, producing 582.4 tonnes of biochar per year. The truck is replaced every five years. This system could be more efficient in farming areas where the topography of the land would be suitable for ease of movement by the truck, and areas where there is adequate road connectivity so that the truck could easily move from field to field to process biomass.

Fig. 2.5.3: A Mobile On-farm Biochar Reactor System (Adapted from IBI site, 24th January, 2013)

CHAPTER THREE

3.0 METHODOLOGY

3.1 The Study Area

The study was conducted in the Bosomtwe-Atwima-Kwahoma District of the Ashanti Region, Twifo-Hemang-Lower-Denkyira District of the Central Region of Ghana and the Tolon/Kumbungu District of the Northern Region.

3.2 Sampling Techniques

In the Bosomtwe-Atwima-Kwahoma District, Ayuom Community was purposively selected on grounds that there has been prior agronomic research on biochar in that community. Ayuom is also in the Semi-deciduous forest agro-ecology with a Peri-Urban setting. For Twifo-Hemang-Lower Denkyira Distict, Afiaso Community was purposively chosen. Afiaso is typical of a semi-deciduous forest with a rural setting and some promotion on biochar is being done there. The Nyankpala community in the Tolon/Kumbungu District was also chosen since some trials on biochar have been going on there, and also to reflect maize production in the Guinea Savanna agro ecology.

3.3 Type and Sources of Data

Data used for the research was mainly of secondary sources. This was supported by qualitative data through interviews, published papers and other archival sources.

3.4 Methods of Data Collection

` Data on the existing cost of production for the slash and burn system in the various study areas was sourced from MoFA (Ministry of Food and Agriculture). This was supported by focused group discussions and qualitative data. Consultations were done with researchers from CSIR to get data on yield projections and fertilization requirement under the use of biochar. Those who were involved in the establishment of the experimental fields were interviewed to help generate data on the cost of biochar application. The cost of biochar preparation was determined through interviews with biochar producers and experimental production of biochar with trash slashed from cropland.

3.5 Mathematical Models

Change in farm net income from the change to slash and char from the slash and burn system for short-term agricultural decision was explored through the partial budget analysis. In the analysis, biochar was treated as a market commodity with a price. We then considered cases where the farmer produces biochar with his own biochar reactor, and with a community owned biochar reactor. Change in net income was calculated as:

$$\Delta NI_{cs} = [B_{ycs} + C_{inep}] - [B_{yep} + C_{incs}] \ldots\ldots\ldots\ldots\ldots\ldots\ldots .(3)$$

Where:

ΔNI_{cs}= Change in net income by switching from the slash and burn practice to the slash-and-char system.

B_{ycs} = Benefits from maize production under the carbon sequestration practice

B_{yep} = Benefits from maize production under the existing slash and burn practice

C_{inep} =Costs of inputs under the existing slash and burn practice

C_{incs} = Costs of inputs under the slash and char practice

Since some of the inputs are the same for the two technologies, they are cancelled out so that only the items that vary across technology are captured in this calculation. Items that vary across technology, considered in this equation include: cost of fertilizer; its carriage to and application on the field, labour for burning of trash, transportation of produce, cost polyethane and juke sack for transporting maize, gathering of biomass and cost of biochar, its carriage and application on the field. No burning is required under the slash and char practice. Rather, gathering of the trash intended for burning on-site is required. Fertilizer is required in reduced quantities for the slash and char practice (reduced by fifty percent). However, biochar is required for application under the slash and char system and not under the slash and burn system. Since yield also increases under the slash and char practice, the amount of money required for jute sacks, polyethane sheet and transportation of produce under the slash and char practice is higher than that required for the existing slash and burn practice.

Farm opportunity cost (abatement cost) per tonne in the short term is given as:

$$C_{ab} = \frac{\Delta NI_{cs}}{CSR(tCO_2eha^{-1})} \text{...}(4)$$

Where C_{ab}=Abatement cost; ΔNI_{cs} = the change in net income by switching from the slash and burn practice to the slash and char practice. CSR=Carbon Sequestration Rate measured in tonnes of CO_2equivalence per hectare.

For long term agricultural decision, cash flows for maize production with and without biochar scenarios were generated and net present values were calculated through the use of spread sheet. The Net Present Value is given by:

$$NPV = \sum_{t=1}^{n} \frac{Bt - Ct}{(1+r)^t} \text{......................}(5)$$

Where B_t= gross benefits for year t, C_t= gross cost for year t; r = the discount rate, and t is the year. The decision rule is to accept projects with positive Net Present Values and reject those with negative NPVs. In financial theory, the project yielding higher NPV is selected if there is a choice between two mutually exclusive alternative projects.

The relative profitability of the two systems was estimated by subtracting the NPV of the Slash and char system from that of the slash and burn system so that a negative answer means the slash and char system is a profitable alternative in the long term. The abatement cost (farm opportunity cost) per tonne is calculated by dividing the difference in the NPVs by the carbon sequestration rate per hectare. To qualify the financial additionality criteria of the Kyoto Protocol for carbon payment, the present value of the carbon sequestration option should be less than the most profitable alternative without carbon payment (De Pinto *et al., 2010*). That is, $NPV_{exp} – NPV_{csp} > 0$

Abatement cost per tonne is given as:

$$C_{ab} = \frac{NPV_{\exp} - NPV_{csp}}{CSR(tCO_2eqHa^{-1})} \text{..................................(6)}$$

Where C_{ab}= Carbon abatement cost; NPV_{exp} = Net present value from the existing production practice; NPV_{csp} = Net present value of carbon sequestration practice; CSR=Carbon Sequestration Rate (measured in tonnes of CO_2 equivalence per hectare). The abatement cost (farm opportunity cost) measures the cost of the carbon sequestration activity to the farmer. That is the net value of the two alternatives at their best use. This could be positive or negative-a positive result meaning that the NPV of the carbon sequestration practice is less that of the slash and burn practice. The higher the positive value the more unprofitable the change from the slash and burn to the slash and char. A negative value on the other hand signifies that the change from slash and burn to the slash and char is profitable. The higher the absolute value of this negative result, the more profitable the change.

If carbon payments exist, the annual farm profits earned by switching from a production practice 'j' to a carbon sequestration practice 's' per year T is given by: $NPV(j,s) = \sum_{t=1}^{T} P_t f(X_i) D_{ft} + P_{ct} C_{srt} D_{ft}(j,s) - W_{it} X_{it} D_{ft}(j,s)$ ……………. (7)

Where $P_{t.}$ is the price of output, f (X_i) is the output of maize per hectare; $D_{ft.}$ is the discount factor for year t; $P_{ct.}$ is the carbon offset price for year t, C_{srt} is the carbon sequestration rate of year t and $W_{i.}$ is the price of input X_i.

CHAPTER FOUR

4. 0 RESULTS AND DISCUSSIONS

4.1 Production Costs

4.1.1 Maize Production Cost

This analysis is done with the assumption that biochar is a market commodity with a price. Production cost of maize is attached in Appendices for the three areas for with and without biochar scenarios. Annual operational cost for maize production under the slash and burn system ranges from GHc 867 to GHc 1774 per hectare depending on the production site. The use of biochar increases the total farm production cost to a range from GHc7054.49 to GHc10127 per hectare. Differences in the operational costs across districts are largely due to variation in the cost of farm labour and differences in some input prices like the rental price of land. Cost of person/man hour of farm labour is found to be the same (GHc10) for both the Atwima-Kwahoma District and the Twifo Hemang Lower Denkyira District. However, it is half this amount for the Tolon/Kumbungu District (GHc 5). Again, gathering of biomass is not needed at Nyankpala since the biomass is plowed into the soil most of the time.

4.1.2 Biochar Production Cost

Table 4.1.2a below establishes the cost of production of biochar per tonne for a Community-based centralized biochar production model. Biochar is assumed to be produced from a centralized point in the community and biomass can be brought in from fields around the Community. The pyrolysis plant can produce 1 tonne of biochar (with a biochar recovery rate of 20%) in three days which amounts to 121 tonnes of biochar per year. This means 5 tonnes of biomass yields 1 tonne of biochar and this can be processed in three days. Biomass is also assumed be trucked in from fields 1km from the biochar production site. The biochar is also transported back to the farm 1 km away from the point of biochar production. Under this assumption, the production of biochar is decoupled from the farming system. Depreciation is computed using the straight-line method, assuming that biochar reactor and the wood cutter have economic life of 30 years. Annual depreciation for building is 3% per annum. From Table 4.1.2a it takes about 54 person/man hours to produce a tonne of biochar. This translates into some 216 working hours. It takes about 550 person/man hours to process the total above ground biomass slashed from a Hectare of crop land, assuming that each hectare yields a total above ground biomass of 50.94 tonnes (based on the biomass output realized per Hectare as part of this study). Operational cost of biochar per tonne is GHc 806.93 (that is GHc 8221 per Hectare). This cost could reduce with improvement in the biochar recovery rate through improvement in the technology, production skill or other factors.

Table 4.1.2a: Cost and Returns per Tonne of Biochar for a Community-based Centralized Biochar Production Model

Item	Qty	Unit Price (GHc)	Total (GHc)
Biochar Output(tonnes)	1	2000	2,000
Establishment Cost			
Land	1	3,000	3,000
Building	1	5,000	5,000
Wood cutter	1	3,000	3,000
Biochar Reactor and installation	1	30,000	30,000
Total			410,00
Equipment			
Wheel barrow	1	65	65
Cutlass	1	15	15
Plastic water container	2	80	160
Shovels	2	20	40
Spring balance	1	120	120
Total			400
Operational Cost			
Sacks	20	1.5	30
Starter fuel wood (kg)	50	0.2	10
Water use per year (drums)	1	2	2
Electricity	1	4	4
Gathering of 5tonnes of biomass (hrs)	102.56	3.75	384.6
Loading of 5tonnes of biomass (hrs)	20	2.5	50
Transportation of biomass (tonnes)	5	13.5	67.5
Offloading of biomass (hrs)	4	2.5	10
Chopping of 5tonnes of biomass into appropriate sizes (hrs)	40	2.5	100
Loading of 5tonnes of biomass into kiln (hrs)	20	2.5	50
Nurturing of the burning process	24	2.5	60
Removal of biochar from kiln (hrs)	2	2.5	5
Weighing and bagging (hrs)	4	2.5	10
Transportation of biochar to the farm (km)	1	13.5	13.5
Depreciation per tone	1	10.33	10.33
Sub-total			806.93
Grand Total			42,206.93

Source: Field Data, 2012 $1≡GHc1.92

Table 4.1.2b: Estimated Cost and Returns of Production per Tonne of Biochar under the Mobile On-Farm Biochar Reactor Model

Item	Qty	Unit Price(GHc)	Total (GHc)
Biochar Output(tonnes)	1	2,000	2,000
Establishment Cost			
Pyrolysis truck	1	346,000	346,000
Total Establishment Cost			346,000
Inputs and Equipment			
Wheel barrow	1	65	65
Cutlass	1	8	8
Plastic water container	2	80	160
Shovels	2	20	40
Spring balance	1	120	120
Sub-total			393
Operational Cost			
Sacks	20	1.5	30
Water use per tonne (drums)	1	2	2
Gathering of Biomass (hrs.)	102.56	3.75	384.6
Chopping of biomass to appropriate sizes	40	2.5	100
Loading of biomass into kiln	20	2.5	50
Nurturing of the charring process	4	2.5	10
Weighing and bagging	4	2.5	10
Fuel for pyrolysis truck	5	7	35
Depreciation Per tone	1	118.82	118.82
Total Operational Cost			740.42
Grand Total			347,133.4

Source: Survey Data $1= GHc1.92

4.2 Short Term Profitability Analysis per Hectare

4.2.1 Hectare Profitability of the Change from Slash and Burn to the Slash and Char System: Biochar as a Market Commodity with a Price

Here, the analysis assumed that the farmer purchases two tonnes of biochar for application which replaces 50% of soil fertilization requirements. Production of biochar is done by someone else and the farmer purchases biochar at the going price. Since fertilizer use is reduced by 50% at the application rate of 2tonnes of biochar (suggested by CSIR), the expenses on fertilizer is halved. The farmer incurs costs on gathering the biomass from the field to make the land clear for planting. From Tables 4.2.1a, 4.2.1b and 4.2.1c below, it can be concluded that the carbon sequestration practice results in a negative change in net income for maize production system in the three areas considered. The negative figures of the change in net income indicate that the change from slash and burn to slash and char is not profitable in the short term given the current production and market conditions. Annual abatement cost per Ha ranges from GH¢ 3472 to GH¢ 6810 depending on the area. The differences in the abatement cost are mainly due to the land productivity differences and market prices of input and outputs in the districts. The price of biochar is currently high (GHc 2.00/kg) due to the production technologies available, the alternative uses of biochar and perhaps the scale of production. On the basis of the change in net income, farmers would not adopt the use of biochar because it reduces their net income.

