FACTORS AFFECTING BIOCHAR TECHNOLOGY ADOPTION BY VEGETABLE FARMERS IN THE KWAHU EAST DISTRICT OF GHANA

BY

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THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN AGRIBUSINESS

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DECLARATION

I, DANIEL NINSON, the author of this thesis, titled; **“FACTORS AFFECTING BIOCHAR TECHNOLOGY ADOPTION BY VEGETABLE FARMERS IN THE KWAHU EAST DISTRICT OF GHANA”**, do hereby declare that with the exception of the relevant references duly cited, the entire research was carried out by me in the Department of Agricultural Economics and Agribusiness, College of Basic and Applied Sciences, University of Ghana, Legon from August 2014 to July 2015. This thesis has never been presented either in whole or in part for any degree in this University or elsewhere.

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Date   Date

DEDICATION

This thesis is dedicated to the Ninson family for the amazing love, support and encouragement throughout my entire education.

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ABSTRACT

Biochar is a type of charcoal that can be used to condition agricultural soils. The application of Biochar to agricultural soils as a conditioner can improve soil fertility and crop productivity. The agricultural sector of Ghana is characterized by low productivity and low level of technology use. The study sought to assess the factors that influence Biochar technology adoption in amending soils for vegetable production in the Kwahu East district of Ghana. Primary data was collected over the 2011 and 2012 seasons based on a Biochar pilot study carried out in 2011 by Millennium Development Authority (MiDA), Adventist Development and Relieve Agency (ADRA), and Crop Research Institute. The Purposive sampling technique was used to select three communities (Aduamoa, Akwasiho and Suminakese) within the study area where Biochar was introduced in 2011. Respondents were subsequently selected at random yielding a sample size of 156 farmers in 2011 and 89 farmers in 2012. Survey data was analysed using Net Farm Income, Double-hurdle regression model and Garret ranking technique. The study concludes that vegetable production under Biochar adoption was more profitable in Akwasiho in both 2011 and 2012 seasons compared to vegetable production not under Biochar adoption. The profitability associated with vegetable production under Biochar adoption by farmers in Aduamoa was mixed and that of farmers in Suminakese was not statistically significant. The most consistent determinants of adoption were Farmer Based Organization (FBO) membership, access to credit and forum participation. The most consistent determinant of intensity of Biochar adoption was FBO membership. The pressing constraints facing farmers in vegetable production and adoption of Biochar were lack of credit and workload associated with Biochar production respectively. The study recommends that farmers in Akwasiho should continue to use and intensify vegetable production under Biochar since results from that community indicated that this is more profitable than vegetable production without the use of Biochar. Project implementers must intensify training on Biochar use especially for farmers in Aduamoa and Suminakese. More agribusinesses must be encouraged to increase the production and commercialization of Biochar in the study area. Credit institutions must be encouraged to supply farmers with more credit.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ADRA	Adventist Development and Relieve Agency
BCR	Benefit Cost Ratio
CPI	Consumer Price Index
DANIDA	Danish International Development Agency
FBO	Farmer Based Organization
GI	Gross Income
GM	Gross Margin
IPM	Integrated Pest Management
IRR	Internal Rate of Returns
ISSER	Institute of Statistical, Social and Economic Research
JHS	Junior High School
MiDA	Millennium Development Authority
NFI	Net Farm Income
NPV	Net Present Value
SHS	Senior High School
SSS	Senior Secondary School
SVGA	Suminakese Vegetable Growers Association
TFC	Total Fixed Cost
TVC	Total Variable Cost
WEBSOC	Green, cohesive Water, Energy-from-Biomass, Soil, Organics, and Crop

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Soil amendments are products that are added to poor soils to improve their structure and fertility. These include (in) organic fertilizers and Biochar. Biochar is a type of charcoal produced by a thermochemical process called pyrolysis of organic waste material under high temperatures and anaerobic conditions (Sparrevik *et al*., 2013). The Biochar production process generates three main products. These are the main Biochar product, bio-oil and synthesis gas. A confluence of these three products provide very important agronomic, environmental and energy benefits (Duku *et al*., 2011).

The application of Biochar to agricultural soils can improve soil quality, fertility and crop productivity (Lal, 2009; Leach *et al*., 2012). Biochar is endowed with alkaline components like Calcium (Ca), Magnesium (Mg) and Potassium (K). Amending agricultural soils with Biochar helps control soil acidity due to its alkaline content (Cornelissen *et al*., 2014). It has the propensity to store nutrients and water, thereby increasing plant growth and reduction in the use of synthetic fertilizers (Teichmann, 2014). These agronomic elements of Biochar are essential boosts for preserving croplands and food security.

Biochar adoption in farming is viewed as one of the most important ways of curbing environmental degradation (Bracmort, 2010; Hunt *et al*., 2010; Shackley *et al*., 2011). Its addition to soils limits nitrous oxide and methane emissions and also increases the net uptake of carbon (Shackley *et al*., 2009). Soils amended with Biochar are able to trap Carbon for hundreds of years. Biochar's carbon-negative effect (Bracmort, 2010;

Schahczenski, 2010) significantly increases soil productivity whilst simultaneously reducing the environmental impact of farming.

Bio-oil and synthesis gas are by-products of the Biochar production process (Brick & Lyutse, 2010; Sohi *et al*., 2010). These can provide rural farmers with a cheap source of energy for farm use. The output energy of Biochar production has been found to be far greater than the energy input of its production (Schahczenski, 2010). The utilization of Biochar is therefore a very efficient way of reducing the overdependence on non-renewable energy sources (McElligott *et al.*, 2011). Farmers' profitability may also be positively impacted as a result of the reduction in cost of farm energy.

In spite of the numerous benefits of Biochar, there are problems and complications that are associated with the production and use of Biochar. Biochar production and use could cause emission of toxins and inhalation of dust which could have dire consequences for respiratory health. The production of Biochar may also result in competition for biomass needed for soil protection (Scholz *et al*., 2014). Bruun & Luxhoi (2008) have also raised some concerns with respect to the carbon-negative effect of Biochar production. They opine that in certain instances, other products like bioenergy which are mostly associated with Biochar production could rather result in carbon emissions.

Ghana has a large availability of agricultural, forestry and municipal solid waste. This makes the Biochar technology a potential for developing a sustainable agricultural system. However, only a small portion of the farmer population in the country has adopted the technology (Duku *et al*., 2011). Many factors determine the adoption rate of agricultural technologies by farmers (Akudugu *et al*., 2012; Barungi *et al*., 2013; Yu & Nin-Pratt, 2014). However, health issues, labour issues, cost of application of technology and gender issues affect farmers' rapid adoption of the Biochar technology (Scholz *et al*., 2014). Farmers will also want to consider all the risk and uncertainties associated with the technology before they finally apply it on their farms.

Analysis of Biochar technology adoption (Scholz *et al*., 2014) should also consider the associated profitability, among other things. Biochar, just like any new agricultural production technology faces the usual conundrum of high cost in the initial stages of adoption (Shackley *et al*., 2011). It is important that both farmers and agribusiness practitioners who specialize in the technology are fully aware of the cost and benefit implications of adopting the technology. Laufer & Tomlinson (2013) opine that few studies have shown that Biochar business is economically viable.

1.2 Problem Statement

One of the major problems of Ghana's agricultural sector is the perpetual decline in soil fertility. This has largely been attributed to continuous cultivation, erosion and rapid organic matter mineralisation which affect food security in the country. More than half of the labour force are engaged in agricultural activities and are mostly small scale farmers who depend on these low productive soils for farming. Ghana's agricultural sector is characterized by low productivity which is hinged on low and erratic rainfall patterns as well as low adoption and application of soil conditioners (Duku *et al*., 2011). Farmers face a lot of constraints in production and in the use of farming innovations.

The national plan for the agricultural sector aims at tremendously improving productivity to enhance food security but this will come with massive impact on the environment. Agricultural activities by farmers contribute to climate change whose devastating impact is felt all over the world. A problem therefore exists about how to significantly increase agricultural productivity whilst simultaneously reducing the environmental impact of agriculture (Collison *et al.*, 2009).

The overall innovativeness of farmers in the agricultural sector will contribute a great deal towards their profitability and poverty reduction. Unfortunately the agricultural sector of the economy is characterized by low level of technology adoption such as Biochar. This is identified as one of the main reasons for low productivity in the sector. The quest to identify the reasons for low level of technology adoption among Ghanaian farmers requires that the factors that influence their decision to adopt or not to adopt specific farming technologies be investigated (Akudugu *et al*., 2012). In 2011, a Biochar-use pilot was carried out in the Eastern Region of Ghana by ADRA Ghana, Millennium Development Authority (MiDA) and the Crop Research Institute of Ghana that involved vegetable farmers.

The key research question arising from this pilot study is: *What has been the farm-level adoption of the Biochar technology and what factors have accounted for this in the pilot areas*? The associated research questions are:

1. What is the profitability associated with the use of Biochar in vegetable production?
2. What are the factors that influence farmers' decision to use Biochar in vegetable production?
3. What are the factors that influence intensity of use of Biochar in vegetable production?
4. What are the constraints facing farmers in vegetable production and the adoption of Biochar?

1.3 Objectives of the Study

The main objective of this study is to assess the factors that influence Biochar technology adoption in amending soils for vegetable production by farmers in the Kwahu East district of Ghana. Specifically the study seeks to:

1. Measure the profitability associated with the use of Biochar in vegetable production.
2. Identify the factors that affect farmer's decision to use Biochar in vegetable production.
3. Estimate factors influencing the intensity of use of Biochar in vegetable production.
4. Identify and rank the constraints facing farmers in vegetable production and adoption of Biochar.

1.4 Relevance of the Study

The application of Biochar to agricultural soils has the potential to significantly increase soil fertility and crop productivity. This will also culminate into lifting many rural farmers out of poverty. It has therefore become very imperative for a lot of studies to be carried out in the area of adoption of the Biochar technology which is by far one of the leading soil conditioners for acidic soils. Factors affecting the use and intensity of use of the technology; profitability analysis; and constraints analysis are areas that have not been addressed fully in the relatively few studies that have been carried out on Biochar in Ghana. This study therefore seeks to address these issues. This will bridge a major gap of knowledge as far as Biochar technology in farming is concerned.

The study will provide information on the level of attractiveness of adopting Biochar production technology as amendment to poor soils. Farmers will have an idea of how their farm incomes can be impacted by the use of Biochar in farming. This will help them make informed decisions as to whether to adopt the technology or otherwise. The study will also give an understanding of the constraints in farming in the study area.

It will also provide information for policy makers, agribusiness practitioners and all other actors in the agricultural sector who want to introduce any form of Biochar production technology to farmers, but probably do not understand the specific factors that affect their decision to adopt farming innovations. Again the study will provide information for prospective researchers who will choose this area and also add onto the body of knowledge that already exist. From the foregoing, this study which seeks to analyse Biochar technology adoption by farmers in the Kwahu East district is very relevant.

1.5 Organization of the Study

This study is organized into five main chapters. Following chapter one is chapter two which provides a thorough review of literature that are of relevance to the study. Literature review is carried out on the areas of Biochar production potential in Ghana, agricultural technology adoption, profitability analysis and constraint analysis in production and adoption. Chapter three deals with the methodology of the study. This encompasses the conceptual and theoretical frameworks, method of data analysis, hypothesis testing, the study area and method of data collection. Chapter four presents the results and discussions of the study whilst the last chapter deals with conclusions and recommendations by summarising the findings and policy implications.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter discusses literature that is relevant to the study. Both theoretical and empirical works are discussed. Prior studies in the areas of Biochar and its potential; agricultural technology adoption; profitability analysis; and constraints analysis are reviewed.

2.2 Biochar and its Potential

Biochar is basically a type of charcoal that has been produced by a thermochemical process called pyrolysis. Some appreciable number of studies have looked at both the agronomic and non-agronomic benefits of using Biochar as soil amendment. Duku *et al*. (2011) assessed Biochar potential in Ghana. They posited that some of the potential agronomic benefits of using Biochar as soil amendment included the improvement in soil quality, fertility and crop productivity. According to the authors, Biochar's agronomic benefit is why it is receiving some considerable interest in the country. The study also claimed that Biochar's impact is greatly felt in agricultural soils that are highly acidic.

Laufer & Tomlinson (2013) in their study also looked at both the agronomic and non-agronomic benefits of Biochar. The authors concluded that Biochar's effect on soils may be exclusive to different soils depending on the Biomass component. Unlike Duku *et al*. (2011) and many other authors, Laufer & Tomlinson (2013) went on to assess the economic performance of the use of Biochar in farming. They concluded that there is evidence that economic performance of the use of Biochar as soil amendment is positive. They posited that the use of Biochar by farmers improved their profitability since their expenditures on fertilizer were reduced. The selling of Biochar was also found to be a viable venture in the scheme of agribusiness.

Scholz *et al*. (2014) also addressed the economics of Biochar, among other things, in their study on Biochar potentials in developing countries. The methodology employed was desk review, survey, findings from an expert workshop, typology and life-cycle assessment. They opined that the economics of Biochar systems in developing countries are influenced by easily quantifiable factors and less easily quantifiable factors. The authors concluded that the price farmers received for surplus crops due to the usage of Biochar as soil amendment was what largely affected the economics of Biochar. Unlike Laufer & Tomlinson (2013), they also addressed some constraints affecting the use of Biochar. Some of the constraints identified included the reliability of the technology used; financing issues; incremental workload; marketing; access to information and unfavourable government policies.

The non-agronomic benefits associated with the use of Biochar as soil amendment have also been addressed by some Biochar studies. Schahczenski(2010) suggested that Biochar can also produce farm-based renewable energy. Biochar has the potential to offer carbon-negative fuel as a co-product. This attribute impacts the environment positively whilst enhancing sustainable agriculture. Woolf *et al.* (2010) in their study corroborated the assertion made by Schahczenski(2010). They also posited that Biochar application can impact environmental degradation while at the same time providing energy and increasing crop productivity.

2.3 Types of Biochar

According to Brick & Lyutse (2010), Biochar can be characterised according to the production technology and biomass source. The production technologies include fast pyrolysis, medium pyrolysis, slow pyrolysis and gasification. Biochar yield for fast pyrolysis is approximately 12%; that of medium pyrolysis is approximately 20%; that of slow pyrolysis is approximately 35% and gasification yields approximately 10% Biochar. Sugarcane bagasse, cocopeat straw, paddy straw, palm kernel shell, wood stem, wood bark and cocoa pod husk(Lee, 2013) are common sources of Biochar biomass.

2.4 Technology Adoption in Agriculture

According to Van den Ban & Hawkins (1992), an innovation (technology) can be considered as an idea, method or object that is deemed new to the farmer. They argued that an innovation is always a combo of the hardware and the software. The adoption of a technology largely depends on the perception farmers have about it. The important thing is the associated changes this technology will require in management of the farm. The changes associated with the technology will make either difficult or easier for adoption. Farmers consider the relative advantage, compatibility, complexity, trialability and observability of the technology.

Leeuwis & Van den Ban (2004) explained that the adoption of innovations is the final stage in a sequence of stages. The traditional adoption process involves awareness, interest, evaluation, trial and the stage where the innovation is applied on a large scale (adoption). Adoption of the innovation is stimulated when people search for different kinds of information during the various stages. Farmers usually become aware of agricultural innovations through the mass media in the early stages. In subsequent stages these farmers tend to prefer interpersonal contact with somebody they can confide in. Leeuwis & Van den Ban (2004) again explained that Rogers (1983) had also proposed five stages for adoption. They are knowledge, persuasion, decision, implementation and confirmation stages. An important distinction between the two set of stages is that consideration is given to the probability of the technology being rejected (Van den Ban & Hawkins, 1992).

Rogers (1983) classified adopters of an innovation (technology) into five groups. This is due to the fact that different people adopt innovations at different times. The adopters are therefore classified into innovators, early adopters, early majority, late majority and laggards. Rogers (1983) also explained that the distribution of adoption over time is normal. Innovators constitute 2.5%, early adopters constitute 13.5%, and early majority and late majority constitute 34% each, whilst laggards constitute 16%. To group farmers into these different categories, the distribution of adoption over time must be normal and the degree of total group adoption must also be considered. Van den Ban & Hawkins (1992) again posited that opinion leaders influence the diffusion of agricultural innovations. They have the propensity to help colleague farmers within the farming community. Most farmers trust them and therefore tend to adhere to the advice they offer the farmers on agricultural technologies. Once the opinion leaders adopt a particular technology, many people will follow. Innovations can diffuse effectively if prospective adopters are more or less homogeneous in resources and social status. The diffusion process therefore involves how innovations spread among members in a community.

2.5 Factors Associated with Farmers' Adoption Decision and Intensity of use of Agricultural Technology

Several studies have analysed the factors that affect the adoption decisions of farmers. The socio-economic factors that are generally deemed to affect adoption include age, farm size, household size, experience, gender, farm income, off-farm income and cost of agricultural technology. The institutional factors also include access to extension service and access to credit. The direction of effect mostly depends on the study being conducted.

Age of farmer is one of the important determinants of farmer's technology adoption decisions. Popp *et al*. (1999) opined that age can have intricate effects on adoption of agricultural technology. They studied the factors affecting the adoption of value-added production on cow-calf farms. In their study, none of the age variables was statistically significant. They were not effective in explaining the variations among traditional cow-calf and value-added producer operations. Beshir(2014) also hypothesized age to have an ambiguous effect on probability of adoption of improved forages in North East Highlands of Ethiopia. However the study results indicated that age was statistically significant. Age of farmer positively affected the probability of adoption. The reason was that older farmers possibly might have acquired more knowledge relative to younger farmers. The age variable was also found to be positively correlated with intensity of use of improved forages but it was not statistically significant.

