CONTRIBUTION OF IMPROVED CHARCOAL KILNS TO THE HOUSEHOLDS' INCOME IN KILINDI DISTRICT, TANZANIA

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ENVIRONMENTAL AND NATURAL RESOURCE ECONOMICS OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2017

ABSTRACT

Contribution of improved charcoal kilns to households' income is not well documented. This study analysed contribution of improved charcoal kilns to households' income in Kilindi district by focusing on; characterizing charcoal producers, economic contribution of improved charcoal kilns and examining factors underlying the use of improved charcoal kilns. The study used questionnaires and checklists to collect data from 200 charcoal producers. Gross margin was used to analyse the contribution of improved kilns to the household income while logistic model was used to examine factors influencing the use of improved kilns. Descriptive statistics were used to characterize charcoal production kilns and extent of usage. Results indicated that about 40% and 60%of charcoal producers use improved kilns and traditional kilns respectively. The results of profit analysis showed that charcoal contributes about 82% of the total income of the households engaged in charcoal production, followed by on farm activities which contributed about 16%. The analysis further showed that producers who use improved kilns had a gross margin of 62% while those who used traditional kilns had 47%. This implies to every TZS 10 000 sales of a charcoal producers retains TZS 6200 and TZS 4700 as a profits when using improved and traditional kilns respectively. The results further showed that age of a producer, membership to charcoal social networks, level of income, producer training and positive perception towards improved charcoal kilns significantly influence a producer to choose improved kilns in the production. The marital status variable significantly reduces likelihood of producer using improved charcoal kiln. The study emphasises the use of improved kilns to increase efficiency and profit margins since the technology is highly profitable as compared to traditional kilns.

DECLARATION

I, Peter Cyprian Fitwangile, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

Peter Cyprian Fitwangile | Date

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The above declaration is confirmed by:

Dr. Felister Mombo | Date

(Supervisor)

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ACKNOWLEDGEMENTS

First and foremost, I would like to express my profound gratitude to the Almighty God for smoothening all aspects of my life and my study in particular.

I would like to extend my heartfelt thanks to my supervisor Dr. Felister Mombo for her valuable advice, insight and guidance to the completion of the research work. Successful and timely accomplishment of this study would have been very difficult without her generous time, devotion and support from the early proposal development till the final write up of the thesis.

My sincere appreciation also goes to my employer the Government of United Republic of Tanzania through Ministry of Natural Resources and Tourism for granting me a study leave as well as sponsoring my MSc. studies at Sokoine University of Agriculture. Besides, I am thankful to the genuine support of all my colleagues who provided me with all the necessary resources, encouragement and valuable advice at all levels of my thesis work.

Last but not the least, my heart-felt thanks and appreciation goes to my beloved wife Catherine M Jullu for the love, support and encouragement. Truly speaking, without her committed support it would have been difficult for me to successfully complete my thesis research work. Finally, my special thanks go to my daughters Janeth, Jackline and Josephine as well as the rest of my family members for their unmentionable tolerance, encouragement and support.

DEDICATION

I dedicate this work to my parents, Anna Lidodi and Cyprian Fitwangile, whom I lost before joining M.Sc. Study. May their souls rest in internal peace. Amen.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND ACRONYMS

CHAPOSA	Charcoal potential in Southern Africa
EPK	Earth Pit Kiln
GM	Gross Margin
HOBK	Half Orange Brick Kiln
IEMK	Improved Earth Mound Kiln
MJ	Mega Joules
MNRT	Ministry of Natural Resources and Tourism
TZS	Tanzania Shillings
USD	United States Dollar
GDP	Gross Domestic Product