Table 4.2.1a: Partial Budget Analysis Ha^{-1} for a Change from Slash and Burn to Slash and Char for Maize Production at Ayuom: Biochar as a Market Commodity with a Price

Item	GHc/Ha	Item	GHc/Ha
Additional Cost (A1)		Reduced Cost(B1)	
Gathering of biomass	3,918.48	Fertilizer	140.4
Cost of biochar	4,000	Carriage of fertilizer	2.394
Transport of biochar	26.6	Fertilizer application	36
Incorporation of biochar	360	Jute sacks	74.1
Fertilizer	70.2	Polyethane sheet	55.575
Labour for fertilizer application	18	Transport of produce	129.675
Carriage of fertilizer	1.197	Burning of trash	10
Jute sacks for maize	113.62	Total Reduced Cost	448.144
Polyethane sheet	85.215		
Transport of produce	198.835		
Total Additional Cost	8,792.147		
Reduced income(A2)		Additional Income(B2)	
None	0	Revenue from increased yield of 50%	1,580
Column Total	8,792.15	Column Total	2,028.144
Change in Net income ((B1+B2)-(A1+A2)			(6,764)

Source: Data Analysis, 2012 based on maize Hectare Budget from MoFA, and field data $1 ≡ GHc1.92

Table 4.2.1b: Partial Budget Analysis Ha^{-1} for a Change from Slash and Burn to Slash and Char for Maize Production at Nyankpala: Biochar as a Market Commodity with a Price

Item	GHc/Ha	Item	GHc/Ha
Additional Cost (A1)		Reduced Cost(B1)	
Cost of biochar	4,000	Fertilizer	140.4
Transport of biochar	26.6	Carriage of fertilizer	2.394
Incorporation of biochar	180	Fertilizer application	18
Fertilizer	70.2	Jute sacks	49.4
Labour for fertilizer application	9	Polyethane sheet	37.05
Carriage of fertilizer	1.197	Transport of produce	86.45
Jute sacks	74.1	Total Reduced Cost	333.694
Polyethane sheet	55.575		
Transport of produce	129.675		
Total Additional Cost	4546.34		
Reduced income(A2)		Additional Income(B2)	
None	0	Revenue from increased yield of 50%	741
Column Total	4546.34	Column Total	1,074.694
Net income((B1+B2)-(A1+A2))			(3471.65)

Source: Data Analysis, 2012 based on maize Hectare Budget from MoFA, and field data $1 ≡ GHc1.92

Table 4.2.1c: Partial Budget Analysis Ha^{-1} for a Change from the Slash and Burn System to the Slash and Char System for Maize Production at Afiaso: Biochar as a Market Commodity with a Price

Item	**GHc/Ha**	**Item**	GHc/Ha
Additional Cost (A1)		Reduced Cost(B1)	
Gathering of biomass	3,918.48	Fertilizer	140.4
Cost of biochar	4,000	Carriage of fertilizer	2.394
Transport of biochar	26.6	Fertilizer application	36
Incorporation of biochar	360	Jute sacks	49.4
Fertilizer	70.2	Polyethane sheet	37.05
Labour for fertilizer application	18	Transport of produce	86.45
Carriage of fertilizer	1.197	Burning of trash	10
Jute sacks	74.1	Total Reduced Cost	361.694
Polyethane sheet	55.575		
Transport of produce	129.675		
Total Additional Cost	8,653.83		
Reduced income(A2)		Additional Income(B2)	
None	0	Revenue from increased yield	1,482
Column Total	8,653.8	Column Total	1,843.69
Net income((B1+B2)-(A1+A2))			(6,810.14)

Source: Data Analysis, 2012 based on maize Hectare Budget from MoFA, and field data   \$1 ≡ GHc1.92

4.2.2 Profitability of the Change from Slash and Burn to the Slash and Char System: Farmer-Owned Biochar Reactor

Table 4.2.2 below represents a situation where a farmer has a biochar reactor and produces biochar from his own field for application. The assumptions made for the biochar production budget under item 4.1.2 above hold for the analysis hereunder. Of the amount of biochar produced, the farmer applies two tonnes to the field and the rest is available for sale. The partial budget was computed from the biochar production budget per hectare under Table 4.1.2a (translated into per hectare basis) as well as the maize production budget per hectare. The farmer incurs cost on both maize and biochar production. He therefore gains revenues from the two activities. From Table 4.2.2, short term maize with biochar production is not profitable since the farmer trades off GHc 7012.84 Ha^{-1} by switching from the slash and burn practice to the proposed practice.

Table 4.2.2: Partial Budget Analysis Ha^{-1} for a Change from the Slash and Burn Practice to the Slash and Char System for Smallholder Maize Production at Ayuom: Farmer-owned Reactor

Item	GHc/Ha	Item	GHc/Ha
Additional Cost (A1)		Reduced Cost(B1)	
Gain/Loss in the sales of capital assets	5,679	Fertilizer value	140.4
Interest Expenses	10,762.18		
Gathering of biomass	3,918.48	Carriage of fertilizer	2.394
Loading of biomass	509.4	Fertilizer application	36
Transportation of biomass	687.69	Jute sacks	74.1
Offloading of biomass	101.88	Polyethane sheet	55.575
Chopping of biomass to appropriate sizes	1018.8	Transport of produce	129.675
Loading of biomass into	509.4	Burning of trash	10

kiln			
Nurturing of the burning process	611.28	Total Reduced Cost	448.144
Removal of biochar from kiln	50.94		
Weighing and bagging	101.88		
Sacks for biochar	305.64		
Starter(Fuel wood for reactor)	101.88		
Water use per year	20.376		
Electricity	40.752		
Depreciation on equipment	123.742		
Transport of biochar	26.6		
incorporation of biochar	360		
Fertilizer	70.2		
Labour for fertilizer application	18		
Carriage of fertilizer	1.197		
Jute sacks for carrying maize	113.62		
Polyethane sheet	85.215		
Transport of produce	198.835		
Total Additional Cost	25,416.99		
Reduced income (A2)		Additional Income (B2)	
None	0	Revenue from improved yield of 50%	1,580
		Sale of Surplus Biochar	16,376
		Total Additional income	17,956
Column Total	25,416.99	Column Total	18,404.1
Change in Net income((B1+B2)-(A1+A2))			(7,012.84)

Source: Data Analysis, 2012 based on maize Hectare Budget from MoFA, and field data $1≡GHc1.92

4.2.3 Production under Incentive

4.2.3.1 Farmer Maize-Biochar Production: Community-Owned Biochar Reactor

The partial budget analysis in Table 4.2.3.1 makes adjustments to the option where a farmer has a biochar reactor. In this analysis, the biochar reactor, the building, land, machines, and other equipment for biochar production are jointly owned by the community. The farmer only transports his biomass to the production site and produces his biochar. He bears the entire costs incidental to the preparation of biochar except capital costs. He produces enough biochar and applies two tonnes to the field so that the rest of the biochar becomes available for sale at GHc 2.00/kg. From the table, it becomes clear that in the short term, the change from the slash and burn practice to the slash and char practice turns to be a profitable activity for a situation where the community owns the biochar production plant and the farmer only goes in with his biomass for charring. The return to management computed indicates that the farm business pays the farm operator GHc 877.43 for his management input. The returns to labour also show that the farm business pays the farmer a higher return to labour than the minimum wage in the domestic economy. The farm business pays the farmer GHc 6.67 for his labour input and this amount is higher than the minimum wage of GHc 4.1 in the domestic economy.

Table 4.2.3.1: Partial Budget Analysis Ha^{-1} for a Change from the Slash and Burn Practice to the Slash and Char Practice for Maize Production at Ayuom: Community-Owned Biochar Reactor

Item	GHc/Ha	Item	GHc/Ha
Additional Cost (A1)		Reduced Cost(B1)	
Gathering of biomass	3,918.48	Fertilizer value	140.4
Loading of biomass	509.4	Carriage of fertilizer	2.394
Transportation of biomass	687.69	Fertilizer application	36
Offloading of biomass	101.88	Jute sacks for maize	74.1
Chopping of biomass into appropriate sizes	1018.8	Polyethane sheet	55.575
Loading of biomass into kiln	509.4	Transport of produce	129.675
Nurturing of the burning process	611.28	Burning of trash	10
Removal of biochar from kiln	50.94	Total Reduced Cost	448.144
Weighing and bagging	101.88		
Sacks for biochar	305.64		
Starter(Fuel wood for reactor)	101.88		
Water use	20.376		
Transport of biochar	26.6		
incorporation of biochar	360		
Fertilizer	70.2		
Labour for fertilizer application	18		
Carriage of fertilizer	1.197		
Jute sacks	113.62		
Polyethane sheet	85.215		
Transport of produce	198.835		
Total Additional Cost	8811.313		
Reduced income (A2)		Additional Income (B2)	
None	0	Revenue from increased yield	1,580
		Sale of Surplus Biochar	16,376
		Total Additional income	17,956
Column Total	8,811.31	Column Total	18,404.1
Net income((B1+B2)-(A1+A2))			592.831

Source: Data Analysis, 2012 based on maize Hectare Budget from MoFA, and field data $1≡GHc1.92

4.2.3.2 Farmer is given Biochar as Incentive for Maize Production

In this analysis, the farmer is incentivized indirectly to sequester carbon dioxide through a provision of biochar to farmers for free. The analysis assumes that biochar production is decoupled from the farming business and production of biochar is done by an entity funded to do so. The only additional cost incurred is the cost of biochar application. From Table 4.2.3.2 below, it can be seen that separating the cost of biochar preparation from the farming business makes the change from slash-and-burn to the slash-and-char system a profitable activity. Change in net income ranges from GHc554 to GHc1181 depending on the production site. Thus the incentive works to cushion farmers against the high cost of the proposed technology. This means that farmers would adopt the slash-and-char system if there is an incentive for doing so. The kind of incentive considered here is where an entity bears every cost with regards to biochar production and farmers only get biochar for free.