Barungi *et al*. (2013) reviewed factors that influence adoption of agricultural technologies. The authors posited that farm size can affect adoption either positively or negatively. Farmers with larger farm size are likely to adopt and intensify the use of agricultural technologies more rapidly in other to take advantage of economies of scale. However technological risk in some instances makes farm size have negative correlation with adoption and intensity of use of agricultural technologies. Beshir *et al*. (2012) assessed the factors that affect adoption and intensity of use of inorganic fertilizer in North eastern highlands of Ethiopia. They hypothesized farm size to have a positive effect on adoption and intensity of adoption. However their findings confirmed the hypothesis that farm size had positively and significantly affected the intensity of use of inorganic fertilizer. This was attributed to the fact that farmers with larger farm sizes were deemed as relatively wealthy and able to afford the cost of the technology.

The effect of household size on adoption of agricultural technology has been positive in most studies. Mignouna *et al*. (2011) argued that household size has positive effect on adoption because farmers with large household size have relatively more labour to use on the innovation. They also stated that household size has positive effect on extent of adoption. This is because the availability of labour guarantees the expansion of farm enterprises and therefore more investment into the technology. Gebremichael & Gebremedhin (2014) assessed the adoption and intensity of use of improved box hive technology. Their findings indicated a positive but insignificant effect of household size on both adoption and intensity of use of the technology.

Farmer's experience is also an important variable that affect adoption decisions of farmers. This is usually measured using proxy variables such as years of farming or the farmer's biological age. Fernandez-Cornejo *et al*. (2001) and Tiamiyu *et al*. (2009) measured farming experience using the years of farming. According to Fernandez-Cornejo *et al*. (2001), more experience is usually assumed to increase the likelihood of adoption. Their findings indicated that experience positively and significantly affected adoption of herbicide-tolerant soybeans. This was attributed to the fact that more experienced farmers were more likely to appreciate that the greatest profitability of innovations accrue to early adopters. Tiamiyu *et al*. (2009) also posited in their study that farming experience could affect adoption ambiguously depending on the length of period. Their findings however indicated that rice farming experience had a positive and a significant effect on level of adoption of improved rice technologies.

Gender has a role to play in the adoption and intensity of use of agricultural technologies. Ayuya *et al*. (2012) in their study indicated that male farmers are more likely to adopt organic soil management practices. This is due to the fact that male farmers are comparatively less risk averse and have access to resources and information. Akudugu *et al*. (2012) in their study found gender to be positively related to adoption of agricultural production technologies. They also explain that male farmers are more likely to adopt agricultural technologies since they control productive resources which are important for adoption and intensity of use.

Martey *et al*. (2013) in their study suggested that off-farm income affect adoption and intensity of adoption positively. This is because farmers who earn off-farm income have the ability to meet the financial demands associated with adoption of improved agricultural technologies. Hanschuch & Wollni (2013) also opined in their study that off-farm income affects adoption of agricultural technologies positively. This is because wealthier farmers have better access to liquidity and are likely to adopt improved technologies.

Nnadi & Nnadi (2009) in their study of adoption behaviours of maize-cassava intercrop technology found farm income to influence adoption positively. They explained that hikes in annual farm income meant farmers have more capital base and therefore able to intensify the use of the agricultural technology. However Zhou *et al*. (2010) held the opinion that farm income has mixed effect on farmer's adoption behaviour.

Mignouna *et al*. (2011) explained that access to extension services enhances farmers' exposure and familiarity to agricultural technologies. Therefore it is expected to have a positive influence on the adoption and intensity of use of agricultural technologies. Extension services create more awareness of the agricultural technologies since they provide necessary information and special skills needed to help farmers apply the innovations. Beshir(2014) found access to extension services to positively influence adoption but negatively influence intensity of use of improved forages technology. He also explained that access to extension services is the major source of information for farmers to familiarize themselves with improved agricultural technologies.

Olagunju & Salimonu (2010) in their findings explained that level of formal education has a positive influence on adoption and intensity of use of agricultural technologies. Formal education here refers to classroom based teaching that is provided by trained teachers. They explained that increased level of formal education means farmers have more knowledge of input uses and their application. This will reduce input abuses which will discourage them. Chiputwa *et al*. (2011) in their study found out that education level has positive correlation with adoption and intensity of use of crop rotation. The reason is that farmers with relatively higher education are better able to use information and look out for appropriate technologies.

Access to credit has also been found to influence adoption of agricultural technologies. Beshir *et al*. (2012) opined that access to credit influences adoption positively. This is because farmers with access to credit can purchase improved agricultural technologies. Gebremichael & Gebremedhin (2014) found access to credit to positively influence intensity of use of agricultural technology because liquidity constraints are minimized.

Scholz *et al*. (2014) in their assessment of Biochar technology adoption opined that increased cost to purchase or apply the technology will discourage adoption and intensity of use. High cost of agricultural technology has always been a barrier to adoption and so influences it negatively. Zhou *et al*. (2010) in their study found cost of fertilizer to significantly and negatively influence the intensity of fertilizer use.

2.6 Profitability Analysis

Various studies have employed different methods to assess the profitability associated with soil amendments, agricultural innovations and other agricultural projects. Most commonly are the Gross margin and Net farm income. Capital budgeting techniques have also been used in some studies to assess the profitability associated with agricultural technology adoption.

Spokas *et al*. (2012) in their study reviewed literature on the analysis of Biochar profitability. The authors opined that all the costs that are associated with the entire Biochar system must be taken into consideration. Some of the costs mentioned include feedstock production, transportation to the pyrolysis unit, net energy consumption, Biochar utilization, among others. Mekuria *et al*. (2013) however assessed the economics of organic and clay-based soil amendments in small-scale agriculture in Lao PDR. The profitability of soil amendments that were assessed included Biochar, bentonite clay, compost, clay-manure compost and Biochar compost. Cost and benefits of soil amendments were determined using a cost-based value method. Profitability from soil amendments was estimated by comparing the marginal benefits with marginal costs. The results of the study indicated net revenues ranging from -794 to 841 and -331 US$ha^{-1} which were accrued due to the enhancement of maize yield by the soil amendments. The authors concluded that agricultural productivity and smallholder farmers' income can be improved using available cheap soil amendments.

Galinato *et al*. (2010) also in their study assessed the profitability of using Biochar as soil amendment as against liming the soil. Their analysis was in three stages and in respect of winter wheat production. The first stage was to estimate the profit without Biochar or agricultural lime. The second stage was to estimate profit without Biochar but with agricultural lime. The third stage was to estimate profit with Biochar but without agricultural lime. Their results showed that the profit without Biochar or agricultural lime application was $23 per acre. The profit with agricultural lime application was $146 per acre. The profit with Biochar but without agricultural lime hovered between -$10,371 and $414 per acre, depending on the carbon offset price and the price of Biochar. They however concluded that the application of Biochar can be profitable to farmers if the market price of Biochar is low enough. In their case the market price of Biochar must be less than $12.05/MT when the price of carbon offset is $1MTCO$_2$ and $100.52/MT for a carbon offset price of $31/MTCO$_2$.

Liverpool-Tasie *et al*. (2014) conducted a study on fertilizer use and profitability for rice production. They assessed the profitability of fertilizer use by estimating the marginal and average products of nitrogen for every agro ecological zone, farming system and rice potential zone. Their results indicated that the profitability of fertilizer use was influenced by the cost of fertilizer and the market price for rice. Marginal Value-Cost Ratio and Average Value-Cost Ratio values greater than 2 were considered to be a good indicator of profitability of nitrogen application for rice farming. They however concluded that fertilizer use in rice production in Nigeria has improved.

Amaza *et al.* (2008) also assessed farmer's perception, profitability and factors influencing the adoption of improved maize varieties. Their findings indicated that improved maize varieties were highly profitable with mean gross margin of €384 per hectare as against the local varieties with a mean gross margin of €204 per hectare. Relatively higher revenue was derived from the adoption of the improved maize varieties and this was attributed to higher yield levels per hectare and relatively higher market price of the improved variety. They however failed to test for the difference in the mean gross margins per hectare for both adopters and non- adopters.

Itam *et al*. (2014) analysed the determinants of cassava production and profitability in Akpabuyo, Cross River State of Nigeria. In the profitability analysis they employed the gross margin or partial budgeting approach to estimate the difference between farmers' gross income and total variable cost. Their findings indicated that cassava production was profitable as the difference between the gross income and total variable cost on per hectare basis was ₦9,520.66. The mean total revenue and mean total variable cost were ₦17,512.60 and ₦7,001.94 respectively.

Usman & Bakar (2013) also assessed the profitability of small scale tomato production using the gross margin analysis. The average revenue for tomato farmers was ₦243,580 and a gross margin of ₦138,970.46. They went on to estimate the gross and operation ratios which were 0.56 and 0.43 respectively. They also computed the return on naira invested and this was 1.33. They however concluded that tomato production was profitable given the gross margin value and computed ratios.

Nwaobiala & Ogbonna (2014) in their study assessed the adoption determinants and profitability of Okra farming. They estimated the gross margin per hectare and benefit-cost ratio to be ₦29,189 and 1.89 respectively. They concluded based on their results that okra production in the study area was profitable. However they failed to estimate separately the average per hectare gross margins for adopters and non-adopters and to test whether the difference in means was significant. The benefit-cost analysis also did not consider the time value of money.

Daniel *et al*. (2010) also assessed the net income and efficiency of resource use among cotton farmers. They estimated the average cost and returns per hectare of the farmers to be ₦46,046.25 and ₦56,224.90 respectively. Using the income analysis, the profit per hectare was ₦10,175.15. The estimated gross ratio of the farm was 0.54 and they argued that 54% of the gross income was used to cover cost. Based on the findings they concluded that cotton production in the study area was a profitable venture.

Sadiq *et al*. (2013) analysed the profitability and production efficiency of small-scale maize producers using the gross margin and net farm income analysis. They estimated the gross margin and net farm income per hectare to be ₦55,191.00 and ₦48,109.00 respectively. They also estimated the percentage profit to be 150% and concluded that maize farming was highly profitable in the study area.

Oseni & Adams (2013) assessed the profitability and costs and benefits associated with certified cocoa production. They employed in their analysis, the net present value, internal rate of return and benefit cost ratio methods. Their findings indicated an NPV of N428, 306.3, BCR of 1.04 and IRR of 31.31% for convention cocoa production using 24% interest rate. Their findings also indicated an NPV of N5, 253,237, BCR of 1.45 and IRR of 59.65% for certified cocoa production with the same interest rate. Their conclusion was that certified cocoa production was more profitable than conventional cocoa production.

2.7 Constraints in Agricultural Technology Adoption

Various agricultural technology adoption literatures indicate that constraints in adoption are largely exclusive to the type of agricultural technology being adopted. Friedrich & Kassam (2009) identified the constraints and opportunities associated with the adoption of conservation agriculture technologies. They categorised the constraints into intellectual and knowledge, social, financial, technical, and infrastructural and policy constraints. The authors asserted that these same constraints provided a justification for meeting many opportunities which enhanced change in the scheme of things.

Chowdhury & Ray (2009) also identified constraints associated with the adoption of Integrated Pest Management (IPM) technologies. They classified the constraints into socio-economic, infrastructural, situational, technological and communication, knowledge and information, and administrative and managerial. Unlike Friedrich & Kassam (2009), they ranked the constraints. Their findings indicated that lack of cosmopoliteness of growers was the most important constraint under the socio-economic category. Lack of preservation and cold-storage facilities was the most important constraint under the infrastructural category. Average distance between the fragments of the cultivated land of growers was the highest ranked among the situational constraints. Inadequate description regarding the precautious to be taken in the case of toxicity related accidents was the highest ranked among technological and communication constraints. Lack of knowledge of the respondents about the economic threshold limit was also the most important constraint in the knowledge and information category. Under the administrative and managerial category, the highest ranked constraint was lack of training of the vegetable growers on the proper use of pesticides. The authors asserted that the most pressing constraint category was knowledge and information constraints category.

Ahmad *et al*. (2007) assessed the constraints associated with adoption of high yielding crop varieties. They identified unavailability of seed and lack of latest knowledge to be the main constraints. The authors concluded that these constraints had reduced the adoption and diffusion rate of high yielding crop varieties. Their study did not show clearly the ranking given to each constraint. Just like any agricultural technology, the adoption and intensity of use of Biochar come with their own constraints. Scholz *et al*. (2014) identified financing, incremental workload, marketing, inadequate access to information, competition between different uses of residues and the complexity of the technology as the major constraints.

Duku *et al*. (2011) also asserted that technology and production costs, and feedstock availability may affect rapid adoption of the technology. Feedstock availability, Biochar handling and Biochar system deployment have also been indicated by Bracmort (2010) as constraints that may hinder the adoption of the technology. However, all the studies on constraints in the adoption of Biochar did not indicate the most important constraint by way of ranking.

2.8 Summary of Review of Literature

A number of studies have been carried out to assess both the agronomic and non-agronomic benefits of applying Biochar as soil amendment. It is apparent that the application of Biochar as soil amendment can improve the fertility of poor agricultural soils. There is some evidence to the fact that Biochar production and application is a profitable venture. Relatively cheap farm-based energy is one of the non-agronomic benefits associated with the use of Biochar in farming.

Many factors have been identified to influence adoption and intensity of adoption of agricultural technologies. Age, farm size, household size, experience, gender, farm income, off-farm income and cost of technology are socio-economic factors that can influence adoption and intensity of use of agricultural technologies. Access to extension service and credit are institutional factors that can also influence the adoption and intensity of use of agricultural technologies. The findings of majority of the studies looked at, point to the fact that the direction of influence is exclusive to a particular technology.

Gross margin and net farm income analysis have been used extensively by many authors to assess the profitability of agricultural projects. Many adoption studies try to estimate the gross margin and net farm income for both adopters and non-adopters of agricultural production technologies and then proceed to compare them. The capital budgeting techniques have also been used to assess the profitability associated with the adoption of agricultural production technologies. Discounted cash flow methods like NPV, BCR and IRR are mostly preferred because they ensure time value of money. There are a number of constraints associated with the use of Biochar in farming. Some of the constraints are the incremental workload, feedstock availability, competition between different uses of residue and inadequate access to information.

CHAPTER THREE: METHODOLOGY

3.1 Introduction

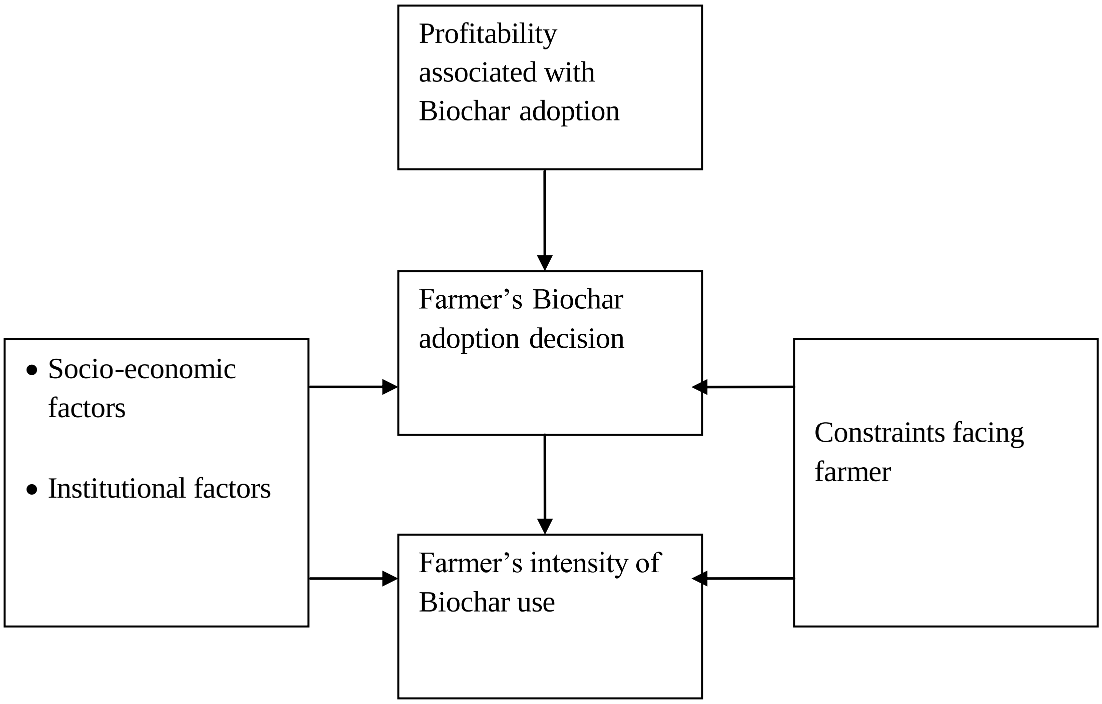
The methodology for this study encompasses the conceptual and theoretical frameworks, method of data analysis and method of data collection.

3.2 Conceptual Framework of the Study

The adoption of any agricultural technology is an investment opportunity. Therefore it is very important for the profitability associated with the use of the technology to be assessed. Gross margin and net farm income (Amaza *et al.*, 2008; Nwaobiala & Ogbonna, 2014) must be assessed because they will change if a farmer decides to adopt an agricultural technology.