CHAPTER ONE

1.0 INTRODUCTION

1.2 Background of the study

Charcoal production and other relating activities are expanding in scope and magnitude in many tropical catchments especially in Sub-Saharan African countries (Oguntunde *et al.*, 2004, Glaser *et al.*, 2002, Ajayi, 2004). Across Sub-Saharan African (SSA), charcoal has the potential to provide accessible, affordable and reliable energy to millions of households, in addition to supporting millions of rural and urban livelihoods through income generation, providing urban–rural financial flows and contributing to the national economy. For example, in Malawi, the charcoal sector contributes an estimated $40 million, roughly 0.5% of national GDP (Kambewa *et al.*, 2007). Its production and trade will become an important source of income for an estimated 12 million people by 2030 yet there are large research gaps in the charcoal literature, which has led to a lack of evidence-based decision-making (Mwampamba *et al.*, 2013).

Charcoal is one among the most important energy source in Tanzania (World Bank, 2009). In the country about 90% of the country's energy needs are satisfied through the use of charcoal and firewood alone. Charcoal consumption per day is approximately 2650 metric tons which is equivalent to 1 million tons per year or approximately 1 m^3 of round wood per capita per year. The value of the entire charcoal sector in the country is approximately USD 1billion (NBES, 2014). The annual supply of wood needed for charcoal production is around 30 million cubic metres. In charcoal production it is estimated 160 000 earth kilns are used every year which is equivalent to 438 per day (Zulu and Richardson, 2012).

Large population in Tanzania, both urban and rural households use charcoal (Kajembe *et al.*, 2013). From 2001 to 2010 charcoal uses for cooking increased by 7% while in urban centres figure is higher than average (MNRT, 2013). According to Word Bank (2009) demand for charcoal is expected to increase even further because of increase of population of about 3% per year, the rising of urban population and relatively high perceived price of alternatives source of energy e.g. Gas (MNRT, 2013). This implies charcoal production activities will continue to be profitable business for those who are involved. There is good evidence that involvement in the charcoal trade can generate substantial incomes for participants (Monela *et al.*, 1993; Khundi *et al.*, 2011; Minten *et al.*, 2013), though incomes may be unevenly distributed. Middle-men are frequently portrayed as the most exploitative actors in the value chain, yet they play essential entrepreneurial roles connecting producers and consumers (Velde *et al.*, 2006).

Despite of the growing urban charcoal demand and markets providing opportunities for income generation from production of charcoal in rural areas where it is often commercialized, resources and thousands of rural and urban entrepreneurs earn vital income from charcoal production and trade (Zulu and Richardson, 2012). Malimbwi and Zahabu (2007) claim that there is limited number of people consider charcoal production to be their main economic activity and profits are used to be concentrated to few mainly transport agent and whole sellers while charcoal producers used to receive very small benefits among all player in the charcoal value chain. The authors besides, argue that small benefit earned among other factors is contributed by the use of highly inefficient use of traditional kilns with conversion efficiency of only 8% to 12%. Despite of the low efficiency rates most of producers use since these kilns presents practical, low investment options for poor producers.

Despite efforts to overcome challenge of low efficiency level by promoting more efficient kilns for charcoal production has been having disappointing rates, World Bank (2009) identified reasons for low adoption including most of charcoal producers are informal and often illegal, high investment cost and low knowledge on advantages of improved kilns compared to traditional kilns.

1.2 Problem Statement

Improved charcoal kilns have a potential of significantly contributing to efficient production and income to charcoal producers (Zulu and Richardson, 2012). Despite this proven fact, most of charcoal producers in Tanzania still use traditional kilns in charcoal making with conversion efficiency of less than 20% which lose about 60 to 80% of the woods energy (Neufeld *et al*., 2005). Besides, advantages of improved kilns in environment and income, their use have failed due to lack of capital for kiln construction, lack of awareness of their advantages and small producers find them to be incontinent since they are stationary while traditional kilns can be easily built from place to place where inputs are available (Zulu and Richardson, 2012).

According to Malimbwi and Zahabu (2007), there is no incentive for charcoal producers to adopt to efficient production technologies because of combination of reasons including market failure, unrealistic fees and royalties, behaviour towards open access resources, and ignorance on advantages in terms of income and long term effects on environment sustainability.