Table 4.2.3.2: Change in Net Income Ha^{-1}: Farmer is given Biochar as Incentive for Maize Production

	Production Site		
	Ayuom	Nyankpala	Afiaso
Change in Net Income (inGHc/Ha)	1181.077	554.947	1116.947

Source: Data analysis, 2012 based on maize Hectare Budget from MoFA, and field data

4.2.4 Effect of Biochar Price Change on Short-term Profitability

The profitability of the options considered under item 4.2 above is influenced by the price of biochar, and in fact, biochar may not be bought or sold at GHc 2 /kg. In the earlier analysis, biochar was market priced at GHc 2/kg. This amounted to the GHc2,000 as price of biochar per tonne, and this price raises the farmer hectare budget extraneously. At the same time, the farmer might be willing to purchase biochar just at the cost of the amount of fertilizer which biochar substitutes. It was assumed earlier that biochar reduces soil fertilization requirement by fifty percent (50%). By this assumption, biochar reduces the amount of money spent on fertilizer by GHc 69.3576 per hectare, implying that the farmer might be willing to buy biochar at the cost of GHc 0.0347/kg. This means that biochar is priced at GHc 34.7/tonne by the farmer.

In a different study of farmers' perception on biochar in the Northern Ghana by Obiri (2012), it was discovered that farmers are willing to buy biochar at GHc 20/bag. This bag of biochar could mimic the standard weight of fertilizer (which is 50kg/bag). Again, a maxi bag full of biochar was found to be 50kg when compacted well enough. This implies that the farmer can value biochar at GHc 0.4/kg. That is GHc 400/tonne of biochar. Table 4.2.4 describes how the change in farm net income would be for a change from the slash and burn system to the slash and char system. The farmer only gains from the change to the proposed system under the option where community owns the biochar reactor. But that gain holds if there is a market for biochar at that price (GHc 2/kg)

Table 4.2.4 Effect of Biochar Price Change on Profitability

Price of Biochar	Change in Net Income Ha^{-1} for Various Production Scenarios (GHc)		
	Farmer buys Biochar	Farmer-owned Reactor	Community owned reactor
GHc 2.0/kg	-6764	-7012.84	9592.831
GHc 0.4/kg	-3564	-20113.6	-3507.97
GHc 0.0347/kg	-2833.4	-23104.7	-6499.05

Source: Data Analysis, 2012

4. 3 Long Term Financial Analysis per Hectare

From the data gathered, crop hectare budgets were created by examining the expected revenues and the assumed costs. The expected revenues in this study are the output of maize multiplied by the price of maize in the respective production sites. Revenue from maize included in this analysis that from the main cropping season. There could be minor season maize production at Ayuom but this is seldom the case for production on the same piece of land due to possible nutrient depletion. Therefore, for a long term agricultural decision such as this where continuous cropping is being considered, it is assumed that maize production happens only in the main cropping season. In the economic analysis, carbon payments were also included as revenue to the economy. The cost elements included variable and fixed costs. Various items considered are shown as appendix under the appendices.

4.3.1 Private Cost-Benefit Analysis for Pure Maize Production per Hectare at Ayuom

Table 4.3.1 presents cashflows for maize production at Ayuom over twenty-eight years given the economic life of the biochar reactor considered for the option where the farmer produces biochar for application himself. The number of years is appalled in the alternative scenarios in order to allow for commoneity of assumptions made for the scenario analysis such as to have a basis for comparison.

Based on the cropping systems of the area, a continuous production for maize was assumed for the analysis where maize is planted year after year for four years after which the land is allowed to fallow for two years. Cultivation of the land resumes in the seventh year. Biochar application rate and intervals for application was decided on with inputs from Soil Scientists from the Council for Scientific and Industrial Research- Soil Research Institute (CSIR-SRI). The farmer buys biochar at the cost of GHc 2/kg for application in the first year and at the beginning of every production cycle. This implies that after each fallow period when the land is cleared to begin a new cropping cycle, the farmer applies 2 tonnes of biochar per hectare.

The total above ground biomass gathered for biochar production as part of this study weighed 50.94 tonnes. This implies that after every six years, the land yields a total above ground biomass of about 50.94 tonnes. These are gathered when the land is cleared at the beginning of each cropping cycle at a cost of GHc 3918.488 per Hectare. The farmer also incurs GHc 26.6 at the beginning of every cycle on the carriage of 2 tonnes of biochar to the farm. Application of biochar to the field is estimated to cost GHc 20 man hour for 18 man hours per ha. The cost of burning of the trash is forgone and the use of biochar is assumed to reduce fertilizer usage by 50% granted that the farmer now applies 90kg of fertilizer per Hectare instead of 180kg per Hectare in the reference scenario. The subsidized price of fertilizer is GHc39 per the bag of 50kg. Maize output without biochar is 37 bags per hectare, each bag selling for GHc 80. Since a bag is equivalent to 100kg, it holds that the price of maize per kilogram at Ayuom is GHc 0.8 and this totals an amount of GHc 2964 as the total revenue from maize production per year per hectare without biochar use at Ayuom. Biochar is reported to double crop productivity on poor soils. Some yield increases of 171% (Talberg, 2009); 100% (Collison *et al.*, 2009), are reported depending on the soil conditions and the application rate, and during the interviews with key informants, biochar was found to increase yield by 50%. Given that, in this study, biochar is assumed to increase yield by 50% at the application rate of 2tonnes per hectare. This results in total revenue of GHc 4545 per hectare for pure maize production at Ayuom. The detailed hectare budget is affixed to the appendices.

From Tables 4.3.1a and 4.3.1b, it is clear that maize production for a situation where a farmer buys 2 tonnes of biochar for application to his farm after every six years is not profitable from the perspective of the individual. This is indicated by the negative Net Present Value of GHc-1530.55. A negative NPV when discounted at the opportunity cost of capital means the project is not able to pay for its costs. It would therefore, have been more profitable to commit funds to some other investment than the use of biochar. Compared with the reference situation in Table 4.3.1b below (which yields a net present value of GHc3353.36), reject the carbon sequestration practice should be rejected in favour of its alternative. At the application rate of two tonnes of biochar after every six years, the farmer loses income. The abatement cost per hectare is GHc4883.914. At the application rate of two (2) tonnes of biochar Ha^{-1}, carbon sequestration rate of biochar per Hectare is 5.13 tonnes of carbon equivalent (tCO_2eq). Therefore, abatement cost per tonne is GHc 952.030, meaning that to sequester a tonne of carbon dioxide, the farmer trades off GHc 952.030 of her existing income under the conventional slash and burn practice. When discounted at the 26% discount rate, the financial rate of return (FRR) obtained was 10% which is lower than the opportunity cost of capital., indicating that the slash and char system is not a profitable alternative for the scenario considered above. FRR measures the average earning power of the funds committed to the project over the life of the project. Therefore, FRR lower than the opportunity cost of capital means the project has a lower earning power relative to other investment opportunities.

Table 4.3.1a: Private Cost Benefit Analysis Ha^{-1} for Maize Production at Ayuom with Biochar

Year	Costs (GHc)	Benefits (GHc)	Cashflow	Discount Factor at 26% Discount Rate	Discounted Cashflows
1	11054.81	4545	-6509.81	0.793651	-5166.52
2	1913.332	4545	2631.668	0.629882	1657.639
3	1913.332	4545	2631.668	0.499906	1315.587
4	1913.332	4545	2631.668	0.396751	1044.116
5	0		0		
6	0		0		
7	11054.81	4545	-6509.81	0.198338	-1291.14
8	1913.332	4545	2631.668	0.157411	414.254
9	1913.332	4545	2631.668	0.12493	328.773
10	1913.332	4545	2631.668	0.09915	260.931
11	0		0		
12	0		0		
13	11054.81	4545	-6509.81	0.049566	-322.665
14	1913.332	4545	2631.668	0.039338	103.5246
15	1913.332	4545	2631.668	0.031221	82.16237
16	1913.332	4545	2631.668	0.024778	65.20823
17	0		0		
18	0		0		
19	11054.81	4545	-6509.81	0.012387	-80.6358
20	1913.332	4545	2631.668	0.009831	25.87142
21	1913.332	4545	2631.668	0.007802	20.53287
22	1913.332	4545	2631.668	0.006192	16.29593
23	0		0		
24	0		0		
25	11054.81	4545	-6509.81	0.003096	-20.1514
26	1913.332	4545	2631.668	0.002457	6.465423
27	1913.332	4545	2631.668	0.00195	5.131288
28	1913.332	4545	2631.668	0.001547	4.072451
NPV(GHc)					-1530.55
FRR					10%

Source: Data Analysis, 2012 based on maize Hectare Budget from MoFA, and field data

Table 4.3.1b: Private Cost benefit Analysis Ha^{-1} for Maize Production with the Slash and Burn Practice at Ayuom

Year	Costs (GHc)	Benefits (GHc)	Net Incremental Cashflow	Discount Factor at 26% Discount Rate	Discounted Cashflows at 26% rate
1	1914.397	2964	1049.603	0.793651	833.0181
2	1860.344	2964	1103.656	0.629882	695.1728
3	1860.344	2964	1103.656	0.499906	551.7244
4	1860.344	2964	1103.656	0.396751	437.8765
5	0	0			
6	0	0			
7	1914.397	2964	1049.603	0.198338	208.1763
8	1860.344	2964	1103.656	0.157411	173.7279
9	1860.344	2964	1103.656	0.12493	137.8793
10	1860.344	2964	1103.656	0.09915	109.428
11	0	0			
12	0	0			
13	1914.397	2964	1049.603	0.049566	52.0245
14	1860.344	2964	1103.656	0.039338	43.41564
15	1860.344	2964	1103.656	0.031221	34.45686
16	1860.344	2964	1103.656	0.024778	27.34671
17	0	0			
18	0	0			
19	1914.397	2964	1049.603	0.012387	13.00124
20	1860.344	2964	1103.656	0.009831	10.84983
21	1860.344	2964	1103.656	0.007802	8.610977
22	1860.344	2964	1103.656	0.006192	6.834109
23	0	0			
24	0	0			
25	1914.397	2964	1049.603	0.003096	3.249087
26	1860.344	2964	1103.656	0.002457	2.711438
27	1860.344	2964	1103.656	0.00195	2.151935
28	1860.344	2964	1103.656	0.001547	1.707885
NPV					3353.364

Source: Data analysis, 2012 based on maize Hectare Budget from MoFA, and field data

4.3.2 Private Cost Benefit Analysis Ha^{-1} for Maize Production at Nyankpala

The assumptions made about the cropping system under 4.3.1 above remains the same expect for site-specific differences in prices and certain operations. Since in the Savanna vegetation, there is limited vegetation (these are mostly plowed into the soil), the farmer does not incur cost on the gathering of biomass. He incurs cost on the transportation and application of biochar to the farm in addition to the cost of biochar. Fertilizer use under the slash and char system is halved by 50%, reducing the cost of fertilizer applied to the soil to GHc 69.35 per hectare.