The Biochar technology introduced to the farmers in the Eastern Region in 2011, just like any other agricultural technology, will come with some associated costs and benefits. Therefore farmers' decision to adopt the technology will be influenced by how their farm profitability (Hyuha *et al*., 2011; Itam *et al*., 2014) are impacted by the adoption of the technology. Figure 3.1 illustrates the important linkages needed to appreciate the factors affecting Biochar technology adoption by farmers in the Kwahu East district of Ghana.

Figure3.1 : Conceptual Framework of the Study



Source: Author's own conceptualization of the study

The intensity of adoption of agricultural technology (Chiputwa *et al.*, 2011; Mignouna *et al.*, 2011; Beshir, 2014) will always come on the back of the adoption of the technology. Farmers must first of all decide to use the technology before they can decide on the extent of use. A particular farmer may decide to go ahead and adopt a particular agricultural production technology after being introduced to it. However the proportion of farm land that will be dedicated by the farmer for crop production using the said production technology is another hurdle for the farmer. Some of them may be very cautious in allocating a large portion of their farm land for such a production technology. This may be due to technological risk and uncertainty (Lee *et al.*, 1980) and the farmer's own attitude towards risk (Fakayode *et al.*, 2012; Kouame & Komenan, 2012) in farm business. The intensity of Biochar technology adoption therefore depends on farmers' adoption decisions.

Farmers' technology adoption decisions and intensity of adoption are both affected by a number of socio-economic and institutional factors (Beshir *et al.*, 2012;

Gebremichael & Gebremedhin, 2014; Yu & Nin- Pratt, 2014). The socio-economic factors include age of farmer, farm size, household size, marital status, farmer's experience in farming, gender of farmer, annual farm income, farmer's educational level, cost of technology, and off-farm income. The institutional factors include access to credit and access to extension services. The probability of a farmer adopting the Biochar technology and his or her intensity of application will depend on these factors. However the findings of several adoption studies have indicated that the direction of effect of a particular independent variable largely depends on the type of agricultural technology being studied. Some authors (Fernandez-Cornejo *et al*., 2001; Chiputwa *et al*, 2011) assume that the same factors affect both adoption and intensity of adoption. Others (Mignouna *et al*., 2011; Barungi *et al*., 2013) have also analysed each hurdle separately.

The farming sector is bedevilled with many constraints. Lack of a reliable market; hikes in cost of production inputs; low access to credit; pest and diseases, inadequate storage facilities, lack of an appropriate farm machinery, inadequate irrigation and inadequate access to extension and advisory services are some of the major constraints in farming. The adoption of agricultural technologies is also associated with many constraints (Ahmad *et al*., 2007; Chowdhury & Ray, 2009; Friedrich & Kassam, 2009). These constraints influence farmers' decision to either adopt or not to adopt. Even after farmers have decided to adopt the technology that has probably been introduced to them, the intensity of use of the technology also has its associated constraints. Some of the constraints in Biochar technology adoption are the associated increased workload, health issues, competing use of farm residues, access to information, cost of Biochar use, government policies, access to market and complexity of the Biochar system (Duku *et al*., 2011; Scholz *et al*., 2014). The rapid adoption of the Biochar technology introduced to the farmers in 2011 will be influenced by these constraints that the farmers face.

3.3 Theoretical Framework of the Study

The theories that are of relevance to the study are critically examined in this section. Adoption, profitability and constraint models are looked at.

3.3.1 The High-payoff Input Model

Several theories have been suggested for explaining the process of agricultural development. Frontier, Conservation, Urban-industrial impact, Diffusion, High-payoff input and the Induced-innovation models have been discussed by Ruttan (1977) as behind the process of agricultural development. However the model of primary concern to this study is the High-payoff input model. The High- payoff input model (Schultz, 1964) surfaced in the 1960s due to the lack of efficiency of policies that were developed based on the conservation, urban industrial impact and the diffusion models. Per the model, traditional agricultural development can only take place when high-payoff inputs are made available to less endowed farmers.

Peasant farmers were generally seen as rational and efficient resource allocators who were only poor because limited technical and economic opportunities were beyond their reach. The high-payoff inputs were categorized into; the ability of both public and private sector research institutions to develop new technical knowledge, the ability of industry to develop, produce and market new technical inputs, and the capacity of farmers to acquire new knowledge and to effectively make use of the inputs (Ruttan, 1977). Ruttan (1977) also suggested that the model emphasises the speeding up of the agricultural development process propagation of new technologies through public investment in research and education. Hayami & Ruttan(1985) proposed the Induced-innovation theory as a modification of the High-payoff theory.

3.3.2 Utility Maximization Theory

The farmer, just like any other investor can be assumed to be risk averse. Therefore the farmer has a quadratic utility function. He or she maximizes expected utility defined over wealth (Von Neumann & Morgenstern, 1947) and under uncertainty. The estimation of the expected utility can be used to determine the farmers' choice under uncertainty.

Following Dobbins *et al*. (1994):

$$U(W) = \alpha + \beta W - \gamma W^2 \qquad (1)$$

Where U and W denote Utility and Wealth respectively, β and γ are arbitrary constant terms which vary for individual farmers, with $\beta > 0$ and $\gamma > 0$. The expectation operator, E is applied to equation 1 to give:

$$E[U(W)] = \alpha + \beta E(W) - \gamma E(W^2) \qquad (2)$$

Also, $V(W) = E(W^2) - [E(W)]^2$ (3)

Where V denotes variance and equation 3 can be rewritten as;

$$E[U(W)] = \alpha + \beta E(W) - \gamma [E(W)]^2 - \gamma V(W) \qquad (4)$$

The use of quadratic utility functions allows for the specification of the expected utility of a choice or decision in terms of the mean and variance of the outcome with the assumption of risk-aversion (Lee *et al*., 1980). It is worth noting that for the farmer to choose a modern technology over the traditional, an incremental utility must always exist. The expected utility from the modern technology must be greater than the expected utility from the traditional technology.

3.3.3 Adoption and Intensity of Adoption Models

Since farmers' decision on whether to adopt a new technology or otherwise can be said to be of a binary nature (Baffoe-Asare *et al.*, 2013), qualitative response regression models can best be used to analyse such decisions. Probit and logit regression models are preferred over the linear probability model when analysing farmers' adoption decisions. This is because the linear probability model is very susceptible to heteroskedasticity and therefore not able to fit the predicted values between 0 and 1, which gives way to unrealistic values (Stock & Watson, 2007). The two models are only different in the type of distribution used. The Probit model uses the standard normal distribution while the Logit model uses the standard logistic distribution. Stock & Watson (2007) specify the probit model as:

$$\Pr(Y = 1/\, X_1, X_2, \dots, X_k) = \Phi(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k) \qquad (5)$$

Where Y which is the dependent variable is binary and Φ is the cumulative standard normal distribution function. $X_1, X_2,$ etc., are the regressors. $\beta_0 \beta_1, etc.,$ are the coefficients to be estimated. The logit model is also specified by Stock & Watson (2007) as:

$$\Pr(Y = 1/\, X_1, X_2, \dots, X_k) = F(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k) \qquad (6)$$

$$= \frac{1}{1+e^{-(\beta_0+\beta_1 X_1+\beta_2 X_2+\cdots+\beta_k X_k)}}$$

Where Y which is the dependent variable is binary and F is the cumulative standard logistic distribution function. X_1, X_2, etc., are the regressors. $\beta_0\beta_1, etc.$, are the coefficients to be estimated. The coefficients of the two models are estimated using the maximum likelihood method and this is preferred over the Ordinary Least Square (OLS) estimator. The log likelihood function for the probit model is given as:

$$In[f_{probit}(\beta_o, \dots, \beta_k; Y_1, \dots, Y_n | X_{1i}, \dots, X_{ki}, i = 1, \dots, n)]$$

$$= \sum_{i=1}^{n} Y_i \, In[\Phi(\beta_o + \beta_1 X_{1i} + \cdots + \beta_k X_{ki})]$$

$$+ \sum_{i=1}^{n} (1 - Y_i) \, In[1 - \Phi(\beta_o + \beta_1 X_{1i} + \cdots + \beta_k X_{ki})] \qquad (7)$$

The maximum likelihood estimator maximizes the log likelihood function to obtain values for the parameters. The log likelihood function of the logit model is analogous to that of the probit above. Only that $\Phi(\beta_o + \beta_1 X_{1i} + \cdots + \beta_k X_{ki})$ is replaced with $[1 + e^{-(\beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki})}]^{-1}$.The Logit model is preferred over the Probit because of its comparative mathematical simplicity (Gujarati, 1992).

Farmers' adoption decisions and intensity of adoption can be analysed separately or jointly using the Tobit or the Double hurdle models. The tobit model is used when the underlying assumption is that the same factors affect both the decision to adopt and intensity of adoption.

The tobit model developed by James Tobin has been explained by Maddala (2001). From the logit and probit models, a latent variable (which cannot be observed) y_i^* exists and a regression model can be specified as;

$$y_i^* = \beta x_i + u_i \qquad (8)$$

A dummy variable is observed in the logit and probit models with the assumption that there is only one explanatory variable.

$$.y_i^* = \begin{cases} 1 & if \quad y_i^* > 0 \\ 0 & if \quad y_i^* \leq 0 \end{cases}$$

Suppose, that y_i^* is observed if $y_i^* > 0$ and is not observed if $y_i^* \leq 0$, then the observed y_i will be expressed as;

$$y_i = \begin{cases} y_i^* = \beta x_i + u_i \; if \quad y_i^* > 0 \\ 0 \qquad\qquad\quad if \quad y_i^* \leq 0 \end{cases} \tag{9}$$

$$u_i \sim IN(0, \sigma^2)$$

The tobit model (Tobin's probit) is also called the censored normal regression model because some of the observations are censored. That is we are not allowed to see those for which $y_i^* \leq 0$. The β and σ parameters are what must be estimated.

The double-hurdle model (Cragg, 1971) is generally preferred when analysing separately, factors affecting adoption and intensity of adoption. It is a combination of the probit and truncated regression models under the assumption of independence between the error terms. Following Beshir *et al.* (2012), the model has an adoption (D) decision with an equation:

$$D_i = 1 \ldots if \ldots . D_i^* > 0 \ldots .. and$$

$$D_i = 0 \ldots .. if \ldots D_i^* \leq 0 \tag{10}$$

$$D_i^* = \alpha' Z_i + U_i$$

Where D_i^* is a latent (unobserved) variable that assumes a value of 1 if a farmer adopts the agricultural technology and 0 otherwise; Z is a vector of explanatory variables and α is also a vector of parameters. The intensity of adoption (Y) decision equation is also given as:

$$Y_i = Y_i^* \dots if \dots Y_i^* > 0 \; and D_i^* > 0$$

$$Y_i = 0 \dots otherwise \qquad (11)$$

$$Y_i^* = \beta' X_i + V_i$$

Where Y_i^* is the observed amount of technology used; X_i is a vector of explanatory variables affecting the intensity of use; and β is a vector of parameter. The log-likelihood (LL) function for the double-hurdle model is given as;

$$Log\ L = \sum_{0} In\left[1 - \Phi(\alpha Z_i')\left(\frac{\beta X_i'}{\sigma}\right)\right] + \sum_{+} In\left[\Phi(\alpha Z_i')\frac{1}{\sigma}\varphi\left(\frac{Y_i - \beta X_i'}{\sigma}\right)\right] \quad (12)$$

The zero (0) means summation over the zero observations and the positive (+) sign also means summation over the positive observations. $\Phi(.)$ is the standard normal cumulative distribution functions and $\varphi(.)$ is also the probability distribution functions (Gebremichael & Gebremedhin,2014). The error terms U_i and V_i are assumed to be independent.

3.3.4 Models for Profitability Analysis

Farmers' decisions to adopt any agricultural technology and their intensity of adoption are themselves investment decisions. Both gross margin and net farm income are models that can be used to assess whether the adoption of any agricultural technology is profitable or not. Gross margin as explained by Barnard & Nix (1973) refers to the farm revenue minus the variable costs attributed to it. The net farm income is its gross margin less the total fixed costs.

The net farm income is given as:

$$NFI = GM - TFC, where$$

$$GM = Gross\ margin$$

$$TFC = Total\ fixed\ cost$$

Where the gross margin is also given as:

$$GM = GI - TVC, where$$

$$GM = Gross\ margin$$

$$GI = Gross\ income$$

$$TVC = Total\ variable\ cost$$

3.3.5 Models for Constraint Analysis

In identifying and ranking the constraints faced by farmers, two methods can be used. These are the Kendall's concordance analysis and the Garrett ranking technique. When applying the Kendall method, the respondents are first presented with the various constraints for them to rank according to order of importance. The agreement (concordance) among the rankings is then tested using the Kendall's concordance analysis. The Kendall's Coefficient of Concordance (W) is an index which measures the degree of concordance or agreement among m (respondents) sets of n ranks (constraints). It measures the ratio of observed variance of sum of ranks to the maximum possible variance of sum of ranks. The reason for this index is to determine the sum of the ranks for every constraint being ranked and then go ahead to examine the variability of this sum. Once the rankings are in perfect concordance, the variability among these sums will be a maximum (Legendre, 2005).

W is limited between 1 and 0 and must always be non-negative (≥ 0). It takes 1 when ranks given by every judge is same as those given by other judges. It takes 0 for maximum disagreement among judges. The total rank score is calculated for each constraint and then used to compute the W. The constraint with least score is usually the most important one. The coefficient of concordance W is given as:

$$W = \frac{(\sum T^2 - (\sum T)^2/n)/n}{m^2(n^2-1)/12} \qquad (13)$$

This is further simplified as:

$$W = \frac{12[\sum T^2 - (\sum T)^2/n]}{nm^2(n^2-1)} \qquad (14)$$

Where:

T= sum of ranks for each constraint being ranked

m = number of respondents doing the rankings

n = number of constraints being ranked

After estimating W, it is tested for significance using the F distribution

H_0: There is no agreement among the respondents with respect to ranking of the constraints

H_1: There is agreement among the respondents with respect to ranking of the constraints

The Garret ranking technique (Sedaghat, 2011) is relatively simple to use in ranking the constraints faced by farmers. Respondents (farmers) are given common constraints to rank according to order of importance. The ranks are then converted into percent positions. The percent position of each rank is given as:

$$\frac{100(R_{ij} - 0.5)}{N_j} \tag{15}$$

Where:

R_{ij}= rank given for the ith constraint by the jth respondent

N_j= number of factors ranked by the jth respondent

The percent position of each rank is then converted into scores using the Garret and Woodworth (1973) table. The mean scores are then estimated for each constraint and arranged in decreasing order of magnitude.

3.4 Method of Data Analysis

The net farm income analysis was employed to estimate the profitability associated with Biochar adoption. The net farm income is estimated as:

$$NFI = GM - TFC$$

$$Where:$$

$$GM = GI - TVC$$

$$GM = Gross\ margin$$

$$GI = Gross\ income$$

$$TVC = Total\ variable\ cost$$

$$TFC = Total\ fixed\ cost$$

The components of the variable cost are planting material, fertilizer, agrochemicals, Biochar, labour cost, transportation and maintenance. The fixed cost consists of depreciation of equipment. Interest on operating costs, and rental value of farmland were not included in the analysis. However in the depreciation estimation, the straight line method was considered. This method is relatively simpler and has been employed in several studies (Yusuf & Malomo, 2007; Ike & Ugwumba, 2011; Nwaobiala & Ogbonna, 2014) for the analysis of profitability. This is given as:

$$Depreciation = \frac{[\,Cost - Residual\ value]}{[Useful\ life]}$$

The double-hurdle model was also employed to achieve both objectives 2 and 3. This is preferred over the other variants since it allows for both decision hurdles (adoption and intensity of adoption) to be analysed separately. Factors that are likely to affect farmers' decision to use Biochar may not necessarily affect the intensity of use of Biochar as soil amendment. Data collected for the 2011 and 2012 seasons were first of all analysed separately.

For the first hurdle, which is the decision of farmers to adopt Biochar or otherwise, the empirical specification of the probit model is given as:

$$\Pr(Y = 1) = \beta_0 + \beta_1 FSIZE + \beta_2 GENDER + \beta_3 AGE + \beta_4 AGESQUARED + \beta_5 EDUC + \beta_6 MSMARRIED + \beta_7 FBO + \beta_8 OUTPUT + \beta_9 CREDIT + \beta_{10} EXTVISIT + \beta_{11} NONFARMJOB + \beta_{12} FPART + U_i$$

Where:

$\Pr(Y = 1)$= Probability that a farmer will use Biochar in farming

$\beta_1 - \beta_{12}$= Coefficients of explanatory variables

β_0= Constant term

U_i= error term

For the second hurdle, the empirical specification is given as:

$$\text{Y} = \beta_0 + \beta_1 FSIZE + \beta_2 GENDER + \beta_3 AGE + \beta_4 AGESQUARED + \beta_5 EDUC + \beta_6 MSMARRIED + \beta_7 FBO + \beta_8 OUTPUT + \beta_9 CREDIT + \beta_{10} EXTVISIT + \beta_{11} NONFARMJOB + \beta_{12}\, FPART + U_i$$

Where:

Y= the dependent variable (Proportion of farm area under Biochar to total farm area)

$\beta_1 - \beta_{12}$= Coefficients of explanatory variables

β_0= Constant term

U_i= error term

The two samples (2011 and 2012) were then pooled together and then analysed. For the pooled sample, the first hurdle (probit) which is also the decision of farmers to adopt Biochar is specified empirically as:

$$\Pr(Y = 1) = \beta_0 + \beta_1 FSIZE + \beta_2 GENDER + \beta_3 AGE + \beta_4 AGESQUARED + \beta_5 EDUC + \beta_6 MSMARRIED + \beta_7 FBO + \beta_8 OUTPUT + \beta_9 CREDIT + \beta_{10} EXTVISIT + \beta_{11} NONFARMJOB + \beta_{12} FPART + \beta_{13} SEASON + U_i$$

Where:

$\Pr(Y = 1)$= Probability that a farmer will use Biochar in farming

$\beta_1 - \beta_{13}$= Coefficients of explanatory variables

β_0= Constant term

U_i= error term

For the second hurdle, the empirical specification is given as:

$$Y = \beta_0 + \beta_1 FSIZE + \beta_2 GENDER + \beta_3 AGE + \beta_4 AGESQUARED + \beta_5 EDUC + \beta_6 MSMARRIED + \beta_7 FBO + \beta_8 OUTPUT + \beta_9 CREDIT + \beta_{10} EXTVISIT + \beta_{11} NONFARMJOB + \beta_{12} FPART + \beta_{13} SEASON + U_i$$

Where:

Y= the dependent variable (Proportion of farm area under Biochar to total farm area)

$\beta_1 - \beta_{13}$= Coefficients of explanatory variables

β_0= Constant term

U_i= error term

3.4.1 Description of Variables used in the Double-hurdle Model

Several variables have been hypothesized to influence farmers' decision to adopt Biochar and the intensity of use of Biochar as soil amendment. The direction of effect is hypothesized to be positive, negative or ambiguous. Table 3.1 presents the description of the regression variables.