This research intends to explore the contribution of improved kilns to the households' incomes of those that are involved in charcoal production. The findings will contributed to inform the producers how much improved kilns are advantageous in terms of increasing income when compared to traditional kilns. The findings can therefore be used by decision and developers in promoting the use of improved kilns in the study area.

1.3 Justification of the Study

Inefficient charcoal kilns causes producers to use more wood to produce a unit of output due to a significant loss during the process. As a result production using inefficient kilns not only causes depletion of wood resources, also charcoal producers loose significant portion of output which could result into higher profit if the loss is controlled. Besides, due to inefficiencies the radius of the area where materials are collected is increasing and therefore increases to transport cost due to distance which further squeezes the profit and therefore income (MNRT, 2001).

Since the results of this study contributed to the justification of using improved charcoal kilns to increase the income of the households engaged in charcoal production, the information gathered shall be used to convince the producers in the study area and the entire country to adopt the technology. Specifically for the study area, producers knowing how and by how much improved kilns are profitable compared to traditional kilns findings will help to change their perception towards the use of improved kilns.

1.4 The Study Objectives

1.4.1 General objective

The study intended to analyse the contribution of improved charcoal kilns to the incomes of the households engaged in charcoal production in Kilindi District.

1.4.2 Specific objectives

The specific objectives were to;

i. Characterize charcoal production kilns in the study area
ii. Analyses economic contribution of improved charcoal kilns to the household income
iii. Examine factors underlying the use of improved charcoal kiln by charcoal producers.

1.5 Research Questions

The study strove to answer the following questions;

i. What types of improved charcoal kilns are used in the study area?
ii. What is the contribution of improved charcoal kilns to the income of charcoal producers?
iii. What factors/constraints hinder the use of improved kiln by charcoal producers?

1.6 Conceptual Framework of the Study

Figure 1 shows a conceptual framework showing the salient factors driving to unsustainable charcoal production and its consequent effects to both the environment and the socio-economic perspective. According to Linda (1999), the conceptual framework acts as a basis for discussing the relationship between different groups, individuals or issues and can always be progressively revisited as further information becomes available.