In the reference slash and burn situation, maize gives a total output of 10bags/acre (24.7 bags per Hectare). Each bag is about 100kg and costs GHc 60. The total revenue from maize under the slash and burn system is thus GHc 1482 per Hectare. Under the slash and char system, land productivity is assumed to be increased by 50%. This leads to a total output of 15bags of maize per acre (37.05 bags of maize per Hectare), which translates into total revenue of GHc 2223 per hectare. Table 4.3.2a and 4.3.2b below give the cashflows for maize production with and without biochar at Nyankpala.

From Table 4.7.1.2a above, the use of the slash and char system for maize production in Nyankpala is not profitable for the scenario where the farmer purchases and applies two tonnes of biochar at the beginning of every four-year production cycle. This is indicated by a negative net present value of GHc-888.888. Net Present Value measures quantitatively, how much the project pays us after covering all its costs. The negative NPV shows that the proposed carbon sequestration activity is not able to recover its cost.

This is further indicated by the Financial Rate of Return of 8% which is lower than the opportunity cost of capital. Since the FRR is lower than the cost of capital charged by the banks, we fail to accept the proposed carbon sequestration activity. FRR measures the worth generating power of the funds committed to the project. The FRR obtained means that funds committed to the carbon sequestration activity have lower worth generating power compared to other investment opportunities. It would rather be appropriate to commit funds to investments other than the proposed carbon sequestration activity.

The slash and burn alternative for maize production at Nyankpala yields a positive net present value of GHc1703.86 (in Table 4.3.2b below), indicating that maize production at Nyankpala under the slash and burn practice is a profitable activity.

Subtracting the NPV of the slash and char practice from that of the slash and burn practice yields a positive result of GHc2392.75, meaning that the change from the slash and burn practice to the slash and char practice is not a profitable activity. That is, by switching from the slash and burn to the slash and char practice, the farmer loses farm income of GHc 2392.86 ha^{-1} for maize production at Nyankpala. Abatement cost per tonne is calculated by dividing the farm opportunity cost per hectare by the carbon sequestration rate per hectare. Granted that each tonne of biochar applied to the field sequesters 2.565 tCO_2eq, abatement cost per tonne for the biochar application rate of 2tonnes per hectare is

GHc466.44. That is by sequestering a tonne of CO_2 equivalent (1tCO_2eq), the farmer trades off GHc466.44 of his farm income.

Table 4.3.2a Private Cost Benefit Analysis Ha^{-1} of Maize Production with Biochar at Nyankpala

Year	Costs (GHc)	Benefits (GHc)	Net Incremental Cashflow	Discount Factor at 26% Discount Rate	Discounted Incremental Cashflow
1	5556.882	2223	-3333.88	0.793651	-2645.94
2	926.9058	2223	1296.094	0.629882	816.3858
3	926.9058	2223	1296.094	0.499906	647.9253
4	926.9058	2223	1296.094	0.396751	514.2264
5	0	0			
6	0	0			
7	5556.882	2223	-3333.88	0.198338	-661.236
8	926.9058	2223	1296.094	0.157411	204.0197
9	926.9058	2223	1296.094	0.12493	161.9204
10	926.9058	2223	1296.094	0.09915	128.5083
11	0	0			
12	0	0			
13	5556.882	2223	-3333.88	0.049566	-165.247
14	926.9058	2223	1296.094	0.039338	50.98576
15	926.9058	2223	1296.094	0.031221	40.46489
16	926.9058	2223	1296.094	0.024778	32.11499
17	0	0			
18	0	0			
19	5556.882	2223	-3333.88	0.012387	-41.2962
20	926.9058	2223	1296.094	0.009831	12.74165
21	926.9058	2223	1296.094	0.007802	10.11242
22	926.9058	2223	1296.094	0.006192	8.02573
23	0	0			
24	0	0			
25	5556.882	2223	-3333.88	0.003096	-10.3202
26	926.9058	2223	1296.094	0.002457	3.184215
27	926.9058	2223	1296.094	0.00195	2.527155
28	926.9058	2223	1296.094	0.001547	2.005678
NPV					-888.888
FRR					8%

Source: Data analysis, 2012 (based on maize Hectare Budget from MoFA, and field data)

Table 4.3.2b: Private Cost Benefit Analysis Ha^{-1} for Maize Production at Nyankpala without Biochar

Year	Costs (GHc)	Benefits (GHc)	Net Incremental Cashflow	Discount Factor at 26% Discount Rate	Discounted Net Benefits at 26% rate
1	948.4035	1482	533.5965	0.793651	423.4893
2	921.3767	1482	560.6233	0.629882	353.1263
3	921.3767	1482	560.6233	0.499906	280.259
4	921.3767	1482	560.6233	0.396751	222.4277
5	0	0			
6	0	0			
7	948.4035	1482	533.5965	0.198338	105.8325
8	921.3767	1482	560.6233	0.157411	88.24839
9	921.3767	1482	560.6233	0.12493	70.0384
10	921.3767	1482	560.6233	0.09915	55.58603
11	0	0			
12	0	0			
13	948.4035	1482	533.5965	0.049566	26.44819
14	921.3767	1482	560.6233	0.039338	22.0538
15	921.3767	1482	560.6233	0.031221	17.50302
16	921.3767	1482	560.6233	0.024778	13.89128
17	0	0			
18	0	0			
19	948.4035	1482	533.5965	0.012387	6.609562
20	921.3767	1482	560.6233	0.009831	5.511378
21	921.3767	1482	560.6233	0.007802	4.37411
22	921.3767	1482	560.6233	0.006192	3.471516
23	0	0			
24	0	0			
25	948.4035	1482	533.5965	0.003096	1.651769
26	921.3767	1482	560.6233	0.002457	1.377327
27	921.3767	1482	560.6233	0.00195	1.093116
28	921.3767	1482	560.6233	0.001547	0.867553
NPV					1703.86

Source: Data analysis, 2012 based on maize Hectare Budget from MoFA, and field data

4.3.3 Private Cost Benefit Analysis Ha^{-1} for Maize production at Afiaso

The assumptions made hereunder are the same with those of the earlier discussions, except for where differences have been highlighted. The price of labour in Afiaso is the same as that of Ayuom (GHc10). Differences in the parameters for the two production sites are mainly in the output prices and the prices of some inputs such as the rental price of land. Each bag sells at GHc120. This leads to total revenue of GHc 2964 per hectare for maize production without biochar at Afiaso. With 50% increment to yield resulting from the application of biochar, total revenue per hectare rises to GHc 4446 per hectare. Fertilizer is applied in each year of the production cycle. But with biochar, the total quantity required is reduced by 50%. Yield is assumed to be same along the 28 years of production since, the possible decline in productivity due to nutrient lose is taken care of by the application of biochar and fertilizer.

Table 4.3.3a above presents cashflows for maize production at Afiaso under the slash and char system. From the table, the NPV of the proposed slash and char system is GHc-154.746 with an IRR of 24%. The negative net present value indicates the project is not able to recover its costs neither is it able to pay the farmer for his investment. The unattractiveness of the slash and char system is also indicated by the Financial Rate of Return which is lower than the opportunity cost of capital. The decision rule with the IRR (FRR) is to accept projects with IRRs equal to or higher than the opportunity cost of capital. The slash and char practice is not to be accepted for a situation where the farmer purchases and applies two tonnes of biochar every six years.

The NPV obtained from the slash and burn practice is GHc 4828.308 (from Table 4.3.3b below). This means that maize production in Afiaso with the slash and burn practice is profitable. This is indicated by the positive net present value. Therefore, in contrast with the slash and char practice, the slash and burn system is preferred on the basis of the net present value. Farm opportunity cost is GHc 4983.054 (that is GHc921.36/tonne of CO_2 equivalence).

Table 4.3.3a: Private Cost Benefit Analysis Ha^{-1} for Maize Production with Biochar at Afiaso

Year	Costs (GHc)	Benefits (GHc)	Net Incremental Cashflow	Discount Factor at 26% Discount Rate	Discounted Incremental Net Benefit
1	10510.69	4446	-6064.69	0.793651	-4813.25
2	1369.063	4446	3076.937	0.629882	1938.106
3	1369.063	4446	3076.937	0.499906	1538.179
4	1369.063	4446	3076.937	0.396751	1220.777
5	0	0			
6	0	0			
7	10510.69	4446	-6064.69	0.198338	-1202.86
8	1369.063	4446	3076.937	0.157411	484.3443
9	1369.063	4446	3076.937	0.12493	384.4002
10	1369.063	4446	3076.937	0.09915	305.0796
11	0	0			
12	0	0			
13	10510.69	4446	-6064.69	0.049566	-300.602
14	1369.063	4446	3076.937	0.039338	121.0406
15	1369.063	4446	3076.937	0.031221	96.06394
16	1369.063	4446	3076.937	0.024778	76.24122
17	0	0			
18	0	0			
19	10510.69	4446	-6064.69	0.012387	-75.1222
20	1369.063	4446	3076.937	0.009831	30.24877
21	1369.063	4446	3076.937	0.007802	24.00696
22	1369.063	4446	3076.937	0.006192	19.05314
23	0	0			
24	0	0			
25	10510.69	4446	-6064.69	0.003096	-18.7735
26	1369.063	4446	3076.937	0.002457	7.559349
27	1369.063	4446	3076.937	0.00195	5.999483
28	1369.063	4446	3076.937	0.001547	4.761495
NPV					-154.746
FRR					24%

Source: Data analysis, 2012 based on maize Hectare Budget from MoFA, and field data

Table 4.3.3b: Private Cost Benefit Analysis Ha^{-1}for Maize Production with the Slash and Burn Practice at Afiaso

Year	Costs (GHc)	Benefits (GHc)	Net Incremental Cashflow	Discount Factor at 26% Discount Rate	Discounted Net Cashflow at 26% rate
1	1454.879	2964	1509.121	0.793651	1197.715
2	1373.799	2964	1590.201	0.629882	1001.639
3	1373.799	2964	1590.201	0.499906	794.9512
4	1373.799	2964	1590.201	0.396751	630.9137
5	0	0			
6	0	0			
7	1454.879	2964	1509.121	0.198338	299.3162
8	1373.799	2964	1590.201	0.157411	250.3155
9	1373.799	2964	1590.201	0.12493	198.6631
10	1373.799	2964	1590.201	0.09915	157.6691
11	0	0			
12	0	0			
13	1454.879	2964	1509.121	0.049566	74.80093
14	1373.799	2964	1590.201	0.039338	62.55535
15	1373.799	2964	1590.201	0.031221	49.64711
16	1373.799	2964	1590.201	0.024778	39.40247
17	0	0			
18	0	0			
19	1454.879	2964	1509.121	0.012387	18.6932
20	1373.799	2964	1590.201	0.009831	15.63296
21	1373.799	2964	1590.201	0.007802	12.40711
22	1373.799	2964	1590.201	0.006192	9.846914
23	0	0			
24	0	0			
25	1454.879	2964	1509.121	0.003096	4.671544
26	1373.799	2964	1590.201	0.002457	3.906771
27	1373.799	2964	1590.201	0.00195	3.100612
28	1373.799	2964	1590.201	0.001547	2.460803
NPV					4828.308

Source: Data Analysis, 2012

4.3.4 Economic Analysis

The financial analysis done earlier looked at the viability of the slash and char system for carbon sequestration given the market prices of inputs and outputs. The economic analysis hereunder provides a measure of the impact of the project from the viewpoint of the whole economy. That is, whether the proposed carbon sequestration activity would contribute to the overall welfare of the economy in terms of national income. This was achieved by valuing inputs and outputs to reflect their scarcity values. In the process, the financial accounts were converted to economic accounts by converting market prices to shadow prices in order to reflect their opportunity cost or the scarcity value. In doing so, the approach of Gittinger (1982) was used.