Table 3.1: Description of Regression Variables, Measurement and Expected signs

Variables	Description	Measurement	Expected sign
FSIZE	Farm size	Acres	+/-
GENDER	Gender of farmer	Dummy (1=male; 0= otherwise)	+/-
AGE	Age of farmer	Years	+/-
AGESQUARED	Age of farmer squared	Years	+/-
EDUC	Educational level	Dummy (1=JHS, 0=otherwise)	+
MSMARRIED	Marital status	Dummy (1=married, 0=otherwise)	+
FBO	FBO membership	Dummy (1= member of Nsonyameye FBO; 0= otherwise)	+
OUTPUT	Output of farmer	Number of boxes(5.5kg)	+
CREDIT	Access to credit	Dummy (1=Yes, 0=otherwise)	+
EXTVISIT	Extension visits	Number	+
NONFARMJOB	Source of off- farm income	Dummy (1= non- farm job; 0= otherwise)	+
FPART	Forum participation	Dummy (1= Yes; 0= otherwise)	+
SEASON	Farming season	Dummy (1=2012, 0=otherwise)	+/-

3.4.2 Hypotheses Testing

The main hypotheses of the study are presented. These include the main hypothesis of the regression analysis and that of the profitability analysis. The decision rule of each of the hypotheses is also given.

3.4.3 Main Hypothesis of the Regression Analysis

$H_0 : \beta_i = 0$

$H_A : \beta_i \neq 0$

Null hypothesis (H_0): The explanatory variables individually have no significant effect on the adoption and intensity of Biochar use

Alternative hypothesis (H_A): The explanatory variables individually have significant effect on the adoption and intensity of Biochar use

3.4.4 Main Hypothesis of the Profitability Analysis

Null hypothesis: The difference between the average per acre NFIs of adopters of Biochar and non-adopters of Biochar in each of the communities is not statistically significant

Alternative hypothesis: The difference between the average per acre NFIs of adopters of Biochar and non-adopters of Biochar in each of the communities is statistically significant

3.4.5 Validation of Hypotheses

The z-test is employed to validate the main hypothesis of the regression analysis. For individual hypothesis, the z-statistic is computed as

$$Z_{stat} = \frac{\beta_i}{SE(\beta_i)}$$

If the z- statistic is greater that the critical value or significant at 1%, 5% or 10%, then we reject the null hypothesis. Otherwise we do not reject the null hypothesis.

The t-test is also employed to test whether the difference in the average per acre NFI of adopters and non-adopters in each of the communities is significant or not. If the T-statistic is also greater than the critical value at 1%, 5% or 10%, then we reject the null hypothesis. Otherwise we do not reject the null hypothesis.

In performing the constraints analysis, the Garret ranking technique was employed. Farmers were given common constraints to rank according to order of significance. The rank assigned to each constraint was then converted into percent position. The percent position of each rank is given as: $\frac{100(R_{ij}-0.5)}{N_j}$

Where:

R_{ij}= rank given for the ith constraint by the jth respondent

N_j= number of factors ranked by the jth respondent

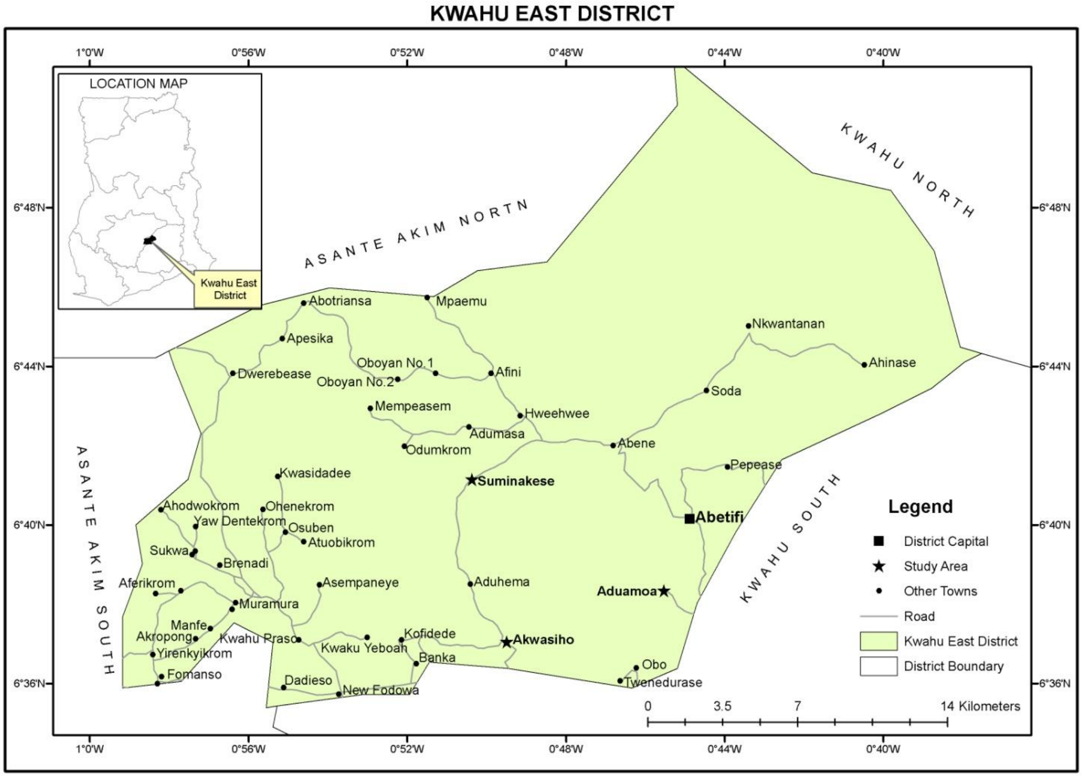
The percent position of each rank was then converted into scores using the Garret and Woodworth (1973) table. The mean scores were then estimated for each constraint and arranged in decreasing order of magnitude.

3.5 The Study Area

The geographical area of study is the Kwahu East district located in the Eastern Region of Ghana. The Kwahu East district covers areas like Aduamoa, Akwasiho, Abetifi, Pepease, Nkwatia, Tafo, Nteso, Kotoso, Abene, Hweehwee and Suminakese. The area occupies about 860 square kilometres of land (MOFA, 2014). The area lies within the Semi-Deciduous forest zone with annual average rainfall between 1580mm and 1780mm. Cash and food crops such as cocoa, coffee, plantain, cassava, yam and vegetables (which include pepper and tomato) are mostly cultivated in the area (MOFA, 2014).

Soils in the area belong to the Forest Ochrosols group. These soils are deeply weathered and their profiles show some appreciable amount of clay accumulation in the subsoil. The soils are red, brown and yellow-brown in colour and well to imperfectly drained. The topsoil is concentrated with some amount of organic matter with strongly leached lower horizons (Obeng, 2000). The texture of the soils varies but the structure is moderate fine granular and friable in consistency. The soils are slightly to moderately acidic in the topsoil with pH normally between 6.5 to 5.1 in 1:1 soil: water ratio (Adjei-Gyapong & Asiamah, 2002). The soils are also less endowed in terms of nutrient level, especially nitrogen and phosphorus. They however quickly respond to soil amendments usually when allowed to fallow for sometime (Adjei-Gyapong & Asiamah, 2002).

Figure 3.2: Map Showing Position of the Study Area



Source: Survey Department of Ghana (2015)

3.6 Method of Data Collection

A Biochar pilot study was carried out in 2011 in the region by ADRA Ghana, Millennium Development Authority (MiDA) and Crop Research Institute that involved vegetable farmers. Farmers were given training on how to locally produce and use Biochar to amend poor soils, using cheap and readily available agricultural crop residues. The Biochar used by the farmers was produced from cocoa pod husk, rice husk, maize residue, among other agricultural crop residues. Given that the soil type of the area is very susceptible to acidity, Biochar was introduced to raise the pH of the soil to an appreciable level. It is very effective for controlling soil acidity, thereby increasing nutrient availability and crop productivity in the study area.

Primary data was collected from vegetable farmers over the 2011 and 2012 seasons using a well structured questionnaire. The purposive sampling technique was used to select the communities (Aduamoa, Akwasiho and Suminakese) within the Kwahu East District where Biochar was introduced in 2011. Respondents were subsequently selected at random yielding a sample size of 156 farmers and 89 farmers in 2011 and 2012 respectively. Vegetable farmers studied in 2012 were included in the 2011 sample. The respondents included piloted farmers, farmers who adopted later and non-adopting farmers.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results and discussions of the study. It presents a discussion on the socio-economic characteristics of farmers, profitability associated with Biochar use, adoption and intensity of use of Biochar. The results and discussion on constraints facing farmers are also presented in the chapter.

4.2 Socio-economic Characteristics of Farmers

Table 4.1 presents a distribution of age, number of extension visits, farm size and output of respondents in both 2011 and 2012 seasons. The total numbers of respondents for both 2011 and 2012 seasons were 156 and 89 respectively.

Table 4.1: Descriptive Statistics of Socio-economic Characteristics of Farmers

	2011 season (Total=156 farmers)				**2012 season (Total= 89 farmers)**			
Category	**Min**	**Max**	**Mean**	**Std. dev**	**Min**	**Max**	**Mean**	**Std. dev**
Age	23	76	49.06	11.94	24	77	49.20	11.15
Extension visits	0	20	3.96	3.25	0	20	4.34	4.21
Farm size (acres)	0.25	5	1.07	0.76	0.25	5	1.26	0.93
Output (5.5kg boxes)	12	2700	512.65	476.42	24	3500	725.56	647.94

Source: Computation from survey data, 2015

The average age of farmers was approximately 49 years in both 2011 and 2012 seasons. This corroborates the opinion held by Akudugu *et al*. (2012) that majority of farmers are within the economically active group of the country. The average number of extension visits received by vegetable farmers was approximately 4 in both years. This means that on the average, farmers had approximately 4 times extension services or visits for both seasons. The overall extension support offered to farmers to reduce the risk of adopting agricultural production technologies is inadequate and this is consistent with the findings of Baffoe-Asare *et al*. (2013).

The average farm size of farmers was 1.07 acres in 2011 and 1.26 acres in the 2012 season. Non-mechanized farming of vegetables is a very arduous venture and therefore most farmers shy away from cultivating on a large scale. Farmers usually devote just a small portion of their total land for vegetable production and use the rest for other farming activities (Ayuya *et al*., 2012). The average amount of produce in the 2011 season was 512.65 boxes and 725.56 boxes in the 2012 season. This means that on the average, farmers did better in terms of output in 2012 than in 2011.

4.3 Cross- tabulation of Adopters and Non- adopters with other Socioeconomic Characteristics of Farmers

Table 4.2 presents a summary of the frequencies and percentages of other socioeconomic characteristics of farmers. The distribution of gender, marital status, Farmer Based Organization (FBO) membership, distribution of farmers within the FBOs and educational level are cross-tabulated with adoption of Biochar and non-adoption of Biochar. Access to credit, access to off-farm income, source of off-farm income and the land tenure of farmers are also cross-tabulated with adoption and non-adoption of Biochar.

Table 4.2: Summary of Frequencies and Percentages of Other Socioeconomic Characteristics of Respondents

	2011 season				2012 season			
	Adopters		Non- adopters		Adopters		Non- adopters	
Category	**Freq.**	**Per.**	**Freq.**	**Per.**	**Freq.**	**Per.**	**Freq.**	**Per.**
Gender								
Male	23	46.94	44	41.12	7	50.00	33	44.00
Female	26	53.06	63	58.88	7	50.00	42	56.00
Marital status								
Single	6	12.24	11	10.28	1	7.14	5	6.67
Married	33	67.35	81	75.70	12	85.71	60	80.00
Widowed	7	14.29	7	6.54	1	7.14	2	2.67
Divorced	3	6.12	8	7.48	0	0.00	8	10.67
FBO membership								
Yes	47	95.92	83	77.57	12	85.71	55	73.33
No	2	4.08	24	22.43	2	14.29	20	26.67
Name of FBO								
Nsonyameye	30	61.22	13	12.15	2	14.29	2	2.67
Adom	2	4.08	14	13.08	1	7.14	13	17.33
Nyame Akwan	5	10.20	10	9.35	2	14.29	6	8.00
Nyamebekyere	2	4.08	19	17.76	1	7.14	13	17.33
Blessing	8	16.33	24	22.43	6	42.86	19	25.33
Perseverance	0	0.00	1	0.93	0	0.00	1	1.33
SVGA	0	0.00	2	1.87	0	0.00	1	1.33
Educational level								
Primary	4	8.16	16	14.95	1	7.14	10	13.33
JHS/JSS	31	63.27	69	64.49	9	64.29	49	65.33
SHS/SSS	5	10.20	4	3.74	2	14.29	5	6.67
Tertiary	4	8.16	6	5.61	2	14.29	5	6.67
None	5	10.20	12	11.21	0	0.00	6	8.00
Access to credit								
Yes	18	36.73	34	31.78	5	35.71	19	25.33
No	31	63.27	73	68.22	9	64.29	56	74.67
Access to off-farm income								
Yes	36	73.47	65	60.75	8	57.14	42	56.00
No	13	26.53	42	39.25	6	42.86	33	44.00
Source of off-farm income								
Non-farm job	28	57.14	51	47.66	8	57.14	32	42.67
Remittance	6	12.24	12	11.21	0	0.00	7	9.33
Both	2	4.08	2	1.87	0	0.00	3	4.00
Land tenure								
Inherited	18	36.73	39	36.45	6	42.86	28	37.33
Outright purchase	11	22.45	9	8.41	0	0.00	2	2.67
Lease	20	40.82	58	54.21	8	57.14	45	60.00
Share cropping	0	0.00	1	0.93	0	0.00	0	0.00

Source: Computation from survey data, 2015

For both adopters and non-adopters in 2011, females happened to be more than males. Female adopters constituted 53.06% as against male adopters who constituted 46.94%. Male and female non-adopters were 41.12% and 58.88% respectively. For the 2012 season, male and female adopters were 50 % each. The non-adopters were made up of 44% and 56% males and females respectively. This means that the overall findings of the study represent fairly the views of both male and female farmers (Akudugu *et al*., 2012).

The distribution of the marital status of farmers' means that majority of them were married. For the adopter group in 2011, about 67.35% were married and about 85.71% were married in the 2012 season. For the non-adopter group, about 75.70% were married in the 2011 season and about 80% of them were married in the 2012 season. The rest of the farmers were single, widowed or divorced. It is very typical of farmers to be married in most typical farming communities in the country and this is corroborated by the findings of Martey *et al*. (2013).

The distribution of the FBO membership category indicates that 95.92% of adopters in 2011 were members and 4.08% of adopters were not members of any FBO. About 77.57% of non-adopters in 2011 were member of an FBO whilst 22.43% of non-adopters were not members of any FBO. About 85.71% of farmers who were adopters in 2012 were members of an FBO whilst 14.29% of them were not members of any FBO. Also 73.33% of farmers who were non-adopters in 2012 were members of an FBO whilst 26.67% of them were not members of any FBO. The FBOs included Nsonyameye , Adom, Nyame Akwan , Nyamebekyere, Blessing, Perseverance and SVGA.

For the 2011 season, 8.16% of farmers who adopted Biochar had primary education. About 63.27% had education up to the JHS/JSS level. About 10.20% had education up to the SHS/SSS level. About 8.16% had education up to the tertiary level and 10.20% had no formal education. Out of the total number of farmers who did not adopt Biochar in 2011, 14.95% had education up to the primary level. About 64.49% had education up to the JHS/JSS level. About 3.74% had education up to the SHS/SSS level. About 5.61% had education up to the tertiary level and 11.21% had no formal education.