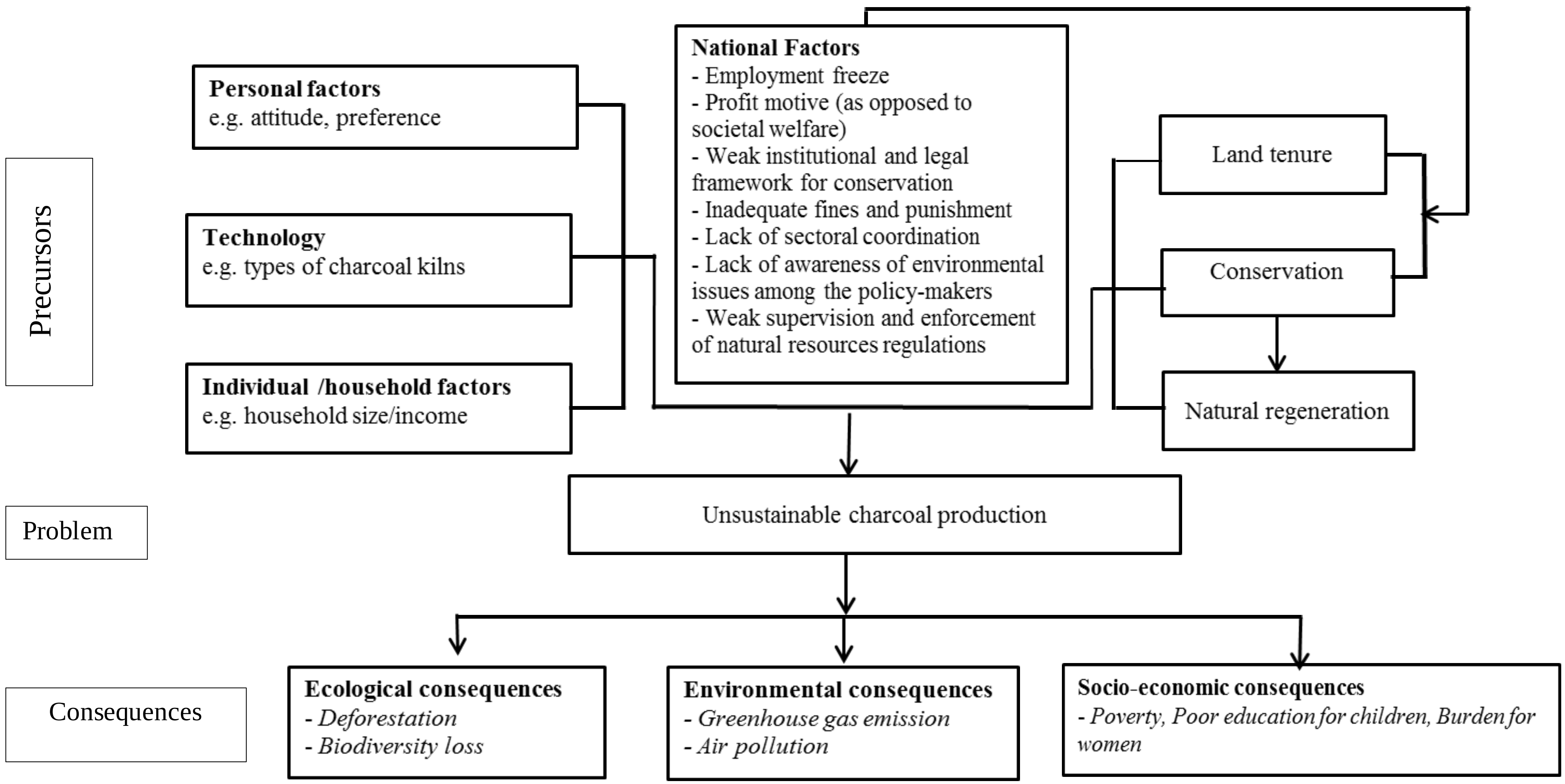

Figure 1: Conceptual frame work as adapted from Lusambo (2009)

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Charcoal Sector

2.1.1 Charcoal consumption

Charcoal is a source of energy for around 90% of the households in Tanzania. Charcoal is mainly produced in rural area and consumed by both urban and rural households (MNRT, 2013; Malimbwi and Zahabu, 2007). According to Kaale (2005) charcoal is preferred by most of its consumers because of its high calorific value of labour 31.8 $MJKg^{-1}$ compared to its close substitutes such as fire wood which has only16 $MJKg^{-1}$. Due to this property it is economical to use in terms of transportation over long distance, less smoke comparing to firewood and easy storage. Unlike firewood, charcoal is less liable to deteriorate by insects and fungi and it produces less smoke (Malimbwi and Zahabu, 2007). Also compared to other available energy sources such as electricity, gas and coal, charcoal is far way cheaper and therefore affordable to most of households around the country (MNRT, 2013).

2.1.2 Charcoal production

In charcoal business there are main three types of producers, full time producers who live nearby forest areas and produce throughout the year, occasional producers who produce to meet cash needs in any point in a year and seasonal producer who produce after farming season is over waiting for another season (Zahabu, 2001; CHAPOSA, 2002).

According to Zahabu and Malimbwi (2007) income of charcoal seem to be above the minimum wage paid in a country therefore attracts many people to engage in it since it does not require any formal education and most of labour used to be derived from household or easily hired. On the other hand small capital and simple manual tools such as hand hoes, axes, spade, and rakes are needed. Also the production process requires simple processes such as tree cutting, billet making, kiln construction, firing, carbonisation, unloading the charcoal, filling the bags and transportation to where charcoal is needed for consumption.