4.3.4.1 Shadow Price of Labour

The opportunity cost of labour was valued at 50% of the going market wage and further reduced by a standard conversion factor (emanating from the official exchange rate). The conversion factor used here is 0.52, calculated from the official exchange rate. The opportunity cost of labour could be calculated by estimating the total person hours required for the project in the peak season and multiplying that by the wage rate in the area for the peak season and reduced further by the conversion factor. The peak season is the season when everybody can find work to do. At that period, the opportunity cost of labour could be equal to the marginal productivity of labour. But it is not clear as to how many days of work would be available in the peak season. In Ayuom, farmers who are not going into production could readily find casual work in the building industry which fetches them GHc 20 per manday or can work on a neighbour's farm for GHc 10 per Manday. But since such employment opportunities might not be there always, they may be more willing to work for lower wage rates other than the going market rate hence the assumption that they might be willing to carry out off-farm labour for a price, 50% of the going market wage. This assumption was also made by Akoto-Agyapong (2010) and Gittinger (1982).

In a labour-abundant society where everybody finds work at a good price in peak seasons like planting and harvesting time, the market wage could be accepted as a good estimate of the opportunity cost. The price of labour in a perfectly competitive market could be determined by its marginal value product (the value of the additional product that any additional labourer employed on the farm could produce). But in most cases, marginal productivity of agricultural labour is close to zero Gittinger (1982). Hence, the approach used in this research offers a good valuation of labour at its scarcity value.

4.3.4.2 Shadow Pricing of other Inputs

Table 4.3.4.2 presents the shadow prices of inputs. The main inputs considered are seed maize, fertilizer, biochar, and sacks for conveying produce. The economic value was attained by multiplying the market price by the conversion factor. The shadow pricing reduces the market prices to allow for possible changes in the market prices due to the exchange rate. The current market price of fertilizer is a subsidized one (under 30% subsidy), the full cost being GHc 1.114/kg. Since subsidy is a transfer payment from one sector of the economy to another, it is removed in the economic account because it is not considered as a benefit. Again, the subsidy on fertilizer operates to reduce the cost of the input and hence restored in the economic account. The shadow price of fertilizer is derived by multiplying the market price obtained upon the removal of subsidy by the standard conversion factor. That is the shadow price of fertilizer per kg is GHc 0.579. Since land is mostly not purchased out-rightly by farmers for production, the opportunity cost of land was obtained by multiplying the rental value by the conversion factor.

Table 4.3.4.2: Shadow Price of Inputs

Input	Market Price (GHc)	Conversion Factor (based on the official exchange rate)	Shadow Price
Seed maize	1.2/kg	0.52	0.624
Sacks	2	0.52	1.04
Polyethene Sheets	1.5	0.52	0.78
Biochar	2/kg	0.52	1.04

Source: Author's Computation based on the official exchange rate \$1 ≡ GHc1.92

4.3.4.3 Economic Valuation of Outputs

Outputs considered are maize production per hectare for the three study areas considered. Table 4.3.4.3b summarizes the computation of the border equivalent farm gate price of imported maize valued at the official exchange rate. Since maize is a tradable commodity and could have been imported, the economic value of maize is its border price (in this case the CIF) adjusted to reflect domestic charges. The CIF of maize ($407) was sourced from Akramov & Malek (2012). Calculations arrived at in Table 4.3.4.3b are based on assumptions made from official sources such as CEPS webpage (27th December, 2012), and Akramov & Malek (2012) in Table 4.3.4.3a. In the economic valuation, taxes at the port such as import duty, import VAT, ECOWAS levy and EDF were not charged since they are considered as transfer payments.

Table 4.3.4.3a: Assumptions made for Import Parity Calculations

Parameters	**Assumptions made**
Processing fees	1%
NHIL	2.5%
Inspection fees	1%
Port fees and charges	30%

Source: CEPS website; Akramov & Malek (2012)

Table4.3.4.3b: Per Tonne Economic Adjustment of International Price of Maize to the Farmgate Gate Price per Bag

Item	GHc
Maize CIF ($)	407
Official Exchange Rate	1.92
CIF in domestic currency	781.44
Processing fees	7.8144
Value Before Vat and NHIL	789.2544
NHIL	19.73136
Port fees and charges	236.7763
Transportation to Wholesale	13.5
Local wholesale border price equivalence	1059.262
Transportation from wholesale to farmgate	317.7786
Border equivalent farmgate price at the official exchange rate	741.4835
Border equivalent farmgate price per bag at the official exchange rate(Ayuom)	74.14835
Border equivalent farmgate price per bag at the official exchange rate(Nyankpala)	63.55572
Border equivalent farmgate price per bag at the official exchange rate(Afiaso)	84.74097

Source: Author's computation based on the assumptions in Table 4.3.4.3a above

4.3.4.4 Valuing Carbon Price

Carbon credit is considered as the environmental benefit in money terms the society gets for sequestering carbon dioxide. Of course, there could be a negative externality to the use of biochar but the positive carbon offset value is an indication of the value the society places on the net environmental impact of the slash and char system on the society. The offset value of $118.5/tonne used for the analysis was calculated from Kulyk (2012) and it already reflects the scarcity value. It is therefore assumed to be the same as the market price.

4.3.4.5 Social Cost Benefit Analysis Ha^{-1} for Maize Production with and without Biochar

4.3.4.5.1 Ayuom

This analysis makes use of the farm budgets prepared for the financial analysis, only that the market prices have been converted to depict their scarcity value. Cashflows were generated for a maize production system at Ayuom that uses the slash and char system and the NPVs computed in as shown in Table, 4.3.4.5 below. Profitability from the view point of the economy improves significantly above that of the financial analysis. This is indicated by the positive Net Present Value of GHc 15089.62 Ha^{-1}. The NPV Ha^{-1} for the reference slash and burn situation is GHc9734.902. When compared with the NPV from the proposed carbon sequestration activity, that of the new alternative is higher. This means that the use of biochar for maize production leads to a higher net positive impact on the economy in terms of income than maize production under the slash and burn method. Given the biochar application rate of 2tonnes per Hectare which gives a carbon sequestration rate of 5.13 tCO_2 $eq.Ha^{-1}$, the abatement cost per hectare is GHc -5354.72. The NPV of the proposed carbon sequestration practice is taken from that of the existing slash and burn practice so that the negative result indicates that the proposed practice is profitable relative to the slash and burn practice from the view point of the economy. Abatement cost per tonne is GHc-1043.805, implying that each tonne of CO_2eq sequestered by the society earns her an amount of GHc 1043.805 Ha^{-1}.

4.3.4.5 .2 Nyanpkala

The assumed cost and benefits are built upon those for the financial analysis for maize production at Nyankpala. The difference is the valuation of inputs and outputs at their opportunity cost. The price of maize is now GHc 63.56 per bag instead of the market price of GHc60 used for the financial analysis. With the output of 24.7 bags of maize per Hectare under the slash and burn practice, total revenue per Hectare is GHc 1569.86. However, with the improvement in crop productivity of 50%, the total economic revenue per hectare rises to GHc2962.638 including payments from the carbon market (GHc 607.898 per Hectare per year) which the society gets for their environmentally safe practice. This revenue is assumed to be realized year after year for the entire 28-year production period since the likely decline in productivity is cushioned by the application of biochar.

It can be read from Table 4.3.4.5 below that the use of biochar for maize production at Nyankpala yields a net present value of GHc 9028.054 per hectare.

This is a positive NPV and indicates that the use of biochar for maize production at Nyankpala is a profitable activity from the viewpoint of the economy. The value obtained indicates that the slash and char system for maize production pays the economy an amount of GHc9028.054 after recovering its costs.

The net present value computed for the maize production under the slash and burn practice is GHc5877.354. The positive NPV shows that maize production under the slash and burn practice is also a profitable activity. Comparing the two NPVs, it can be read that by switching from the current slash and burn practice to the proposed carbon sequestration practice, the economy gains an additional income of GHc3150.7 per hectare. Therefore the CO_2 abatement cost per tonne is GHc-614.17. The negative figure indicates that biochar soil carbon sequestration leads to a net saving of GHc614.17 by the economy for each tonne of CO_2eq.

4.3.4.5 .3 Afiaso

The assumed costs and benefits are both built up from the private project accounts. The detailed hectare budget for the economic analysis here is affixed to the appendices. From the hectare budgets, NPVs were computed and reported in Table 4.3.4.5 below. As can be seen from the table, maize production at Afiaso under the slash and char practice pays the society an amount of GHc10660.23 after paying for its costs.

The net present value obtained for maize production under the slash and burn is GHc6063.251 per Hectare, indicating that maize production under the slash and burn practice is a profitable activity. However, on the basis of the NPV for project selection among mutually exclusive alternative projects, the ones with higher NPVs are preferred. Therefore, the slash and char practice presents the best alternative from the viewpoint of the economy on the basis of the net present value. Comparing the two NPVs, the economy gains and additional income of GHc4596.979 per hectare by switching from the traditional slash and burn practice to the slash and char practice. Farm opportunity cost per tonne of CO_2eq is GHc-896.067

Table 4.3.4.5: Profitability of Maize Production Ha^{-1} with Biochar from the Economy's Viewpoint

	Production Site		
	Ayuom	**Nyankpala**	**Afiaso**
NPV (in GHc Ha^{-1}) from Carbon Sequestration	15089.62	9028.054	10660.23
Reference Case NPV (GHc)	9734.902	5877.354	6063.251

Source: Data analysis, 2012 based on the financial Hectare Budgets

4.3.5 Sensitivity Analysis

4.3.5.1 Effect of Incentive on the Profitability of Maize Production with Biochar (Ha^{-1})

Table 4.3.5.1 presents a sensitivity analysis per hectare from the viewpoint of the farmer at 26% discount rate for pure maize production in the three study areas. This analysis uses market prices and also assumes that all farm operations are carried out by hired labour. The assumptions made under the financial analysis are maintained.

Scenario 1: Presents the situation for the traditional slash and burn system where the farmer applies no biochar. The trash is also burnt on-site and there is no gathering of biomass or incorporation of biochar.

Scenario 2: Scenario 2 explores a situation where the farmer is given an incentive to cover the cost incurred on the application (incorporation) of biochar to the field. The farmer bears the cost of acquiring the two tonnes of biochar, transportation of biochar to the field and gathering of biomass in addition to the other costs that do not vary with the technologies.

Scenario 3: Under scenario 3, the farmer receives two tonnes of biochar for free at the community to be transported to the farm by himself. The gathering of biomass and the incorporation of biochar are both at the cost of the farmer. Since there is no gathering of biomass at Nyankpala, the farmer at Nyankpala incurs no cost on the gathering of biomass.