For the 2012 season, 7.14% of adopters had formal education up to the primary level. About 64.29% had education up to the JHS/JSS level. Those who had education up to the SHS/SSS and tertiary levels formed 14.29% each. There was no farmer in the adopter group without some level of formal education. Out of the total number of farmers who did not adopt Biochar in 2012, 13.33% had education up to the primary level. About 65.33% had education up to the JHS/JSS level. About 6.67% had education up to the SHS/SSS and tertiary levels each. About 8% of the non-adopters had no formal education. This indicates that very few farmers had access to post-basic education and this is consistent with the findings of Kuwornu *et al*. (2013). Members with higher level of education usually seek employment in the non-farming sector.

Out of the number of Biochar technology adopters in 2011, 36.73% had access to credit whilst 63.27% had no access to credit. From the total number of farmers who did not adopt Biochar in 2011, 31.78% had access to credit whilst 68.22% had no access to credit. Out of the total number of farmers who adopted Biochar in 2012, 35.71% had access to credit whilst 64.29% had no access to credit. Out of the number that did not adopt Biochar in 2012, about 25.33% had access to credit whilst 74.67% had no access to credit. This means that most farmers in the study area had limited access to credit and this is consistent with the assertions of Amaza *et al*. (2008). Many credit institutions in the study area do not want to supply farm credit to the farmers.

With respect to access to off-farm income, 73.47% of adopters had access whilst 26.53% of adopters had no access in 2011. For the 2011 season non- adopter group, 60.75% had access to off-farm income whilst 39.25% had no access. About 57.14% and 42.86% of adopters had access and no access respectively in 2012. In that same season, 56% and 44% of non-adopters had access to off-farm income and no access to off-farm income respectively. Farmers who had access to off-farm income did so from various sources. The sources from which farmers had access to off-farm income included non-farm job, remittance or both non-farm job and remittance.

Land was acquired by farmers through inheritance, outright purchase, by means of lease and by means of share cropping. For the 2011 season, 36.73% of adopters acquired their farm lands through inheritance. About 22.45% of adopters purchased their lands. About 40.82% of them acquired their lands by means of lease and no farmer from the adopter group acquired their lands by means of share cropping. Out of the total number of farmers who did not adopt Biochar in that same year, 36.45% acquired their lands by means of inheritance. About 8.41% of the non-adopters purchased their farm lands. About 54.21% of them acquired their lands by means of lease and 0.93% acquired their lands by means of share cropping.

For the 2012 season, 42.86% of the adopters inherited their farm lands. About 57.14% of them acquired their farm lands by means of lease. No farmer from the adopters purchased their lands or acquired their lands by means of share cropping. About 37.33% of farmers who did not adopt Biochar in 2012 inherited their farm lands. About 2.67% of them purchased their lands and 60% acquired their lands by means of lease. No farmer from the non-adopter group acquired their lands through share cropping. Majority of farmers acquired their farmland through lease and this is typical of farmers in the study area. The findings of Usman & Bakar (2013) confirm this assertion.

4.4 Adoption of other Farm Technologies apart from Biochar

All the farmers interviewed indicated that they have used other farm technologies apart from Biochar. They indicated that they have adopted either one or a combination of such farm technologies including Soil conservation practice, Integrated Pest Management (IPM) or improved seed. They were introduced to these technologies by extension agents, other farmers or the Biochar project implementers, prior to the introduction of Biochar.

4.5 Awareness and Participation in the 2011 Biochar Demonstration Forum

Out of the 156 farmers interviewed, 70.5% said they heard of the Biochar demonstration forum in 2011. The farmers indicated they became aware of the technology through extension agents, other farmers and the project implementers. Vegetable farmers were introduced to Biochar use as soil amendment. They were also given training on how to produce their own Biochar and use it to condition agricultural soils. About 29.5% of the respondents said they did not hear of the Biochar demonstration forum. About 57.1% of the farmers interviewed said they indeed participated in the demonstration forum or attended the training in 2011 whilst 42.9% said they did not participate in the forum. Table 4.3 presents the frequencies and percentages of farmers' awareness and participation in the 2011 Biochar demonstration forum.

Table 4.3: Frequencies and Percentages of Farmers' Awareness and Participation in the 2011 Biochar Demonstration Forum

		Frequency	Percent
Awareness of Biochar demonstration forum			
	Yes	110	70.5
	No	46	29.5
Participation in the Biochar demonstration forum			
	Yes	89	57.1
	No	67	42.9

Source: Computation from survey data, 2015

4.6 Adoption of Biochar Technology as Soil Amendment

Table 4.4 summarises the distribution of adopters and non-adopters within the study area. Out of the 156 farmers who cultivated vegetable in 2011, Akwasiho farmers formed 54.49%. Aduamoa farmers formed 29.49% and Suminakese farmers also formed 16.03%. About 10.90% of farmers adopted Biochar in Akwasiho whilst 43.59% did not adopt. About 19.23% adopted in Aduamoa whilst 10.26% did not adopt. About 1.28% also adopted Biochar in Suminakese whilst 14.74% did not adopt. In total, out of the 156 farmers who cultivated vegetable in 2011, about 31.41% adopted whilst about 68.59% did not adopt.

Out of the 89 farmers who cultivated vegetable in 2012, Akwasiho farmers constituted about 68.54%. Aduamoa farmers also constituted 4.5% whilst Suminakese farmers constituted about 26.97%. Akwasiho farmers who adopted Biochar formed 11.24% whilst those who did not adopt formed 57.30%. For Aduamoa, the adopters and non-adopters formed 2.25% each. About 2.25% adopted Biochar in Suminakese whilst 24.72% did not adopt. In total, out of the 89 farmers, 15.74% adopted whilst 84.26% did not adopt.

Table 4.4: Frequencies and Percentages of Adoption of Biochar Technology as Soil Amendment by Farmers' Location

	2011[Total=156]		2012[Total= 89]	
Community	**Freq**	**Percent**	**Freq**	**Percent**
Akwasiho				
Adopters	17	10.90	10	11.24
Non-adopters	68	43.59	51	57.30
Total	85	54.49	61	68.54
Aduamoa				
Adopters	30	19.23	2	2.25
Non-adopters	16	10.26	2	2.25
Total	46	29.49	4	4.50
Suminakese				
Adopters	2	1.28	2	2.25
Non-adopters	23	14.74	22	24.72
Total	25	16.03	24	26.97

Source: Computation from survey data, 2015

4.7 Net Farm Income (GH¢) Analysis Associated with Adoption of Biochar

Table 4.5 presents a summary of the profitability associated with the adoption of Biochar or otherwise. The real average per acre gross margin and net farm income (NFI) of farmers have been computed separately for adopters and non-adopters in the three communities. The base year is 2011 with a Consumer Price Index (CPI) of 1.0. The variable costs included planting material, fertilizer, insecticide, weedicide, labour, transportation, maintenance and Biochar. Depreciation of equipments was included in the analysis as a fixed cost.

Table 4.5: Real Average per Acre Net Farm Income (GH¢) of Farmers

	2011		2012	
	Adopters	**Non-adopters**	**Adopters**	**Non-adopters**
Aduamoa				
Gross Income	1920.63	1840.00	259.46	3024.77
Total variable cost	1040.06	1038.25	420.95	1207.66
Gross margin	880.57	801.75	-161.49	1817.12
Total fixed cost	86.29	68.72	27.52	90.23
Net farm income	794.29	733.03	-189.01	1726.89
Akwasiho				
Gross Income	2359.17	1819.52	4789.64	2251.34
Total variable cost	1010.06	1129.37	1804.82	1197.01
Gross margin	1349.10	690.15	2984.82	1054.33
Total fixed cost	57.63	47.20	60.55	44.80
Net farm income	1291.47	642.94	2924.27	1009.53
Suminakese				
Gross Income	4428.00	5297.48	8562.16	12269.04
Total variable cost	2334.50	2418.94	5184.23	2517.26
Gross margin	2093.50	2878.54	3377.93	9751.78
Total fixed cost	24.67	13.09	26.74	11.16
Net farm income	2068.83	2865.45	3351.19	9740.62

Source: Computation from survey data, 2015[CPI 2011= 1.0]

For the 2011 season, the real average per acre NFI of adopters of Biochar in Aduamoa was higher than that for non-adopters of Biochar. The real average per acre NFI for the adopters of Biochar was GH¢794.29 and that for the non-adopters of Biochar was GH¢ 733.03. However it did turn out to be the reverse in the 2012 season. Farmers who did not adopt Biochar had a higher real average per acre NFI. Farmers who adopted Biochar made a loss of GH¢189.01 on the average as against those who did not adopt Biochar who made a profit of GH¢1726.89 in terms of real average per acre NFI. The real average per acre NFI for farmers who adopted Biochar in Akwasiho was GH¢1291.47 and GH¢642.94 for non-adopters, in the 2011 season. In the 2012 season, adopters of Biochar made a profit of GH¢2924.27 in terms of real average per acre NFI whilst non-adopters of Biochar made a profit of GH¢1009.53. The real average NFI for adopters and non-adopters of Biochar in Suminakese were GH¢2068.83 and GH¢2865.45 respectively, in 2011. Also for 2012, adopters of

Biochar in Suminakese made a profit of GH¢3351.19 whilst non-adopters of Biochar made a profit of GH¢9740.62 in terms of real average per acre NFI.

4.8 T-test of Difference between Net Farm Income (NFI) of Biochar Adopters and Non-adopters

Table 4.6 summarizes a t-test of the difference in means of real NFI of adopters and non-adopters. For farmers in Aduamoa, in the 2011 season, the difference in means was positive but not statistically significant. This means that even though the adoption of Biochar resulted in a relatively higher real average per acre NFI, the difference was not statistically significant. For the 2012 season, the difference was negative and statistically significant at 5%. Adopters of Biochar were relatively less profitable.

Table 4.6: T- test of Difference between Net Farm Income of Biochar Adopters and Non-adopters

	2011 [H_0 : diff=0]			2012 [H_0 : diff=0]		
	Freq.	Mean(GH¢)	P-value	Freq.	Mean(GH¢)	P-value
Aduamoa						
Adopters	30	794.29	0.423	2	-189.01	0.030
Non-adopters	16	733.03		2	1726.89	
Akwasiho						
Adopters	17	1291.47	0.082	10	2924.27	0.008
Non-adopters	68	642.94		51	1009.53	
Suminakese						
Adopters	2	2068.83	0.374	2	3351.19	0.389
Non-adopters	23	2865.45		22	9740.62	

Source: Computation from survey data, 2015

The adoption of Biochar in Akwasiho was more profitable in both 2011 and 2012 seasons. The difference was positive and significant at 10% in 2011 and also positive and significant at 1% in the 2012 season. This was because the demonstration forum started from that community. Farmers who did not adopt Biochar in Suminakese had higher real average NFI in both seasons than those who adopted Biochar, but the difference in means was not statistically significant. Results from Suminakese were counterintuitive. Soil acidity for which Biochar was introduced to farmers in Aduamoa and Akwasiho was not a problem in Suminakese. Soils in this community are very good for vegetable cultivation and therefore the effect of Biochar was not that significant as against the situation in Akwasiho.

4.9 Factors Affecting the Adoption of Biochar Technology

Table 4.7 presents the regression results of the factors that influence the adoption of Biochar technology. Apart from the 2011 and 2012 seasons, the effect of the factors is discussed for the regression derived through the pooling of the 2011 and 2012 samples.

Farm size significantly affected adoption in the 2011 season only. It had a positive influence on farmers' decision to use Biochar and a marginal effect of approximately 0.11. This means that farmers with larger farm sizes were more likely to adopt the Biochar technology in the 2011 season. This was consistent with the findings and assertions of Barungi *et al*. (2013) and Beshir *et al*. (2012). The effects of age and age squared on the adoption decision of farmers were significant in 2011 and for the pooled sample regression. Age positively affected adoption decision whilst age squared negatively affected adoption decision. Age however can be used as a proxy for experience. This means that younger farmers were more likely to adopt the Biochar technology relative to older farmers (age squared).

Marital status was significant in the 2012 season only. Marital status affected farmers' decision to adopt Biochar in a positive direction. The probability of adoption is increase by approximately 7 % (marginal effect) if farmer were married. Farmers who were married were more likely to use the Biochar technology and this was consistent with the apriori expectation of the study. Family labour (Mignouna *et al*.,

2011) was more likely to increase with spouse and children adding on. More labour could be available for the production and application of Biochar.

Table 4.7: Regression Results of Factors affecting the Adoption of Biochar Technology

	2011 [n=156]		2012 [n=89]		Pooled sample [n=245]	
	Probit regression		Probit regression		Probit regression	
	Coefficient (p-value)	Marginal effect	Coefficient (p-value)	Marginal effect	Coefficient (p-value)	Marginal effect
FSIZE	0.3860** (0.037)	0.1088	-0.2637 (0.377)	-0.0263	0.1476 (0.280)	0.0357
GENDER	0.2905 (0.371)	0.0832	-0.0966 (0.843)	-0.0096	0.1742 (0.492)	0.0426
AGE	0.2329** (0.046)	0.0657	0.0827 (0.657)	0.0082	0.1815* (0.052)	0.0439
AGESQUARED	-0.0021* (0.063)	-0.0006	-0.0005 (0.768)	-0.0001	-0.0015* (0.080)	-0.0004
EDUC	0.1768 (0.550)	0.0488	-0.3426 (0.475)	-0.0375	-0.0178 (0.940)	-0.0043
MSMARRIED	0.1340 (0.720)	0.0368	1.1733* (0.080)	0.0703	0.3487 (0.255)	0.0768
FBO	1.7186*** (0.000)	0.5641	2.4428** (0.018)	0.7098	1.5121*** (0.000)	0.4892
OUTPUT	0.0004 (0.156)	0.0001	0.0012*** (0.004)	0.0001	0.0006*** (0.004)	0.0001
CREDIT	0.5526* (0.072)	0.1665	1.2136** (0.048)	0.1948	0.5402** (0.029)	0.1436
EXTVISIT	0.0014 (0.978)	0.0004	-0.1208 (0.155)	-0.0120	-0.0277 (0.471)	-0.0067
NONFARMJOB	0.0908 (0.750)	0.0256	1.1991** (0.025)	0.1436	0.3808* (0.099)	0.0926
FPART	1.3177*** (0.000)	0.3381	1.6058*** (0.006)	0.1991	1.2309*** (0.000)	0.2858
SEASON	-	-	-	-	-0.2975 (0.225)	-0.0690
Constant term	-9.4543*** (0.003)	-	-6.8772 (0.175)	-	-7.9124*** (0.002)	
LR Chi2(12)	80.17		26.54		102.08	
Prob>Chi2	0.0000		0.0090		0.0000	
Pseudo R2	0.4129		0.3427		0.3654	
Log likelihood	-57.00		-25.46		-88.62	

***,**,&* represent significance levels at 1%,5% and 10% respectively

Source: Computation from survey data, 2015

FBO membership significantly and positively affected the adoption of Biochar in both seasons and in the pooled data analysis. Farmers who were members of Nsonyameye and located in Aduamoa were more likely to adopt Biochar. This was became the intensity of Biochar training in Aduamoa was relatively high. The probability of adoption is increased by approximately 56% in 2011 and 71% in 2012, if farmer were member of that FBO. For the pooled data regression, the probability of adoption is increased by approximately 49% if farmer were member of that FBO.

Output of farmers significantly influenced their decision to use Biochar in the 2012 season and for the pooled data analysis. The probability of adoption increased with higher output. This means that farmers with more output were more likely to have more farm income and an increase in their capital base (Nnadi &Nnadi, 2009). They are therefore able to adopt agricultural technologies.

Access to credit was also significant in both seasons and for the pooled data analysis. Farmers who had access to credit were more likely to adopt Biochar. This was however consistent with the findings of Gebremichael & Gebremedhin (2014). The availability of credit to the farmers means that cost associated with the adoption of Biochar would be taken care of. Therefore farmers could afford to try the technology which was introduced to them. Access to credit increased the probability of adopting Biochar by approximately 17% and 19.5% in 2011 and 2012 respectively. The probability of adoption is increased by approximately 14% for the pooled data analysis.

Farmers who had access to off-farm income through non-farm job were also likely to adopt Biochar in 2012. They were also likely to adopt Biochar per the pooled data analysis. As expected, the probability of adoption increased by approximately 14% in 2012 when farmers had access to off-farm income through non-farm job. For the pooled data, the probability is increased by approximately 9%. This means that farmers had more income to cover the cost of producing Biochar. This has been opined by Martey *et al*. (2013) and Hanschuch & Wollni (2013).

The Biochar forum organized for farmers in 2011 significantly affected their decision to adopt the technology in both years. The probability of adopting Biochar as soil amendment increased with forum participation. It was highly expected that forum participation will significantly affect the probability of adopting Biochar. Farmers' participation in the forum increased the probability of adoption by approximately 34% and 20% in 2011 and 2012 respectively. The probability of adopting Biochar is also increased by approximately 29% for the pooled sample analysis. In summary, FBO membership, access to credit and forum participation were the most consistent factors affecting the adoption of Biochar in all the regression analysis.

4.10 Intensity of Adoption of Biochar Technology

Table 4.8 summarizes the regression results of the intensity of adoption after farmers had adopted Biochar. The coefficients and associated probability levels are estimated using the truncated regression model.

Farm size significantly and negatively affected the intensity of Biochar adoption in 2011 season and for the pooled data analysis. The intensity of Biochar adoption is decreased by approximately 0.12% and 0.15% for the 2011 season and for the pooled data analysis respectively, for every 1% increase in farm size. This means that the bigger the farm size, the lower the intensity of Biochar use. This was consistent with the findings of Beshir(2014). Gender of farmer affected the intensity of Biochar use in the 2012 season only. This means that for the 2012 season, male farmers who adopted Biochar were more likely to intensify its use by approximately 0.87%. Male farmers had more resources at their disposal and could afford to produce more Biochar. This was consistent with the findings of Akudugu *et al*. (2012).