2.2 Charcoal Making Process

Charcoal can be produced through various methods such as simple earth kilns, brick kilns and other ways in which the process essentially charcoal is produced under a process called pyrolysis which involves breaking down of the chemical structure of wood under high temperature in the absence of air; after the process is complete charcoal is removed from the kilns. According to Hofstad (1997) around two thirds of energy is lost during the process and severity of the problem depends on the techniques of the producer such as using traditional methods or improved methods as discusses in the following subsections.

2.2.1 Traditional charcoal production

Until the beginning of the twentieth century virtually all charcoal was produced by traditional methods. Wood was put in dug-out earth pits, lit and covered with earth. The combustion of part of the wood produced enough heat to carbonize the remainder. This method allowed somewhat more control over combustion and carbonization than the pit method. Both techniques persist to this day in many developing countries, mainly because they are cheap. However, they often produce very low yields (typically 1 kg of charcoal from 8 to 12 kg or more of wood), inconsistent quality (because it is difficult to maintain uniform carbonization) and environmental pollution from the release of tars and poisonous gases (Abdallah and Monela, 2012).

Traditional charcoal production has led to severe deforestation around the biggest cities in Tanzania causing environmental stress and degradation, diminishing watershed management and rising vulnerability towards climate change. Tanzania has lost approximately 15% of its forest cover and more than 37% of its forest and woodland habitat (World Bank, 2009). About 70% of the deforestation is due to fuel wood harvests caused mainly by urban households. Dar es Salaam alone uses approximately 500 000 tons of charcoal annually and the amount of charcoal consumed is expected to further rise in the coming years. Over 90% of Tanzanian households use wood based fuel (charcoal or firewood) as their primary source of fuel.

2.2.2 Improved traditional methods

In the 1970s and 1980s, efforts were made to improve traditional charcoal making by equipping earth kilns with chimneys made from oil drums (Casamance kilns) and by introducing small-scale steel or brick kilns. Currently in Tanzania there are two known improved kiln efficiency projects, the Half Orange Brick Kiln (HOBK) and the Improved Earth Mound Kiln (IEMK). The average carbonization efficiency of these improved technologies is estimated to be in between 27–35% which seem to be more advanced compared to the kilns EPK and EMK. Therefore use of the Improved Earth Mound Kiln (IEMK) with better kiln management could be a better option than EPK and HOBK. The IEMK is based on the traditional earth mound kiln but modified by limiting air supply thereby controlling inlet air and limiting the exhaust air to a single chimney.

According to Bailis (2013) the EMK is the common method of making charcoal Tanzania with conversion efficiency ranging 10 and 20%. CHAPOSA (2002) reported that in Tanzania 1 m^3 of wood has a yield of 2.7 bags meaning that with a kiln with average efficiency of 19%, 18 trees of 32cm at breast height can produce 56 kg of charcoal.

Factors influencing kiln efficiency variation included moisture content of the wood involved in kiln preparation and its weight meaning that tree species used significantly affects kiln efficiency (Hofstad, 1997). Other factors which affect efficiency according to Ishengoma and Nagoda (1991) include lack of proper control during carbonisation process as a result of complete combustion of some of the wood; CHAPOSA (2002) reported that the is problem is common especially for seasonal charcoal producers who are not well experienced.

In the country there are improved kiln efficiency projects including the Half Orange Brick Kilns and Improved Earth Mound Kiln with average efficiency ranging 27 and 35%. Among the options Half Orange Brick kilns are somehow costly and needs billets to be processed into specific sizes which is time consuming and increases transport cost, Improved Earth Mound Kilns however are relatively cheap and do not suffer the negatives of Half Orange Brick Kilns which make it best option for charcoal producers.