Scenario 4: Under the incentive scenario 4, the farmer is given incentive to cover the cost of gathering biomass and incorporation of biochar into the soil. The farmer acquires his own biochar and transports it to the field by himself.

Scenario 5: Under scenario 5, the farmer gathers the biomass at his own cost but he gets biochar for free. He also gets credit to cover the cost of conveying biochar to the field and incorporating it into the soil.

Scenario 6: The farmer is given an incentive for production in the form of two tonnes of biochar for each hectare of land to be cropped. The farmer offers the total above ground biomass meant for burning on-site to a biochar producing entity. It is assumed that the production of biochar is done by a different entity and supplied to the farmer on his farm for free. The cost of gathering biomass, transporting them to the production site, the cost of charring and transportation of biochar to farmers are borne by the biochar producing entity funded to do so. The farmer only bears the cost of incorporating biochar into the soil.

Scenario 7: Explores the option where the farmer is fully funded for the slash and char practice. He offers the total above ground biomass meant for burning on-site to a biochar producing entity which produces biochar and gives back two tonnes of biochar to the farmer. Under this incentive package, the farmer receives biochar on his field for free. The farmer also gets funds to cover the cost of incorporating biochar into the soil.

Table 4.7.4.1 Effect of Incentive on Private Profitability Ha^{-1}

Incentive Scenarios	NPVs (in GHc Ha^{-1}) for the Maize production in the Various Communities		
	Ayuom	**Nyankpala**	**Afiaso**
1.Reference slash and burn situation	3324.795	1703.86	4828.308
2.Subsidy for incorporation of biochar	-1114.16	-680.626	261.7796
2.Subsidy for gathering of biomass	3001.614	-888.888	4377.41
3.Subsidy for the cost of biochar	3095.752	3737.571	4471.714
4.Subsidy for both gathering of biomass and incorporation of biochar	3417.993	-680.626	4793.935
5. Subsidy for biochar and gathering of biomass	7628.054	3737.571	9003.87
6.Subsidy for gathering of biomass, biochar and carriage of biochar	7762.805	3768.337	9034.636
7.Subsidy for gathering of biomass, biochar, carriage of biochar and incorporation of biochar	8075.199	3976.6	9451.161

Source: Data analysis, 2012 (based Hectare Budget from MoFA and data from field work)

4.3.5.2 Effect of Biochar Price Change on Private Profitability

In the earlier analysis, biochar was market priced at GHc 2/kg. This amounted to the cost of GHc4000 spent on the two tonnes of biochar per hectare. However, this price raises the farmer hectare budget extraneously. At the same time, the farmer might be willing to purchase biochar just at the cost of the amount of fertilizer which biochar substitutes. It was assumed earlier that biochar reduces soil fertilization requirement by fifty percent (50%). By this assumption, biochar reduces the amount of money spent on fertilizer by GHc 69.3576 per hectare, implying that the farmer might be willing to buy biochar at the cost of GHc 0.0347/kg.

In a different study of farmers' perception on biochar in the Northern Ghana by Obiri (2012), it was discovered that farmers are willing to buy biochar at GHc 20/bag. This bag of biochar could mimic the standard weight of fertilizer (which is 50kg/bag). Again, a maxi bag full of biochar was found to be 50kg when compacted well enough. This implies that the farmer can value biochar at GHc 0.4/kg. That is GHc 400/tonne of biochar. At this amount, the farmer would require GHc 800 for biochar per hectare at the application rate of two tonnes. From Table 4.3.5.2, farmers in Ayuom, Nyankpala and Afiaso would realize a Net Present Values of GHc 3015.622, GHc 3657.302 and GHc 4391.44 respectively if the price of biochar were GHc 0.0347/kg (the price at which the cost of biochar applied equals the cost of fertilizer forgone)

With the assumption that biochar costs GHc 0.4/kg (that is GHc 400/tonne), maize production with biochar yields NPVs of GHc 2170.599, GHc 2812.279 and GHc3546.422 for Ayuom, Nyankpala and Afiaso respectively. In the discussions done here, the assumptions made in the financial analysis are not varied and only the price of biochar is allowed to change.

Table 4.3.5.2: Effect of Biochar Price Change on Private Profitability Ha^{-1}

Price of Biochar	NPV Ha^{-1} (in GHc) for the Various production Sites		
	Ayuom	**Nyankpala**	**Afiaso**
GHc 0.0347/kg	3015.622	3657.302	4391.445
GHc 0.4/kg	2170.599	2812.279	3546.422

Source: Data Analysis, 2012 (based on Hectare Budget from MoFA and data from field work)

4.3.5.3 Feasibility of Alternative Biochar Production Scenarios

Here, the analysis assumes that the farmer produces the biochar needed for application (not purchasing it). There are a number of methods for doing this-either through a centralized system, through a household level stove or through the use of a pyrolysis truck.

4.3.5.3.1 Maize Production with Centralized Biochar Production System

This analysis makes use of the hectare biochar production budget described in this study. As explained earlier, the total above ground biomass gathered for biochar production as part of this study weighed 50.94 tonnes per Hectare. Accordingly, the farmer gets a total above ground biomass of 50.94 tonnes which yield him 10.188 tonnes of biochar, given a biochar recovery rate of 20% computed from the biochar production unit at Ramsyer in Kumasi. In the farming business, the farmer produces biochar once in the production cycle of four years. Thus the farmer produces biochar in the first year from the slashed biomass and continues to crop on the land for four years. The land is allowed to fallow for two years after which cultivation resumes. The farmer chars biomass from the field only after the fallow period when there is biomass. He applies 2 tonnes out of the 10.188 tonnes produced to the field and sells the rest of the biochar at GHc 2/kg. Holding the assumptions made under the financial analysis constant, the annual revenue in the first year is the revenue from maize and biochar sold. In the second, third and the forth years, the farmer only gets revenue from maize and not biochar because no biochar is produced in those years.

Table 4.3.5.3.1below presents the net present values calculated for maize production in the study areas. Maize production at Ayuom, Nyankpala and Afiaso are not profitable considering the negative NPVs realized. However, the slash and char system turns profitable if the farmer is given a free biochar reactor. Under this package, it is assumed that the farmer is given a biochar reactor or there is a biochar reactor installed in the community, and farmers could go and char their biomass there for free. All other costs incidental to biochar production and application are borne by the farmer.

Table4.3.5.3.1: Long Term Profitability of Maize Production Ha^{-1}: Centralized Biochar Reactor

	Net Present Value Ha^{-1} (GH¢)		
	Ayuom	**Nyankpala**	**Afiaso**
Centralized Biochar Reactor System	-29610.9	-28803.2	-28237.4
With Free Biochar Reactor	3215.08	4022.771	4588.618

Source: Data analysis, 2012 (based on Hectare Budget from MoFA and data from field work)

4.3.5.3.2 Maize Production with Mobile On-farm Biochar Reactor System

This analysis uses the hectare biochar production budget under Table 4.1.2b translated into per Hectare basis. Here, the farmer produces biochar with a pyrolysis truck which is able to move from farm to farm and combust biomass. Again, biochar production takes place only in the 1st, 7th, 13th, 19th and the 25th years when there is enough biomass after land clearing because of the fallow period. That is; as discussed in the case above, the farmer produces and applies biochar only in the first year of the production cycle. Cultivation goes on for four years until a fallow period of two years. Production continues in the seventh year and the cycle is repeated. The total production cost is the maize production cost plus all other costs incidental to the acquisition of pyrolysis truck and producing the biochar. Total revenue is the income from output of maize plus sales of biochar in excess of farm fertilization requirement of two tonnes. As can be read from Table 4.3.5.3.2, maize production in the study with pyrolysis truck is not profitable, except when there is a free pyrolysis truck which goes to the farm to char biomass for farmers. The farmer only hires the labour required and bears other costs inherent to the charring of biomass but the truck is given to maybe a group of farmers.

Table 4.3.5.3.2: Profitability of Maize Production Ha^{-1}: Mobile On-farm Pyrolysis Truck

	Net Present Value (GH¢)		
	Ayuom	**Nyankpala**	**Afiaso**
With mobile Pyrolysis truck	-361955	-362788	-360581
With free truck to farmers	16638.52	15805.04	18011.91

Source: Data analysis, 2012(based on Hectare Budget from MoFA and data from field work)

4.3.5.4 Profitability Ha^{-1} for Different Levels of Biochar & Fertilizer: A typical Case of the Guinea Savanna Vegetation

In Table 4.3.5.4**,** different levels of biochar and fertilizer used on an experimental field at Nyankpala and the corresponding yields obtained from each treatment together with the NPVs computed have been presented for each case. Three levels (0kg, 2000kg and 4000kg) of biochar were considered for 0kg, 30kg, 60kg and 90kg of fertilizer. Each level of biochar was replicated for the various levels of fertilizer. The fertilizer used is of a urea source and to each replication; there was a basal application of 20kg of phosphorus (P). All the NPVs for the various options are negative, meaning that maize production for each of the scenarios here is not profitable.

Table 4.3.5.3: Profitability Ha^{-1} for Different Levels of Biochar & Fertilizer at Nyankpala

Treatment	Amount of Biochar Used (kg)	Amt of Fertilizer Used (kg)	Grain Yield Obtained (kg)	Computed NPVs (GH¢)
1	0	0	360	-1290.34
2	0	30	430	-1292.1
3	0	60	500	-1293.85
4	0	90	520	-1359.07
5	2000	0	550	-5914.61
6	2000	30	600	-5941.75
7	2000	60	710	-5892.73
8	2000	90	840	-5818.31
9	4000	0	860	-10178.3
10	4000	30	1130	-9926.11
11	4000	60	1220	-9902.47
12	4000	90	1420	-9739.19

Source: Computation built upon Ammal *et al*., (2013)

4.3.5.5 Discounting and Climate Change

Most environmental projects are long time in nature. Therefore for long term measures like climate change mitigation, it is suggested that discounting would make the project less attractive. Thus, a project that provides a clean environment may be discriminated against if discounted and thus, higher discount rates would accelerate the depletion of resources. If the discount rate is greater than the renewal rate of resources, it will speed up the use of resources until they are depleted. It is also argued that discounting is not incompatible with the notion of sustainable resource management where the interest of the present generation is believed to be appalled with those of the future generation. For these reasons, the use of discount rates which approach zero is proposed. The discount rate used for the private cost-benefit analysis is 26%. In order to solve the anomaly encountered in using discounted measures to evaluate environmental projects, 0% discount rate (as suggested by Anthoff *et al. (200)* is now used for the analysis hereunder. From Table 4.3.5.5, it can be observed that equalizing the interest of the present generation to that of the future generation makes the slash and char practice attractive to the farmer than the reference slash and burn practice.

Table 4.3.5.5 Private Profitability of Maize with Biochar: Equal Generational Interest

	Production Sites		
	Ayuom	Nyankpala	Afiaso
NPV Ha^{-1} at 0% Discount Rate (GHc)	6925.9	2772.004	15830.6
Reference situation NPV at 26% Discount Rate (GHc)	3324.795	1703.86	4828.31

Source: Data Analysis, 2012

CHAPTER FIVE

5. SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

The study identified the operational costs of maize production under the slash and char practice as well as costs and returns of biochar per tonne. Profitability analysis was first done for short term agricultural decisions. This was followed by profitability analysis for long term agricultural decisions from the viewpoint of the private person. Adjustments were then made to arrive at economic analysis, where shadow prices were used.