Age and age squared significantly influenced intensity of adoption in the 2012 season only. As expected, younger farmers who had adopted Biochar were more likely to intensify its use as against their older counterparts (age squared). Farmers, who had been educated up to the JSS level and had adopted Biochar in 2012, were more likely to intensify the use of the technology. Education up to the JSS level increased the intensity of Biochar use by approximately 0.72%. With education, the farmers are able to read and appreciate better the importance of using Biochar as soil amendment and to handle it properly. This was consistent with the findings of Olagunju & Salimonu (2010).

Table 4.8: Regression Results of Intensity of Adoption of Biochar Technology

	2011 [n=49]		2012 [n=14]		Pooled sample [n=63]	
	Truncated regression		Truncated regression		Truncated regression	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
FSIZE	-0.1170**	0.030	-0.0142	0.902	-0.1471***	0.005
GENDER	-0.0737	0.334	0.8687***	0.000	0.0089	0.910
AGE	0.0300	0.321	0.3525***	0.000	0.0329	0.310
AGESQUARED	-0.0003	0.269	-0.0032***	0.000	-0.0003	0.254
EDUC	-0.0321	0.610	0.7219***	0.000	-0.0030	0.964
MSMARRIED	-0.0171	0.842	-0.8337***	0.000	-0.0504	0.589
FBO	0.1741**	0.015	-0.8230***	0.000	0.0874	0.256
OUTPUT	0.0000	0.771	-0.0007***	0.000	-0.0001	0.291
CREDIT	-0.0575	0.346	0.1723	0.109	0.0247	0.715
EXTVISIT	-0.0011	0.938	0.0184	0.145	-0.0095	0.513
NONFARMJOB	-0.0589	0.340	0.8162***	0.000	0.0128	0.853
FPART	-0.1815*	0.074	-0.0178	0.849	-0.1806*	0.072
SEASON	-	-	-	-	0.1376*	0.078
Constant term	0.5220	0.515	-8.3892***	0.000	0.5169	0.557
/ Sigma	0.1806***	0.000	0.0399***	0.000	0.2218***	0.000
Lower limit	0		0		0	
Upper limit	+ inf		+ inf		+ inf	
Wald chi2(12)	28.26		1122.46		25.16	
Prob> chi2	0.0051		0.0000		0.0220	
Log likelihood	14.34		25.22		5.74	

***,**,&* represent significance levels at 1%,5% and 10% respectively

Source: Computation from survey data, 2015

Marital status of farmers significantly affected the intensity of Biochar use in 2012. Contrary to expectation, the direction of effect was negative. This means that married farmers who had adopted Biochar in 2012 were less likely to intensify its use.

Intensity of adoption is decreased by approximately 0.83% if farmer was married. FBO membership was significant in influencing the intensity of Biochar use in both 2011 and 2012. As explained above, those in Nsonyameye FBO received massive training on Biochar production and its use. Farmers were therefore more likely to adopt and intensify its use in the 2011 season because the direction of effect was positive. However the direction of effect was negative in 2012. Farmers who adopted Biochar were rather less likely to intensify its use.

Output negatively affected the intensity of Biochar use in the 2012 season only. Farmers with higher output were less likely to use more Biochar after having adopted the technology. This was against the a priori expectation of the study. Farmers who had adopted Biochar and also had access to off- farm income through non-farm job were more likely to intensify its use in 2012. This was consistent with the assertions of Martey *et al*. (2013) and Handschuch & Wollni (2013). Access to off-farm income through non-farm job increased the intensity by approximately 0.82%.

Biochar forum participation negatively influenced the intensity of Biochar use in the 2011 season and for the pooled data analysis. Farmers who participated in the forum and had adopted Biochar reduced their intensity of use by approximately 0.18%. The effect of season was only considered in the pooled sample analysis. The effect of season positively influenced the intensity of Biochar use. Farmers were more likely to intensify their Biochar use by approximately 0.14% if they adopted it in the 2012 season. In summary, the most consistent factor that affected the intensity of adoption of Biochar was FBO membership. It was significant in both 2011 and 2012 seasons.

4.11 Constraints Facing Farmers in Vegetable Production

From table 4.9, lack of credit for farming was the most pressing constraint with a mean score of 62.75. Lack of reliable market for farm produce was ranked number two, with a mean score of 61.98. Incidence of pest and disease was next with a mean score of 44.08. High cost of material input was the fourth most important constraint with a mean score of 40.99. Lack of storage facilities was the least pressing constraint with a mean score of 39.55.

Table 4.9: Constraints in Vegetable Production using the Garret Ranking Technique

Constraint	Mean score	Rank
Lack of credit for farming	62.75	1
Lack of reliable market for farm produce	61.98	2
Incidence of pest and disease	44.08	3
High cost of material inputs	40.99	4
Lack of storage facilities for harvested produce	39.55	5

Source: Computation from survey data, 2015

Lack of credit was the most important constraint facing vegetable producers in the study area. Most of the credit institutions perceive farming business as risky. They are therefore reluctant in extending more credit facilities to farmers. This has also been observed by Kuwornu *et al*. (2013). The very few farmers who are able to access credit do not get what is required and on time and therefore are not able to make good use of the credit facilities. Only approximately 33% and 27% of farmers had access to credit in 2011 and 2012 respectively.

Lack of reliable market followed as the second most important constraint facing vegetable farmers in the study area. Farmers are always faced with the conundrum of ready market and good price when their produce is ready for the market. Majority of farmers in the district harvest their produce almost at the same time of the season since they largely depend on the rains for production. They end up becoming price takers and therefore receive low prices for their produce or no market at all. There are very few exporters in the district whose demand cannot meet all the supply from farmers.

The third most pressing constraint facing farmers was incidence of pest and disease. This received a mean score of 44.99. Some farmers lost almost all their farm produce to incidence of pest and disease. Others had to buy more agrochemicals in other to bring this constraint under control and to salvage some amount of produce. They risk losing all their produce if this measure is not taken. High cost of material inputs and lack of storage facilities were the least important constraints facing farmers.

4.12 Constraints Facing Farmers in the Adoption of Biochar

Incremental workload was the most important constraint facing farmers with a mean score of 62.05. Health issue was ranked second with a mean score of 61.47. Biochar handling followed with a mean score of 49.80. High cost of Biochar was the fourth most important constraint facing farmers with a mean score of 39.41. Competing use of farm residue was the least important constraint with a mean score of 38.23. Table 4.10 summarizes the ranking results.

Table 4.10: Constraints in the Adoption of Biochar using Garret Ranking Technique

Constraint	Mean score	Rank
Incremental workload	62.05	1
Health issues	61.47	2
Biochar handling	49.80	3
High cost of Biochar	39.41	4
Competing use of farm residues	38.23	5

Source: Computation from survey data, 2015

The incremental workload associated with the production and handling of Biochar (Scholz *et al*., 2014) was the most important constraint facing farmers in adopting it in the study area. Biochar is very hard to find on the market so farmers had to produce it all by themselves. They however complained that it was an arduous task for them to produce it. They had to go through the process of mobilizing as many farm residues as they could. This is followed by the creation of an artificial pyrolizer in which the burning of the residues will take place.

The health issues associated with the use of Biochar was the second most important constraint facing farmers in the study area. They claim that the production and use of Biochar pose some health challenges. One might even suffer burns in the process of burning the farm residues. The product is quite dusty and farmers might also suffer some breathing challenges (Bracmort, 2010). They will be very much grateful if the produce could be readily available on the market. They would then be spared from all the trouble they have to go through in trying to produce their own.

The handling of Biochar (Bracmort, 2010) followed as the third most important constraint facing farmers in adopting Biochar. Most of the farmers indicated that they knew very little about the proper handling of the product. They had no much education about how to apply the product and even what quantity to apply. They therefore could not risk killing their plants by adopting the technology. The fourth most important constraint was the cost associated with the production and use of Biochar as soil amendment. Competing use of farm residues was the least important constraint facing farmers in the adoption of Biochar. This was ranked last by the farmers because farm residues abound in the study area. They indicated that they do not have much problem securing farm residues for production of Biochar if they really want to use it.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1 Introduction

This concluding chapter presents a summary of the major findings of the study. The summary of major findings is then followed by the conclusions drawn out of the findings. The chapter concludes with the policy recommendations drawn out of the study.

5.2 Summary of Major Findings

The study revealed that more females adopted Biochar than males in the 2011 season. In the 2011 season, female adopters formed 53.06% of the total number of farmers who adopted the technology. In the 2012 season, they formed 50% of adopters. In the 2011 season, majority of adopters were members of the Nsonyameye farmer based organization located in Aduamoa. They formed 61.22% of adopters. However in the 2012 season, majority of Biochar technology adopters came from Blessing farmer based organization located in Akwasiho. They also formed 25% of the total number of farmers who adopted Biochar in 2012. Out of the total number of farmers who produced vegetables in 2011, approximately 31% adopted Biochar. However in 2012, only about 16% adopted the technology.

The profitability analysis indicated that farmers who adopted Biochar in Aduamoa in the 2011 season had comparatively higher real average per acre NFI but this was not statistically significant. Those who adopted Biochar in 2012 made a loss of GH¢ 189.01 whilst non-adopters made a profit of GH¢1726.89 on average. Farmers who adopted Biochar in Akwasiho made more profit in both 2011 and 2012. The real average per acre NFI for adopters and non-adopters was GH¢ 1291.47 and GH¢ 642.94 respectively, in the 2011 season. In the 2012 season, the real average per acre

NFI for adopters and non-adopters was GH¢2924.27 and GH¢1009.53 respectively. Biochar technology adopters in Suminakese made less profit in both 2011 and 2012 seasons but this was not statistically significant.

The probability of farmers' to adopt the Biochar technology in 2011 was significantly influenced by farm size, age ,age squared, FBO membership, access to credit and forum participation. Apart from age squared, all the factors influenced adoption of Biochar in the positive direction. However gender, educational level, marital status, output, extension visits and off-farm income source did not have any significant influence on the adoption decisions of farmers. The probability of farmers' to adopt the Biochar technology in 2012 was also significantly influenced by marital status, FBO membership, output, access to credit, off-farm income source and forum participation. They positively influenced the adoption decisions of farmers. Farm size, gender, age, age squared, educational level and extension visits were not significant in influencing farmers' decision to adopt Biochar. For the pooled data analysis, farmers adoption decision was influenced by age, age squared, FBO membership, output, access to credit, off-farm income source and forum participation. However FBO membership, access to credit and forum participation were significant in both years as well in the pooled data analysis.

The intensity of Biochar use was significantly influenced in the 2011 season by farm size, FBO membership and forum participation. Farm size and forum participation influenced intensity of Biochar use negatively whilst FBO membership positively influenced intensity of use. Gender, age, age squared, educational level, marital status, output, access to credit, extension visits and off-farm income source did not significantly influence the intensity of use in the 2011 season. In the 2012 season, intensity of Biochar use was significantly influenced by gender, age, age squared, educational level, marital status, FBO membership, output and off-farm income source. Gender, age, educational level and off-farm income source had positive influence on intensity of use. Age squared, marital status, FBO membership and output influenced intensity of use in the negative direction. Farm size, access to credit, extension visits and forum participation did not have any significant influence on the intensity of use of Biochar. However when the two season samples were put together and analysed, farm size, forum participation and season were the factors that significantly influenced adoption intensity. Farm size and forum participation influenced intensity of adoption negatively whilst season influenced intensity of adoption positively. FBO membership was the only consistent factor that influenced the intensity of use of Biochar across the two seasons.

5.3 Conclusions

The difference in means of real average NFI of adopters and non-adopters of Biochar was positive and statistically significant across the two seasons for farmers located in Akwasiho. The profitability of adopters of Biochar was about two times that of non-adopters in 2011 and about three times in 2012. This implies that the adoption of Biochar in that community was more profitable. Farmers who adopted Biochar in that community were more likely to gain more profit than those who did not adopt Biochar. The profitability associated with adoption of Biochar in Aduamoa was mixed. The difference in profitability of Biochar adopters and non-adopters in Suminakese was not statistically significant. It can therefore be implied that there is no evidence statistically that the use of Biochar in Suminakese could impact farmers profitability.

Farm size, age, age squared, FBO membership, access to credit and forum participation were the most important factors affecting the adoption decisions of farmers in the 2011 season. The most important factors in the 2012 season were marital status, FBO membership, output, access to credit, off farm income source and forum participation. However for the pooled sample analysis, age, age squared, FBO membership, output, access to credit, off-farm income source and forum participation were the most important factors that influenced adoption of Biochar. FBO membership, access to credit and forum participation were the most consistent factors across all the seasons. It can however be implied that farmers' choice of Biochar as a soil conditioner will depend on whether or not they belong to an FBO, have access to farm credit or participated in the forum organized in 2011.

Farm size, FBO membership and forum participation were the most important factors affecting the intensity of Biochar use in the 2011 season. The most important factors in the 2012 season were gender, age, age squared, educational level, marital status, FBO membership, output and off-farm income source. Farm size, forum participation and season were also the most important factors affecting intensity of Biochar use in the combined analysis of the 2011 and 2012 samples. FBO membership was the most consistent factor that affected the intensity of Biochar use across both seasons. This implies that farmers' decision to intensify the use of Biochar depends on whether or not they were members of an FBO and the particular FBO they belong to.

The most important constraints facing farmers in vegetable production were lack of credit and reliable market for farm produce. The least important constraint was lack of storage facilities for harvested produce. The most important constraints facing farmers in the adoption of Biochar technology were incremental workload and health issues associated with the technology. The least important constraint affecting farmers in the use of Biochar was competing use of farm residues.

5.4 Policy Recommendations

Farmers in Akwasiho should continue to use and intensify vegetable production under Biochar since results from that community indicated that it is more profitable than vegetable production without the use of Biochar. The adoption of Biochar in this community resulted in relatively higher real average NFI for the farmers. The profitability of adopters was two times higher in 2011 and three times higher in 2012 than the profitability of non-adopters.

Project implementers must intensify training on Biochar use especially for farmers in Aduamoa and Suminakese whilst targeting more farmers in other to intensify the adoption of Biochar. Farmers need to be educated more on the agronomic benefits associated with the use of Biochar. Those who have already adopted must be supported through the provision of resources so they can intensify the use of the technology. Project implementers must also do well to introduce the technology to more farmers in the study area.

Credit institutions must be encouraged by all stakeholders of the agricultural sector to supply more credit to farmers in the study area. The supply of credit to farmers must also be timely so the farmers can make good use of it. Government must also set up an efficient regulatory body of the vegetable market to offer some appreciable level of protection to vegetable farmers in the study area.

More agribusinesses must be encouraged to increase the production and commercialization of Biochar. Farmers can then spare the material resources and energy they have to use in producing their own Biochar. The agribusinesses can also seize the opportunity to create and capture more value.

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APPENDICES

SAMPLE QUESTIONNAIRE

UNIVERSITY OF GHANA

DEPARTMENT OF AGRICULTURAL ECONOMICS AND AGRIBUSINESS

FACTORS AFFECTING BIOCHAR TECHNOLOGY ADOPTION BY VEGETABLE FARMERS IN THE KWAHU EAST DISTRICT OF GHANA

The main objective of this study is to assess the adoption factors at the farm-level of Biochar technology in amending soils for farming by vegetable farmers in the Kwahu East district of Ghana in the 2011 and 2012 crop seasons. Biochar is a **type of charcoal** produced by a thermochemical process called pyrolysis of organic waste material under high temperatures and anaerobic conditions. The application of Biochar to agricultural soils can improve soil quality, fertility and crop productivity.

All respondents are assured that their details will be kept confidential and not appear anywhere, since this is just an academic exercise in partial fulfilment for the award of a Master of Philosophy degree in Agribusiness.

GENERAL INFORMATION

Name of farmer..
Questionnaire number

Date of interview..

Farmer's contact number...................................

Enumerator's ID..................................	Start time...........................	End time.............................
Area [ ] Aduamoa [ ] Akwasiho [ ] Suminakese		

[A] SOCIO-ECONOMIC INFORMATION

1. Gender of respondent [ ] Male [ ] Female `	2. Age of respondent (years)...........
3. Educational background	[ ] Primary [ ] JHS/JSS [ ] SHS/SSS [ ] Tertiary [ ] None [ ] other (specify).............................
4. What is your household size?	5. Is farming your only work? [ ] Yes [ ]No
6. If no, indicate one major work you do in addition?	[ ] Teacher [ ] Trader [ ] Artisan [ ] Other (specify)...
7. Farmer Based Organization(FBO) membership [ ] Yes [ ] No	8. If yes, what is the name of the FBO ....

9. Marital Status [ ] Single [ ] Married [ ] Widowed [ ] other (specify).....................		
10. How many years have you been cultivating pepper?..		
11. Access to extension services	2011 [ ] Yes [ ]No	2012 [ ] Yes [ ] No
12. If yes, state the number of visits	2011.................................	2012..............................
13. Access to farm credit	2011 [ ] Yes [ ] No	2012 [ ] Yes [ ] No
14. If yes, what type of farm credit	2011 [ ] Cash credit [ ] In-kind [ ] Both	2012 [ ] Cash credit [ ] In-kind [ ] Both
15. Access to off-farm income	2011 [ ] Yes [ ]No	2012 [ ] Yes [ ]No
16. If yes, what is the major source of off-farm income	2011 [ ] Non-farm job [ ] Remittances [ ] Other (specify)......................................	2012 [ ] Non-farm job [ ] Remittances [ ] Other (specify)......................................