Maize production cost under the reference slash and burn case is found to range from GHc 867 to GHc 1774 per Hectare depending on the production site. The use of biochar increases the total farm production cost to a range from GHc7054.49 to GHc10127 per Hectare if the farmer purchases and applies two tonnes of biochar per Hectare. Where a farmer produces biochar from a centralized biochar reactor, establishment cost is found to be GHc410,000; equipment cost is found to be GHc400 and operational cost is found to be GHc806.93/tonne of biochar.

For short term agricultural decisions, the slash and char practice leads to a reduction in the farmer's net income in the absence of an incentive for production. Annual carbon abatement cost per Ha (that is farm opportunity cost as the farmer switches from the slash and burn practice to the carbon sequestration practice) ranges from GH¢ 3472 to GH¢ 6810 depending on the area, granted that biochar is a market commodity with a price. If the farmer owns the biochar reactor, the change in net income per Hectare is GHc (7012.84) for a short term maize production at Ayuom, meaning that the farmer trades off GHc7012.84 if he switches from the slash and burn to the slash and char practice and granted that biochar production is integrated into the maize production and the farmer owns the biochar reactor. However, the slash and char system is profitable at Ayuom with a change in net income of GHc9592.83 and a return on labour higher than the minimum wage; if the farmer produces biochar from a Community owned biochar reactor. Another incentive explored in this study is the case where a farmer is given biochar for maize production. Farmers' net income increases between GHc 554.95 and GHc1181.10 per Hectare across the study areas if biochar production is decoupled from maize production, so that the farmer is given biochar for free. The profitability of the slash and char practice is influenced by the labour intensity of the slash and char system and the high volumes of biochar proposed for application (2 tonnes of biochar Ha^{-1}) as well as the price of biochar. The situation may worsen if the farmer is to apply biochar every year. Agronomic studies can consider the best application rate and as to whether biochar application should be one off or with other applications in subsequent years as well as the carbon sequestration potential of biochar for different locations.

For long term agricultural decisions for maize production, the slash and char was found to be unprofitable from the viewpoint of the individual (the farmer) for all the study areas and the scenarios considered. This is indicated by the negative NPVs per Hectare of GHc-1530.55, GHc -888.888 and GHc-154.746

for Ayuom, Nyankpala and Afiaso respectively. The FRRs for maize production with biochar were 8%, 10% and 24% for Nyankpala, Ayuom and Afiaso respectively when discounted at the opportunity cost of capital. It would therefore have been better to commit resources to other investments in the economy than investments in the slash and char practice. In all cases, the reference situations were profitable, with per Hectare net present values of GHc3353.364, GHc1703.86 and GHc4828.308 for Ayuom, Nyankpala and Afiaso respectively. Carbon abatement cost per tCO_2eq is between GHc466.44 and GHc952 from the view point of the farmer across the study areas. This means that, where there is incentive for farmers, it should be high enough to cover the farm opportunity cost of between GHc466.44 and GHc952 or in a form that would cover farm operations equivalent to GHc466.44 and GHc952. This amount just makes the sum of discounted net benefit from maize under the slash and char practice just equal to that under the slash and burn practice. Therefore, for successful adoption, it is recommended that such and incentive for slash and char adoption should be more than the carbon abatement cost (in money terms).

However, profitability improved with the analysis from the viewpoint of the society. Maize production for each of the three areas considered was seen to be profitable with a positive NPV which is higher than that of the reference scenario. Maize production under the slash and char system at Ayuom yielded a positive NPV of GHc15089.62 (the reference situation being GHc 9734.902) per Hectare. Maize production at Nyankpala gave an NPV of GHc 9028.054 (with a reference NPV of GHc 5877.354) per Hectare, while maize production with biochar at Afiaso yielded a net present value of GHc 10660.23 (with NPV of the reference situation being GHc 6063.251) per Hectare. Economic carbon abatement cost ranges from GHc614.17 and GHc1043.805 per tCO_2eq. This means that the economy gains between GHc614.17 and GHc1043.805 on each tonne of carbon equivalent. Government

Provision of incentive to farmers in terms of biochar for production removes some of the production anomalies and makes the slash and char system attractive to farmers. From the analysis done, the slash and char system is not profitable to the farmer and he would therefore not adopt it given the option of the slash and burn practice. Rather, to the society, the slash and char practice has a positive impact on the overall social welfare. Therefore, government could motivate farmers to adopt the slash and char practice since it has positive environmental benefits, and yields an overall positive impact on the economy in terms of national income. This incentive could be to resource entities to produce biochar for farmers. Governments could also empower farmers through provision of funds to help them hire their own labour for the extra activities that the slash and char system brings to the production system.

The analysis done evaluated the slash and char system against the slash and burn system. However, there are other fertility management systems like slash-and-mulch and the use of manure for crop production especially in the northern Ghana which are equally harmful for the environment since organic fertilizer would still mineralize to the atmosphere as potent gases. Further studies could consider the economics of biochar adoption against these fertility management options. The production of biochar also evolves the production of bio-diesel and syngas whose economic values have not been explored in this study because of limited information. As a result, economic gains by farmers from sales of bio-diesel and syngas were not considered for the cases where the farmer produces his own biochar. This could also be considered

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APPENDICES

A. Private Hectare Budget for Maize production with Biochar at Ayuom

Item	Quantity/Person Hours	Unit Cost	Cost Per Acre	Cost Per Ha
Land clearing	1	160	160	395.2
St amping	2	10	20	49.4
Burning	1	10	10	24.7
Seedmaize	9	1.2	10.8	26.676
Planting	5	10	50	123.5
Labour for first weed control	5	10	50	123.5
Labour for second weed control	5	10	50	123.5
N0: P30 K60 (kg)	36	0.78	28.08	69.3576
Carriage of fertilizer (kg)	36	0.0133	0.4788	1.18264
Labour for fertilizer application (kg)	36	0.2	7.2	17.784
Gathering of biomass	105.762	15	1586.43	3918.48
Cost of biochar (kg)	809.72	2	1619.44	4000.02
Transport of biochar in kilograms per km	809.72	0.0133	10.7693	26.6001
incorporation of biochar	7.29	20	145.8	360.126
Land rental per year	1	150	150	370.5
Harvesting and dehusking	4	10	40	98.8
Jute sacks	23	2	46	113.62
Polyethane sheets	23	1.5	34.5	85.215
Transport of produce	23	3.5	80.5	198.835
				10127
Benefits				
Expected Yield with 50% increase (bags)	23	80	1840	4544.8

Source: MoFA Hectare Budget with Filling in with Field Data, 2012

B. Hectare Budget for Maize Production Under Slash and Burn at Ayuom

Item	Quantity/Person Hours	Unit Cost	Cost Per Acre	Cost Per Ha
Land clearing	1	160	160	395.2
Stumping	2	10	20	49.4
Burning	1	10	10	24.7
Seedmaize	9	1.2	10.8	26.676
Planting	5	10	50	123.5
Labour for first weed control	5	10	50	123.5
Labour for second weed control	5	10	50	123.5
N90: P30 K60 (kg)	73	0.78	56.94	140.642
Carriage of fertilizer (kg)	73	0.0133	0.9709	2.39812
Labour for fertilizer application (kg)	73	0.2	14.6	36.062
Land rental per year	1	150	150	370.5
Harvesting and dehusking	4	10	40	98.8
Jute sacks	15	2	30	74.1
Polyethane sheets	15	1.5	22.5	55.575
Transport of produce	15	3.5	52.5	129.675
Total				1774.23
Benefits				
Expected Yield (bags)	15	80	1200	2964

Source: MoFA Hectare Budget with Filling in with Field Data, 2012

C. Economic Hectare Budget for Maize production with Biochar at Ayuom

Item	Quantity/Person Hours	Unit Cost (GHc)	Cost Per Acre (GHc)	Cost Per Ha (GHc)
Land clearing	1	41.6	41.6	102.752
Stumping	2	2.6	5.2	12.844
Burning	1	2.6	2.6	6.422
Seedmaize	9	0.624	5.616	13.8715
Planting	5	2.6	13	32.11
Labour for first weed control	5	2.6	13	32.11
Labour for second weed control	5	2.6	13	32.11
N0: P30 K60 (kg)	36	0.579	20.844	51.4847
Carriage of fertilizer (kg)	36	0.00346	0.12456	0.30766
Labour for fertilizer application (kg)	36	0.052	1.872	4.62384

Gathering of biomass	105.762	3.9	412.472	1018.81
Cost of biochar (kg)	809.72	1.04	842.109	2080.01
Transport of biochar in kilograms per km	809.72	0.00346	2.80163	6.92003
incorporation of biochar	7.29	5.2	37.908	93.6328
Land rental per year	1	78	78	192.66
Harvesting and dehusking	4	2.6	10.4	25.688
Jute sacks	23	1.04	23.92	59.0824
Polyethane sheets	23	0.78	17.94	44.3118
Transport of produce	23	0.91	20.93	51.6971
Expected Yield with 50% increase (bags)	23	74.1483	1705.41	4212.36
Payment from carbon sequestration	2.0769	118.5	246.113	607.898

Source: MoFA Hectare Budget with Filling in with Field Data, 2012

D. Economic Hectare Budget for Maize production without Biochar at Ayuom

Item	Quantity/Person Hours	Unit Cost (GHc)	Cost Per Acre(GHc)	Cost Per Ha (GHc)
Land clearing	1	41.6	41.6	102.752
Stumping	2	2.6	5.2	12.844
Burning	1	2.6	2.6	6.422
Seedmaize	9	0.624	5.616	13.8715
Planting	5	2.6	13	32.11
Labour for first weed control	5	2.6	13	32.11
Labour for second weed control	5	2.6	13	32.11
N90: P30 K60 (kg)	73	0.579	42.267	104.399
Carriage of fertilizer (kg)	73	0.00346	0.25258	0.62387
Labour for fertilizer application (kg)	73	0.052	3.796	9.37612
Land rental per year	1	78	78	192.66
Harvesting and dehusking	4	2.6	10.4	25.688
Jute sacks	15	1.04	15.6	38.532
Polyethane sheets	15	0.78	11.7	28.899
Transport of produce	15	0.91	13.65	33.7155
Expected Yield (bags)	15	74.1483	1112.22	2747.19