17. Acquisition and ownership of farmland

Plot 1	[ ] Inherited [ ] Bought it [ ] Lease [ ] Share cropping [ ] other (specify)...
Plot 2	[ ] Inherited [ ] Bought it [ ] Lease [ ] Share cropping [ ] other (specify)...
Plot 3	[ ] Inherited [ ] Bought it [ ] Lease [ ] Share cropping [ ] other (specify)...
Plot 4	[ ] Inherited [ ] Bought it [ ] Lease [ ] Share cropping [ ] other (specify)...

[B] ADOPTION OF OTHER FARM TECHNOLOGIES

18. Have you used any farm technology/ innovation since you starting farming? [ ] Yes [ ] No
19. If yes, which among the following did you used? [ ] Soil conservation practice [ ] Integrated Pest Management (IPM) [ ]Crop Insurance [ ] Improved seed
20. Which among the following introduced you to the above innovations? [ ] Extension agent [ ] other farmers [ ] NGO [ ] other (specify)..

[C] AWARENESS AND PARTICIPATION IN BIOCHAR DEMONSTRATION FORUM

21. Did you hear of the Biochar demonstration forum that was carried out in 2011? [ ] Yes [ ] No
22. If yes, from which source(s) did you first hear of the demonstration forum?
    [ ] Extension agent [ ] Radio [ ] Television [ ] other farmers [ ] other (specify)....................................
23. Did you participate in the 2011 demonstration forum? [ ]Yes [ ]No

24. Did you apply Biochar to your pepper farmland in the stated years?	2011 [ ] Yes [ ]No	2012 [ ] Yes [ ]No

25. If no to Q21, are you currently aware of the Biochar technology? [ ] Yes [ ]No
26. If yes, from which source(s) did you first hear of the technology?
    [ ] Extension agent [ ] Radio [ ] Television [ ] other farmers [ ] other (specify)..
27. Did you apply Biochar to your pepper farmland in either 2011 or 2012?
    [ ] Yes [ ] No

28. If yes, please indicate the year(s)	2011 [ ] Yes [ ]No	2012 [ ] Yes [ ]No

[D] INTENSITY OF USE OF BIOCHAR

29. Size of farmland under pepper cultivation

	2011		2012	
Plot	Size(Ft)	Convert to acres	Size(Ft)	Convert to acres
1				
2				
3				
4				

30. Did you produce your own Biochar?	2011 [ ] Yes [ ]No	2012 [ ] Yes [ ]No
31. If no, where did you source your Biochar?	2011 [ ] Market [ ] Project implementers [ ] Other farmers [ ] Other (specify)........................	2012 [ ] Market [ ] Project implementers [ ] Other farmers [ ] Other (specify)........................
32. Cost of Biochar / Unit (GH¢)?	2011..............................	2012..............................

33. Indicate the amount(Kg) of Biochar and proportion (acres) of plot land that Biochar was applied

	2011		2012	
Plot	Amount(Kg)	Proportion of plot of land that Biochar was applied(acres)	Amount(Kg)	Proportion of plot of land that Biochar was applied(acres)
1				
2				
3				
4				

[E] COST ASSOCIATED WITH PEPPER CULTIVATION

34. Provide answers to the questions in the tables below:

2011	PLOT 1			PLOT 2		
	Quantity used	Unit price(GH¢)	Total amount (GH¢)	Quantity used	Unit price(GH¢)	Total amount (GH¢)
Planting material						
Fertilizer(NPK)						
Fertilizer (Sulphate of Ammonia)						
Insecticide						
Weedicide						
Biochar						
Others (specify)						

2011	PLOT 3			PLOT 4		
	Quantity used	Unit price(GH¢)	Total amount (GH¢)	Quantity used	Unit price(GH¢)	Total amount (GH¢)
Planting material						
Fertilizer(NPK)						
Fertilizer (Sulphate of Ammonia)						
Insecticide						
Weedicide						
Biochar						
Others (specify)						

2012	PLOT 1			PLOT 2		
	Quantity used	Unit price(GH¢)	Total amount (GH¢)	Quantity used	Unit price(GH¢)	Total amount (GH¢)
Planting material						
Fertilizer(NPK)						
Fertilizer (Sulphate of Ammonia)						
Insecticide						
Weedicide						
Biochar						
Others (specify)						

2012	PLOT 3			PLOT 4		
	Quantity used	Unit price(GH¢)	Total amount (GH¢)	Quantity used	Unit price(GH¢)	Total amount (GH¢)
Planting material						
Fertilizer(NPK)						
Fertilizer (Sulphate of Ammonia)						
Insecticide						
Weedicide						
Biochar						
Others (specify)						

Equipments	Quantity	Unit cost(GH¢)	Year Purchased	Expected lifespan	Share for pepper
Cutlass					
Hoe					
Wheel barrel					
Wellington Boot					
Sprayer					
Watering can					
Tape measure					
Others(specify)					

2011	Labour				
PLOT 1	No. of workers	Number of days worked	Rate per day(GH¢)	Total cost (GH¢)	Share for pepper(GH¢)
Land preparation					
Planting					
Fertilizer application					
Insecticide application					
Weeding					
Daily watering					
Harvesting					
Others (specify)					
PLOT 2	No. of workers	Number of days worked	Rate per day(GH¢)	Total cost (GH¢)	Share for pepper(GH¢)
Land preparation					
Planting					
Fertilizer application					
Insecticide application					
Weeding					
Daily watering					
Harvesting					
Others (specify)					
PLOT 3	No. of workers	Number of days worked	Rate per day(GH¢)	Total cost (GH¢)	Share for pepper(GH¢)
Land preparation					
Planting					
Fertilizer application					

Insecticide application					
Weeding					
Daily watering					
Harvesting					
Others (specify)					
PLOT 4	No. of workers	Number of days worked	Rate per day(GH¢)	Total cost (GH¢)	Share for pepper(GH¢)
Land preparation					
Planting					
Fertilizer application					
Insecticide application					
Weeding					
Daily watering					
Harvesting					
Others (specify)					

2012	Labour				
PLOT 1	No. of workers	Number of days worked	Rate per day(GH¢)	Total cost (GH¢)	Share for pepper(GH¢)
Land preparation					
Planting					
Fertilizer application					
Insecticide application					
Weeding					
Daily watering					
Harvesting					
Others (specify)					
PLOT 2	No. of workers	Number of days worked	Rate per day(GH¢)	Total cost (GH¢)	Share for pepper(GH¢)
Land preparation					
Planting					
Fertilizer application					
Insecticide application					
Weeding					
Daily watering					
Harvesting					
Others (specify)					
PLOT 3	No. of workers	Number of days worked	Rate per day(GH¢)	Total cost (GH¢)	Share for pepper(GH¢)
Land preparation					
Planting					
Fertilizer application					
Insecticide application					
Weeding					
Daily watering					
Harvesting					
Others (specify)					
PLOT 4	No. of workers	Number of days worked	Rate per day(GH¢)	Total cost (GH¢)	Share for pepper(GH¢)
Land preparation					
Planting					
Fertilizer application					
Insecticide application					
Weeding					
Daily watering					
Harvesting					
Others (specify)					

	2011		2012	
OTHER COST	Total amount spent(GH¢)	Share for pepper	Total amount spent(GH¢)	Share for pepper
Irrigation				
Transportation				
Maintenance				

[F]FARMERS' REVENUE FOR PEPPER CULTIVATION

35. Please provide answers in the tables below:

2011	Number of boxes(5.5kg) harvested	Total weight (kg)	Price per box (GH¢)
PLOT 1			
PLOT 2			
PLOT 3			
PLOT 4			

2012	Number of boxes(5.5kg) harvested	Total weight (kg)	Price per box (GH¢)
PLOT 1			
PLOT 2			
PLOT 3			
PLOT 4			

[G] CONSTRAINTS GENERALLY FACING FARMERS IN PEPPER CULTIVATION

36. Rank the following constraints on a scale of one (1) to five (5), with one (1) as the most important.

Constraint	
Lack of credit for crop farming	
Lack of reliable market for farm produce	
Incidence of pest and disease	
Lack of storage facilities for harvested produce	
High cost of material inputs	

[H] CONSTRAINTS IN APPLYING BIOCHAR AS SOIL AMENDMENT

37. Rank the following constraints on a scale of one (1) to five (5), with one (1) as the most important.

Constraint	
Incremental workload	
Biochar handling	
Health issues	

Competing use of farm residues	
High cost of Biochar	

PROFITABILITY ANALYSIS AND T-TEST FOR THE 2011 SEASON

Aduamoa Community

Average cost and revenue per acre for adopters(GH¢)30	2011 per acre(GH¢)		Average cost and revenue per acre for non adopters(GH¢)16	2011 per acre(GH¢)
GROSS INCOME	1920.633333		GROSS INCOME	1840
VARIABLE COSTS			VARIABLE COSTS	
Planting material	19.79166667		Planting material	19.5
Fertilizer(NPK)	47.77		Fertilizer(NPK)	46.5
Fertilizer(Sulphate of Ammonia)	32.53333333		Fertilizer(Sulphate of Ammonia)	34.875
Insecticide	12.4		Insecticide	12.5
Weedicide	17.3		Weedicide	17.125
Biochar	36.21666667		Biochar	0
Labour	834.5833333		Labour	859.375
Transportation	16.33333333		Transportation	28.4375
Maintenance	23.13333333		Maintenance	19.9375
TOTAL VARIABLE COST	1040.061667		TOTAL VARIABLE COST	1038.25
GROSS MARGIN	880.5716667		GROSS MARGIN	801.75
FIXED COST			FIXED COST	
Depreciation of equipments	86.28611111		Depreciation of equipments	68.72010417
TOTAL FIXED COST	86.28611111		TOTAL FIXED COST	68.72010417
NET FARM INCOME(GM-FIXED COST)	794.2855556		NET FARM INCOME(GM-FIXED COST)	733.0298958

```
Two-sample t test with equal variances
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
ACRENF.. |      30    794.2856    125.7438    688.7272    537.1106    1051.461
ACRENF.. |      16    733.0299     359.247    1436.988   -32.68704    1498.747
---------+--------------------------------------------------------------------
combined |      46    772.9792    147.0633    997.4321    476.7785     1069.18
---------+--------------------------------------------------------------------
    diff |            61.25566    312.1272               -567.7953    690.3066
------------------------------------------------------------------------------
    diff = mean(ACRENFIADUAADO~1) - mean(ACRENFIADUANON~1)        t =   0.1963
Ho: diff = 0                                     degrees of freedom =       44

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.5773         Pr(|T| > |t|) = 0.8453          Pr(T > t) = 0.4227
```

Akwasiho Community

Average cost and revenue per acre for adopters(GH¢)17	2011 per acre(GH¢)		Average cost and revenue per acre for non adopters(GH¢)68	2011 per acre(GH¢)
GROSS INCOME	2359.166667		GROSS INCOME	1819.519608
VARIABLE COSTS			VARIABLE COSTS	
Planting material	17.79901961		Planting material	15.1875
Fertilizer(NPK)	61.20588235		Fertilizer(NPK)	71.77083333
Fertilizer(Sulphate of Ammonia)	25.19117647		Fertilizer(Sulphate of Ammonia)	32.22855392
Insecticide	17.02941176		Insecticide	17.66470588
Weedicide	12.94117647		Weedicide	13.6004902
Biochar	26.5		Biochar	0
Labour	843.2058824		Labour	965.872549
Transportation	4.617647059		Transportation	11.66176471
Maintenance	1.573529412		Maintenance	1.38627451
TOTAL VARIABLE COST	1010.063725		TOTAL VARIABLE COST	1129.372672
GROSS MARGIN	1349.102941		GROSS MARGIN	690.1469363
FIXED COST			FIXED COST	
Depreciation of equipments	57.62867647		Depreciation of equipments	47.20463772
TOTAL FIXED COST	57.62867647		TOTAL FIXED COST	47.20463772
NET FARM INCOME(GM-FIXED COST)	1291.474265		NET FARM INCOME(GM-FIXED COST)	642.9422986

```
. ttest ACRENFIAKWASIADOPT2011 == ACRENFIAKWASINONADOPT2011, unpaired

Two-sample t test with equal variances
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
ACRENF.. |      17    1291.474    617.4362    2545.755   -17.43196     2600.38
ACRENF.. |      68    642.9423    173.5451    1431.089    296.5448    989.3397
---------+--------------------------------------------------------------------
combined |      85    772.6487    185.8552    1713.501    403.0552    1142.242
---------+--------------------------------------------------------------------
    diff |             648.532    461.9764               -270.3206    1567.385
------------------------------------------------------------------------------
    diff = mean(ACRENFIAKWASIA~1) - mean(ACRENFIAKWASIN~1)         t =   1.4038
Ho: diff = 0                                     degrees of freedom =       83

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.9179         Pr(|T| > |t|) = 0.1641          Pr(T > t) = 0.0821
```

Suminakese Community

Average cost and revenue per acre for adopters(GH¢)2	2011 per acre(GH¢)		Average cost and revenue per acre for non adopters(GH¢)23	2011 per acre(GH¢)
GROSS INCOME	4428		GROSS INCOME	5297.478261
VARIABLE COSTS			VARIABLE COSTS	
Planting material	45		Planting material	23.56521739
Fertilizer(NPK)	21		Fertilizer(NPK)	63.55072464
Fertilizer(Sulphate of Ammonia)	0		Fertilizer(Sulphate of Ammonia)	7.246376812
Insecticide	8.5		Insecticide	13.45652174
Weedicide	5		Weedicide	17.38405797
Biochar	18		Biochar	0
Labour	2225.5		Labour	2287.782609
Transportation	11.5		Transportation	5.956521739
Maintenance	0		Maintenance	0
TOTAL VARIABLE COST	2334.5		TOTAL VARIABLE COST	2418.942029
GROSS MARGIN	2093.5		GROSS MARGIN	2878.536232
FIXED COST			FIXED COST	
Depreciation of equipments	24.67		Depreciation of equipments	13.08504831
TOTAL FIXED COST	24.67		TOTAL FIXED COST	13.08504831
NET FARM INCOME(GM-FIXED COST)	2068.83		NET FARM INCOME(GM-FIXED COST)	2865.451184

```
. ttest ACRENFISUMINAADOPT2011 == ACRENFISUMINANONADOPT2011, unpaired

Two-sample t test with equal variances
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
ACRENF.. |       2     2068.83     2212.17    3128.481   -26039.45    30177.11
ACRENF.. |      23    2865.451    692.8931    3322.999    1428.479    4302.424
---------+--------------------------------------------------------------------
combined |      25    2801.721    650.4948    3252.474    1459.166    4144.277
---------+--------------------------------------------------------------------
    diff |           -796.6212    2443.687               -5851.773    4258.531
------------------------------------------------------------------------------
    diff = mean(ACRENFISUMINAA~1) - mean(ACRENFISUMINAN~1)         t =  -0.3260
Ho: diff = 0                                     degrees of freedom =       23

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.3737         Pr(|T| > |t|) = 0.7474          Pr(T > t) = 0.6263
```

PROFITABILITY ANALYSIS AND T-TEST FOR THE 2012 SEASON

Aduamoa Community

Average cost and revenue per acre for adopters(GH¢)2	2012 real aver. per acre(GH¢)		Average cost and revenue per acre for non adopters(GH¢)2	2012 real aver.per acre(GH¢)
GROSS INCOME	259.4594595		GROSS INCOME	3024.774775
VARIABLE COSTS			VARIABLE COSTS	
Planting material	6.306306306		Planting material	18.01801802
Fertilizer(NPK)	65.31531532		Fertilizer(NPK)	41.89189189
Fertilizer(Sulphate of Ammonia)	42.79279279		Fertilizer(Sulphate of Ammonia)	26.12612613
Insecticide	9.459459459		Insecticide	15.31531532
Weedicide	7.207207207		Weedicide	24.32432432
Biochar	23.64864865		Biochar	0
Labour	266.2162162		Labour	1072.072072
Transportation	0		Transportation	9.90990991
Maintenance	0		Maintenance	0
TOTAL VARIABLE COST	420.9459459		TOTAL VARIABLE COST	1207.657658
GROSS MARGIN	-161.4864865		GROSS MARGIN	1817.117117
FIXED COST			FIXED COST	
Depreciation of equipments	27.52252252		Depreciation of equipments	90.22522523
TOTAL FIXED COST	27.52252252		TOTAL FIXED COST	90.22522523
NET FARM INCOME(GM-FIXED COST)	-189.009009		NET FARM INCOME(GM-FIXED COST)	1726.891892

```
. ttest REALACRENFIADUAADOPT2012 == REALACRENFIADUANONADOPT2012, unpaired

Two-sample t test with equal variances
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
REALAC.. |       2    -189.009    11.17117    15.79842   -330.9522   -47.06582
REALAC.. |       2    1726.892    494.4595    699.2713   -4555.811    8009.595
---------+--------------------------------------------------------------------
combined |       4    768.9414    588.7774    1177.555   -1104.811    2642.694
---------+--------------------------------------------------------------------
    diff |           -1915.901    494.5856               -4043.931    212.1293
------------------------------------------------------------------------------
    diff = mean(REALA~AADOPT2012) - mean(RE~ANONADOPT2012)        t =  -3.8737
Ho: diff = 0                                     degrees of freedom =        2

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0303         Pr(|T| > |t|) = 0.0606          Pr(T > t) = 0.9697
```