Source: MoFA Hectare Budget with Filling in with Field Data, 2012

E. Economic Hectare Budget for Maize Production with Biochar at Nyankpala

Item	Quantity/Person Hours	Unit Cost (GHc)	Cost Per Acre (GHc)	Cost Per Ha (GHc)
Stumping	2	1.3	2.6	6.422
Plowing and harrowing	1	13	13	32.11
Burning	1	1.3	1.3	3.211
Seedmaize	9	0.624	5.616	13.8715
Planting	5	1.3	6.5	16.055
Labour for first weed control	5	1.3	6.5	16.055
Labour for second weed control	5	1.3	6.5	16.055
N0: P30 K60 (kg)	36	0.579	20.844	51.4847
Land rental per year	1	26	26	64.22
Carriage of fertilizer (kg)	36	0.00346	0.12456	0.30766
Labour for fertilizer application (kg)	36	0.026	0.936	2.31192
Gathering of biomass	106	2.6	275.6	680.732
Cost of biochar (kg)	809.72	1.04	842.109	2080.01
Transport of biochar in kilograms per km	809.72	0.00346	2.80163	6.92003
incorporation of biochar	7.29	2.6	18.954	46.8164
Harvesting and dehusking	4	1.3	5.2	12.844
Jute sacks	15	1.04	15.6	38.532
Polyethane sheets	15	0.78	11.7	28.899
Transport of produce	15	0.91	13.65	33.7155
Benefits				
Expected Yield with 50% increase (bags)	15	63.5557	953.336	2354.74
Payment from carbon sequestration	2.0769	118.5	246.113	607.898

Source: MoFA Hectare Budget with Filling in with Field Data, 2012

F. Private Hectare Budget for maize production with Biochar at Nyankpala

Item	Quantity/Person Hours	Unit Cost	Cost Per Acre	Cost Per Ha
Stumping	2	5	10	24.7
Plowing and harrowing	1	50	50	123.5
Burning	1	5	5	12.35
Seedmaize	9	1.2	10.8	26.676
Planting	5	5	25	61.75
Labour for first weed control	5	5	25	61.75
Labour for second weed control	5	5	25	61.75

N0: P30 K60 (kg)	36	0.78	28.08	69.3576
Land rental per year	1	50	50	123.5
Carriage of fertilizer (kg)	36	0.0133	0.4788	1.18264
Labour for fertilizer application (kg)	36	0.1	3.6	8.892
Gathering of biomass	106	7.5	795	1963.65
Cost of biochar (kg)	809.72	2	1619.44	4000.02
Transport of biochar in kilograms per km	809.72	0.0133	10.7693	26.6001
incorporation of biochar	7.29	10	72.9	180.063
Harvesting and dehusking	4	5	20	49.4
Jute sacks	15	2	30	74.1
Polyethane sheets	15	1.5	22.5	55.575
Transport of produce	15	3.5	52.5	129.675
				7054.49
Benefits				
Expected Yield with 50% increase (bags)	15	60	900	2223

Source: MoFA Hectare Budget with Filling in with Field Data, 2012

G. Private Hectare Budget for Maize production without Biochar Nyankpala

Item	Quantity/Person Hours	Unit Cost	Cost Per Acre	Cost Per Ha
Stumping	2	5	10	24.7
Plowing & Harrowing	1	50	50	123.5
Seedmaize	9	1.2	10.8	26.676
Planting	5	5	25	61.75
Labour for first weed control	5	5	25	61.75
Labour for second weed control	5	5	25	61.75
N90: P30 K60 (kg)	73	0.78	56.84	140.4
Carriage of fertilizer (kg)	73	0.0133	0.9709	2.39812
Labour for fertilizer application (kg)	73	0.1	7.3	18.031
Land rental per year	1	50	50	123.5
Harvesting and dehusking	4	5	20	49.4
Jute sacks	10	2	20	49.4
Polyethane sheets	10	1.5	15	37.05
Transport of produce	10	3.5	35	86.45

Total				866.755
Benefits				
Expected Yield (bags)	10	60	600	1482

Source: MoFA Hectare Budget with Filling in with Field Data, 2012

H. Economic Hectare Budget for Maize Production without Biochar at Nyankpala

Item	Quantity/Person Hours	Unit Cost	Cost Per Acre	Cost Per Ha
Stumping	2	1.3	2.6	6.422
Plowing & Harrowing	1	13	13	32.11
Seedmaize	9	0.624	5.616	13.8715
Planting	5	1.3	6.5	16.055
Labour for first weed control	5	1.3	6.5	16.055
Labour for second weed control	5	1.3	6.5	16.055
N90: P30 K60 (kg)	73	0.579	42.267	104.399
Carriage of fertilizer (kg)	73	0.00346	0.25258	0.62387
Labour for fertilizer application (kg)	73	0.026	1.898	4.68806
Land rental per year	1	26	26	64.22
Harvesting and dehusking	4	1.3	5.2	12.844
Jute sacks	10	1.04	10.4	25.688
Polyethane sheets	10	0.78	7.8	19.266
Transport of produce	10	0.91	9.1	22.477
Benefits				
Expected Yield (bags)	10	63.557	635.57	1569.86

Source: MoFA Hectare Budget with Filling in with Field Data, 2012

I. Private Hectare Budget for Maize Production with Biochar at Afiaso

Item	Quantity/Person Hours	Unit Price	Cost Per Acre	Cost Per Ha
Land clearing	1	40	40	98.8
Stamping	2	10	20	49.4
Burning	1	10	10	24.7
Seedmaize	9	1.2	10.8	26.676
Planting	5	10	50	123.5

Labour for first weed control	5	10	50	123.5
Labour for second weed control	5	10	50	123.5
N0: P30 K60 (kg)	36	0.78	28.08	69.3576
Carriage of fertilizer (kg)	36	0.0133	0.4788	1.18264
Labour for fertilizer application (kg)	36	0.2	7.2	17.784
Gathering of biomass	105.762	15	1586.43	3918.48
Cost of biochar (kg)	809.72	2	1619.44	4000.02
Transport of biochar in kilograms per km	809.72	0.0133	10.7693	26.6001
incorporation of biochar	7.29	20	145.8	360.126
Land rental per year	1	125	125	308.75
Harvesting and dehusking	4	10	40	98.8
Jute sacks	15	2	30	74.1
Polyethane sheets	15	1.5	22.5	55.575
Transport of produce	15	3.5	52.5	129.675
Benefits				
Expected Yield with 50% increment(bags)	15	120	1800	4446

Source: MoFA Hectare Budget with Filling in with Field Data, 2012

J. Private Hectare Budget for Maize Production without Biochar at Afiaso

Item	Quantity/Person Hours	Unit Price	Cost Per Acre	Cost Per Ha
Land clearing	1	40	40	98.8
Stumping	2	10	20	49.4
Burning	1	10	10	24.7
Seedmaize	9	1.2	10.8	26.676
Planting	5	10	50	123.5
Labour for first weed control	5	10	50	123.5
Labour for second weed control	5	10	50	123.5
N90: P30 K60 (kg)	73	0.78	56.94	140.642
Carriage of fertilizer (kg)	73	0.013	0.9709	2.39812
Labour for fertilizer application (kg)	73	0.2	14.6	36.062
Land rental per year	1	125	125	308.75
Harvesting and dehusking	4	10	40	98.8
Jute sacs	10	2	20	49.4
Polyethane sheets	10	1.5	15	37.05

Transport of produce	10	3.5	35	86.45
				1329.63
Benefits				
Expected Yield (bags)	10	120	1200	2964

Source: MoFA Hectare Budget with Filling in with Field Data, 2012

K. Economic Hectare Budget for maize production with Biochar at Afiaso

Item	Quantity/Person Hours	Unit Price (GHc)	Cost Per Acre (GHc)	Cost Per Ha (GHc)
Land clearing	1	10.4	10.4	25.688
Stamping	2	2.6	5.2	12.844
Burning	1	2.6	2.6	6.422
Seedmaize	9	0.624	5.616	13.871
Planting	5	2.6	13	32.11
Labour for first weed control	5	2.6	13	32.11
Labour for second weed control	5	2.6	13	32.11
N0: P30 K60 (kg)	36	0.579	20.844	51.484
Carriage of fertilizer (kg)	36	0.00346	0.12456	0.3076
Labour for fertilizer application (kg)	36	0.052	1.872	4.6238
Gathering of biomass	105.762	3.9	412.472	1018.8
Cost of biochar (kg)	809.72	1.04	842.109	2080.0
Transport of biomass in kilograms per km	809.72	0.00346	2.80163	6.9200
incorporation of biochar	7.29	5.2	37.908	93.632
Land rental per year	1	65	65	160.55
Harvesting and dehusking	4	2.6	10.4	25.688
Jute sacks	15	1.04	15.6	38.532
Polyethane sheets	15	0.78	11.7	28.899
Transport of produce	15	0.91	13.65	33.715
Benefits				
Expected Yield with 50% increment(bags)	15	84.7409	1271.11	3139.6
Payment from carbon sequestration	2.0769	118.5	246.113	607.89

Source: MoFA Hectare Budget with Filling in with Field Data, 2012

L. Economic Hectare Budget for Maize Production without Biochar at Afiaso				
Item	Quantity/Person Hours	Unit Price (GHc)	Cost Per Acre (GHc)	Cost Per Ha (GHc)
Land clearing	1	10.4	10.4	25.688
Stumping	2	2.6	5.2	12.844
Burning	1	2.6	2.6	6.422
Seedmaize	9	0.624	5.616	13.8715
Planting	5	2.6	13	32.11
Labour for first weed control	5	2.6	13	32.11
Labour for second weed control	5	2.6	13	32.11
N90: P30 K60 (kg)	73	0.579	42.267	104.399
Carriage of fertilizer (kg)	73	0.00346	0.25258	0.62387
Labour for fertilizer application (kg)	73	0.052	3.796	9.37612
Land rental per year	1	65	65	160.55
Harvesting and dehusking	4	2.6	10.4	25.688
Jute sacs	10	1.04	10.4	25.688
Polyethane sheets	10	0.78	7.8	19.266
Transport of produce	10	0.91	9.1	22.477
Benefits				
Expected Yield (bags)	10	84.74	847.4	2093.08

Source: MoFA Hectare Budget with Filling in with Field Data, 2012

M. Investment Cost Schedule for Maize Production per Hectare under a Centralized Biochar Reactor System

Year	GHc
0	41,000
1	0
2	0
3	0
4	0
7	0
8	0
9	0
10	0
13	0
14	0
15	0
16	0
19	0
20	0
21	0
22	0
25	0
26	0
27	0
28	0

N. Production and Administrative Cost Schedule for Maize Production per Hectare under a Centralized Biochar Reactor System

Year	GHc
0	0
1	1465.889
2	665.3686
3	665.3686
4	665.3686
7	1072.889
8	665.3686
9	665.3686
10	1058.369
13	1072.889
14	665.3686
15	665.3686
16	665.3686
19	1072.889
20	1058.369
21	665.3686
22	665.3686
25	1072.889
26	665.3686
27	665.3686
28	665.3686

O. Operational Cost Schedule for Maize Production per Hectare under a Centralized Biochar Reactor System

Year	GHc
0	0
1	9194.955
2	1082.302
3	1082.302
4	1082.302
7	9194.955
8	1082.302
9	1082.302
10	1082.302
13	9194.955
14	1082.302
15	1082.302
16	1082.302
19	9194.955
20	1082.302
21	1082.302
22	1082.302
25	9194.955
26	1082.302
27	1082.302
28	1082.302

P. Revenue Schedule for Maize Production per Hectare under a Centralized Biochar Reactor System

Year	GHc
0	0
1	20920.8
2	4544.8
3	4544.8
4	4544.8
7	20920.8
8	4544.8
9	4544.8
10	4544.8
13	20920.8
14	4544.8
15	4544.8
16	4544.8
19	20920.8
20	4544.8
21	4544.8
22	4544.8
25	20920.8
26	4544.8
27	4544.8
28	36211.46