Akwasiho Community

Average cost and revenue per acre for adopters(GH¢)10	2012 real aver. per acre(GH¢)		Average cost and revenue per acre for non adopters(GH¢)51	2012 real aver. per acre(GH¢)
GROSS INCOME	4789.63964		GROSS INCOME	2251.336631
VARIABLE COSTS			VARIABLE COSTS	
Planting material	27.74774775		Planting material	17.68651004
Fertilizer(NPK)	80.40540541		Fertilizer(NPK)	65.61561562
Fertilizer(Sulphate of Ammonia)	35.58558559		Fertilizer(Sulphate of Ammonia)	29.06141436
Insecticide	22.82282282		Insecticide	16.88865336
Weedicide	11.8018018		Weedicide	13.82382382
Biochar	43.40840841		Biochar	0
Labour	1554.624625		Labour	1026.714361
Transportation	26.12612613		Transportation	21.80827887
Maintenance	2.297297297		Maintenance	5.406583054
TOTAL VARIABLE COST	1804.81982		TOTAL VARIABLE COST	1197.005241
GROSS MARGIN	2984.81982		GROSS MARGIN	1054.33139
FIXED COST			FIXED COST	
Depreciation of equipments	60.55165165		Depreciation of equipments	44.79647785
TOTAL FIXED COST	60.55165165		TOTAL FIXED COST	44.79647785
NET FARM INCOME(GM-FIXED COST)	2924.268168		NET FARM INCOME(GM-FIXED COST)	1009.534912

```
. ttest REALACRENFIAKWASADOPT2012 == REALACRENFIAKWASNONADOPT2012, unpaired

Two-sample t test with equal variances
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
REALAC.. |      10    2924.268    1328.839    4202.158   -81.77457    5930.311
REALAC.. |      51    1009.535    227.4766    1624.508    552.6346    1466.435
---------+--------------------------------------------------------------------
combined |      61    1323.426    296.3929    2314.902    730.5516      1916.3
---------+--------------------------------------------------------------------
    diff |            1914.733    767.9035                378.1618    3451.305
------------------------------------------------------------------------------
    diff = mean(REALA~SADOPT2012) - mean(RE~SNONADOPT2012)        t =   2.4935
Ho: diff = 0                                     degrees of freedom =       59

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.9923         Pr(|T| > |t|) = 0.0155          Pr(T > t) = 0.0077
```

Suminakese Community

Average cost and revenue per acre for adopters(GH¢)2	2012 real aver. per acre(GH¢)
GROSS INCOME	8562.162162
VARIABLE COSTS	
Planting material	57.65765766
Fertilizer(NPK)	38.73873874
Fertilizer(Sulphate of Ammonia)	0
Insecticide	15.31531532
Weedicide	7.207207207
Biochar	31.08108108
Labour	5027.927928
Transportation	6.306306306
Maintenance	0
TOTAL VARIABLE COST	5184.234234
GROSS MARGIN	3377.927928
FIXED COST	
Depreciation of equipments	26.73873874
TOTAL FIXED COST	26.73873874
NET FARM INCOME(GM-FIXED COST)	3351.189189

Average cost and revenue per acre for non adopters(GH¢)22	2012 real aver. per acre(GH¢)
GROSS INCOME	12269.04177
VARIABLE COSTS	
Planting material	25.11602512
Fertilizer(NPK)	73.28692329
Fertilizer(Sulphate of Ammonia)	9.425334425
Insecticide	14.004914
Weedicide	18.83701884
Biochar	0
Labour	2371.225771
Transportation	5.364455364
Maintenance	0
TOTAL VARIABLE COST	2517.260442
GROSS MARGIN	9751.781327
FIXED COST	
Depreciation of equipments	11.15902266
TOTAL FIXED COST	11.15902266
NET FARM INCOME(GM-FIXED COST)	9740.622304

```
. ttest REALACRENFISUMIADOPT2012 == REALACRENFISUMINONADOPT2012, unpaired

Two-sample t test with equal variances
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
REALAC.. |       2    3351.189    1174.036    1660.338   -11566.35    18268.73
REALAC.. |      22    9740.622    6625.944    31078.43   -4038.782    23520.03
---------+--------------------------------------------------------------------
combined |      24     9208.17    6073.351    29753.22   -3355.515    21771.85
---------+--------------------------------------------------------------------
    diff |           -6389.433    22426.74               -52899.65    40120.78
------------------------------------------------------------------------------
    diff = mean(REALA~IADOPT2012) - mean(RE~INONADOPT2012)        t =  -0.2849
Ho: diff = 0                                     degrees of freedom =       22

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.3892         Pr(|T| > |t|) = 0.7784          Pr(T > t) = 0.6108
```

REGRESSION RESULTS FOR THE 2011 SEASON

```
Probit regression                                 Number of obs   =        156
                                                  LR chi2(12)     =      80.17
                                                  Prob > chi2     =     0.0000
Log likelihood = -57.000505                       Pseudo R2       =     0.4129
```

ADOPTION	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
FSIZE	.3859589	.1855192	2.08	0.037	.0223479	.7495698
GENDER	.2905182	.3248572	0.89	0.371	-.3461901	.9272265
AGE	.2329222	.1165809	2.00	0.046	.0044277	.4614166
AGESQUARED	-.0020524	.0011039	-1.86	0.063	-.004216	.0001113
EDUC	.1768066	.2959677	0.60	0.550	-.4032794	.7568927
MSMARRIED	.1339837	.3736612	0.36	0.720	-.5983788	.8663463
FBO	1.718612	.3343562	5.14	0.000	1.063286	2.373938
OUTPUT	.0004162	.0002935	1.42	0.156	-.000159	.0009914
CREDIT	.5525945	.3066695	1.80	0.072	-.0484667	1.153656
EXTVISIT	.0013576	.0502312	0.03	0.978	-.0970937	.0998089
NONFARMJOB	.090764	.2844086	0.32	0.750	-.4666667	.6481947
FPART	1.317659	.3201701	4.12	0.000	.690137	1.945181
_cons	-9.454279	3.152436	-3.00	0.003	-15.63294	-3.275619

```
Marginal effects after probit
      y  = Pr(ADOPTION) (predict)
         =  .2023185
```

variable	dy/dx	Std. Err.	z	P>|z|	[95%	C.I.]	X
FSIZE	.1088032	.0514	2.12	0.034	.008056	.209551	1.07212
GENDER*	.0831913	.09494	0.88	0.381	-.102896	.269279	.429487
AGE	.0656616	.03069	2.14	0.032	.005504	.125819	49.0641
AGESQU~D	-.0005786	.00029	-1.97	0.049	-.001154	-2.8e-06	2548.95
EDUC*	.0487855	.07985	0.61	0.541	-.107718	.205289	.641026
MSMARR~D*	.0367851	.09933	0.37	0.711	-.157899	.231469	.730769
FBO*	.5640643	.102	5.53	0.000	.364149	.763979	.275641
OUTPUT	.0001173	.00008	1.40	0.162	-.000047	.000282	512.654
CREDIT*	.1665338	.09774	1.70	0.088	-.025027	.358095	.333333
EXTVISIT	.0003827	.01415	0.03	0.978	-.027358	.028124	3.96154
NONFAR~B*	.0255716	.08007	0.32	0.749	-.131357	.1825	.50641
FPART*	.3380903	.07289	4.64	0.000	.195231	.480949	.570513

(*) dy/dx is for discrete change of dummy variable from 0 to 1

```
Truncated regression
Limit:    lower =          0                      Number of obs =        49
          upper =       +inf                      Wald chi2(12) =     28.26
Log likelihood =  14.344418                       Prob > chi2   =    0.0051
```

ADOPTINTEN~Y	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
FSIZE	-.116996	.0540444	-2.16	0.030	-.222921	-.011071
GENDER	-.0736722	.076188	-0.97	0.334	-.2229979	.0756535
AGE	.0300394	.0302482	0.99	0.321	-.0292461	.0893248
AGESQUARED	-.000318	.000288	-1.10	0.269	-.0008825	.0002464
EDUC	-.0320574	.0628191	-0.51	0.610	-.1551806	.0910658
MSMARRIED	-.0170827	.0859734	-0.20	0.842	-.1855874	.151422
FBO	.1739851	.0718717	2.42	0.015	.033119	.3148511
OUTPUT	.0000178	.0000611	0.29	0.771	-.0001019	.0001375
CREDIT	-.0575427	.0610019	-0.94	0.346	-.1771043	.0620189
EXTVISIT	-.0011156	.0144231	-0.08	0.938	-.0293844	.0271532
NONFARMJOB	-.0588788	.0616982	-0.95	0.340	-.1798051	.0620475
FPART	-.1814859	.1017413	-1.78	0.074	-.3808952	.0179235
_cons	.5220459	.8017445	0.65	0.515	-1.049345	2.093436
/sigma	.18064	.0182863	9.88	0.000	.1447995	.2164805

REGRESSION RESULTS FOR THE 2012 SEASON

```
Probit regression                                 Number of obs   =         89
                                                  LR chi2(12)     =      26.54
                                                  Prob > chi2     =     0.0090
Log likelihood = -25.457772                       Pseudo R2       =     0.3427
```

ADOPTION	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
FSIZE	-.2636934	.2987903	-0.88	0.377	-.8493116	.3219247
GENDER	-.0965729	.4867541	-0.20	0.843	-1.050593	.8574476
AGE	.0827429	.18662	0.44	0.657	-.2830255	.4485114
AGESQUARED	-.0005082	.0017233	-0.29	0.768	-.0038859	.0028695
EDUC	-.3426309	.4796177	-0.71	0.475	-1.282664	.5974025
MSMARRIED	1.173292	.6712544	1.75	0.080	-.1423423	2.488926
FBO	2.442827	1.028957	2.37	0.018	.4261088	4.459546
OUTPUT	.0012039	.0004146	2.90	0.004	.0003912	.0020165
CREDIT	1.213581	.6139466	1.98	0.048	.0102681	2.416895
EXTVISIT	-.1207953	.0849773	-1.42	0.155	-.2873477	.0457571
NONFARMJOB	1.199145	.5351507	2.24	0.025	.1502687	2.248021
FPART	1.605765	.5889195	2.73	0.006	.4515045	2.760026
_cons	-6.877237	5.066423	-1.36	0.175	-16.80724	3.052769

```
Marginal effects after probit
      y  = Pr(ADOPTION) (predict)
         =  .04789119
```

variable	dy/dx	Std. Err.	z	P>|z|	[95%	C.I.]	X
FSIZE	-.0262758	.02993	-0.88	0.380	-.084939	.032387	1.26124
GENDER*	-.0095516	.0482	-0.20	0.843	-.104017	.084914	.449438
AGE	.0082449	.01867	0.44	0.659	-.028351	.04484	49.2022
AGESQU~D	-.0000506	.00017	-0.30	0.768	-.000387	.000286	2543.9
EDUC*	-.0374687	.05875	-0.64	0.524	-.152624	.077687	.651685
MSMARR~D*	.0702523	.04239	1.66	0.097	-.012832	.153337	.808989
FBO*	.709824	.29705	2.39	0.017	.127619	1.29203	.044944
OUTPUT	.00012	.00005	2.25	0.024	.000016	.000224	725.562
CREDIT*	.194757	.11812	1.65	0.099	-.036752	.426266	.269663
EXTVISIT	-.0120367	.00789	-1.53	0.127	-.027502	.003428	4.33708
NONFAR~B*	.1435988	.07716	1.86	0.063	-.007624	.294822	.449438
FPART*	.1990868	.07886	2.52	0.012	.044523	.35365	.47191

(*) dy/dx is for discrete change of dummy variable from 0 to 1

```
Truncated regression
Limit:   lower =          0                     Number of obs =      14
         upper =       +inf                     Wald chi2(12) =1122.46
Log likelihood =    25.2219                     Prob > chi2   = 0.0000
```

ADOPTINTEN~Y	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
FSIZE	-.0141786	.1145868	-0.12	0.902	-.2387647	.2104075
GENDER	.8687426	.0589268	14.74	0.000	.7532482	.9842369
AGE	.3525363	.0432741	8.15	0.000	.2677207	.4373519
AGESQUARED	-.0032136	.0003621	-8.88	0.000	-.0039232	-.002504
EDUC	.7219475	.0546784	13.20	0.000	.6147799	.8291151
MSMARRIED	-.8337177	.0973555	-8.56	0.000	-1.024531	-.6429044
FBO	-.822965	.1962023	-4.19	0.000	-1.207514	-.4384156
OUTPUT	-.0006885	.0000842	-8.17	0.000	-.0008535	-.0005234
CREDIT	.1722699	.1074528	1.60	0.109	-.0383336	.3828735
EXTVISIT	.0183957	.0126217	1.46	0.145	-.0063424	.0431338
NONFARMJOB	.8161616	.0821556	9.93	0.000	.6551396	.9771837
FPART	-.0177559	.093063	-0.19	0.849	-.200156	.1646442
_cons	-8.389201	1.459039	-5.75	0.000	-11.24887	-5.529537
/sigma	.039935	.007547	5.29	0.000	.0251431	.0547268

POOLED SAMPLE REGRESSION RESULTS

```
Probit regression                               Number of obs   =        245
                                                LR chi2(13)     =     102.08
                                                Prob > chi2     =     0.0000
Log likelihood =  -88.62269                     Pseudo R2       =     0.3654
```

ADOPTION	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
FSIZE	.1476157	.1366991	1.08	0.280	-.1203096	.415541
GENDER	.174242	.2535883	0.69	0.492	-.3227819	.6712659
AGE	.1815234	.0935636	1.94	0.052	-.0018578	.3649047
AGESQUARED	-.0015381	.0008791	-1.75	0.080	-.0032612	.0001849
EDUC	-.0177768	.2345049	-0.08	0.940	-.477398	.4418445
MSMARRIED	.3487478	.3065683	1.14	0.255	-.2521149	.9496106
FBO	1.512107	.2845329	5.31	0.000	.9544326	2.069781
OUTPUT	.0005712	.0002006	2.85	0.004	.0001781	.0009643
CREDIT	.5401584	.2475978	2.18	0.029	.0548758	1.025441
EXTVISIT	-.0276669	.0383946	-0.72	0.471	-.1029189	.0475851
NONFARMJOB	.3808404	.2309928	1.65	0.099	-.0718971	.8335779
FPART	1.2309	.2574419	4.78	0.000	.7263235	1.735477
SEASON	-.2975016	.2451129	-1.21	0.225	-.7779142	.1829109
_cons	-7.912396	2.528246	-3.13	0.002	-12.86767	-2.957125

```
Marginal effects after probit
      y  = Pr(ADOPTION) (predict)
         =  .15850834
```

variable	dy/dx	Std. Err.	z	P>|z|	[95%	C.I.]	X
FSIZE	.035697	.03275	1.09	0.276	-.028482	.099876	1.14082
GENDER*	.0425995	.06278	0.68	0.497	-.080442	.165641	.436735
AGE	.0438967	.02136	2.06	0.040	.002033	.08576	49.1143
AGESQU~D	-.0003719	.0002	-1.84	0.066	-.000769	.000025	2547.11
EDUC*	-.0043099	.057	-0.08	0.940	-.11603	.10741	.644898
MSMARR~D*	.0768009	.06019	1.28	0.202	-.041177	.194779	.759184
FBO*	.4892116	.09859	4.96	0.000	.295983	.68244	.191837
OUTPUT	.0001381	.00005	2.82	0.005	.000042	.000234	589.996
CREDIT*	.1436295	.07124	2.02	0.044	.003995	.283264	.310204
EXTVISIT	-.0066905	.00932	-0.72	0.473	-.024956	.011575	4.09796
NONFAR~B*	.0925902	.05602	1.65	0.098	-.017216	.202397	.485714
FPART*	.285794	.05491	5.20	0.000	.17817	.393418	.534694
SEASON*	-.0690371	.05438	-1.27	0.204	-.17563	.037556	.363265

(*) dy/dx is for discrete change of dummy variable from 0 to 1

```
Truncated regression
Limit:   lower =          0                          Number of obs =      63
         upper =       +inf                          Wald chi2(13) =   25.16
Log likelihood =  5.7412831                          Prob > chi2   = 0.0220
```

ADOPTINTEN~Y	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
FSIZE	-.1471025	.0526568	-2.79	0.005	-.250308	-.043897
GENDER	.0088792	.0788046	0.11	0.910	-.145575	.1633333
AGE	.0328855	.0323885	1.02	0.310	-.0305947	.0963657
AGESQUARED	-.0003478	.0003049	-1.14	0.254	-.0009453	.0002498
EDUC	-.0030476	.0676424	-0.05	0.964	-.1356242	.1295291
MSMARRIED	-.050428	.0933811	-0.54	0.589	-.2334516	.1325955
FBO	.0874169	.0769028	1.14	0.256	-.0633098	.2381436
OUTPUT	-.0000625	.0000592	-1.06	0.291	-.0001786	.0000536
CREDIT	.0247277	.0676057	0.37	0.715	-.1077771	.1572326
EXTVISIT	-.0095166	.0145354	-0.65	0.513	-.0380053	.0189722
NONFARMJOB	.0127782	.0691393	0.18	0.853	-.1227324	.1482888
FPART	-.1805542	.1004419	-1.80	0.072	-.3774168	.0163084
SEASON	.1376439	.0780451	1.76	0.078	-.0153217	.2906095
_cons	.5168821	.8794802	0.59	0.557	-1.206867	2.240632
/sigma	.2218198	.0199586	11.11	0.000	.1827016	.260938