2.3 Theoretical Framework

The analysis of contribution of improved charcoal kilns to the income of the households of charcoal producers in the study area rests on the theories of adoption of a technology, profitability (gross margins) and theory of demand and supply.

2.3.1 Adoption theory

In adoption theory, individual will adopt particular technology over the other given that the utility derived from using is greater than other competing technology. Therefore after individual put into consideration his or her socio-economic constraints such as his or her own budget, government laws and test and preferences then individual will choose the technology which he or she think maximizes his or her utility objective function.

In economic perspective profitability theories comes in when an individual among other factors wants to determine whether or not the investment is profitable; the profit analysis was conducted to determine how much return is obtained after deducting all costs involved during production process. Therefore basing on the above theoretical rationality the general objective of the study was addressed through profit analysis and adoption analysis by looking on the factors influencing the use of improved charcoal kilns in the study area.

2.3.2 Gross margin

In order to determine how profitable using a certain charcoal production technology, it is important to know how production costs related to production revenue. In economic theory the gross margin for charcoal producer who using a given technology is amount of unit currency the charcoal producer retain as gross profit after deduction of all cost incurred during production.

In theory, do determine which kiln is profitable to charcoal producers, the gross margins of both improved kilns and traditional kilns was computed and the most profitable was the technology with statistically significant higher value of the gross margin.

2.3.3 Demand and supply

In deciding what to producer and how to produce there are variables which producers has control on them such as quantity to produce, number of labour to hire, tools and other inputs. However, there are other variables which producer do not have control over them and are taken as given since they are determined by interaction of market forces of demand and supply. According to laws of demand and supply in a market of commodity such as charcoal where there are many buyers and sellers, price of output, as well as other production inputs used be taken as given.

2.4 Empirical Studies on Charcoal Profitability

According to Dobie *et al.* (2015) kiln profitability is widely affected by several costs. In charcoal production at different levels there are costs which are expected and common to all producers. The most common costs involved during charcoal making are cost of tree cutting and processing, kiln construction, carbonisation, charcoal unloading, charcoal, packing, tools costs, empty bag costs, transport cost and labour cost. Sometimes depending on location other costs such as fees and taxes can be involved.

According to Dobie *et al.* (2015) tree cutting and tree preparation is most important single cost since through amount of tree cut down for charcoal making will widely influence other cost during production. Other important cost is labour cost since labours are the one who involved in the operations. Most of charcoal producers in Tanzania use family labour which can lead to actual cost to go down. However labour cost is still important cost factor common to all charcoal producers Zahabu and Malimbwi (2007).

Apart from that Mndeme (2008) identified tools costs as another important cost in charcoal production although during production process some of the tools can be reused over number of years until complete depreciation. In account the issue of reusing of tool Mndeme (2008) calculated a cost of using a tool by taking its purchasing price dividing by its expected life span and number of times it was used to reach a cost of tool per kiln. Other cost such as fees, taxes and other contributions used to be specific to production area and normally used not to be common to all of the producers; when reported by a producer its computation is also made similar to tool cost to reach a figure which will show its value per kiln (Mndeme, 2008).

On the other hand price use received by a producer used to be another important factor in profitability of charcoal, however due to existence of many producers of charcoal and many buyers price determination used to be determined by the market which producers used to take a given by market forces of demand and supply. Therefore in order to get more profit, producer is compelled to increase efficiency in charcoal production by reducing wasting resources by using various ways including adopting to the use of improved kilns.

In most of the studies conducted to analyse profitability in charcoal production common methods involves a gross margin analysis in which all monetary costs involved during charcoal production are deducted from the total revenue (Sulumbe *et al.,* 2010). The use of gross margins were used as proxies for profitability which is income going to the producers Erbaugh *et al.,* 2008). Therefore in this study the contribution of improved kilns to the income of the households were using similar methodology in which the gross margin of using improved kilns was computed to know by how much improved kilns are profitable. However, because charcoal producers are facing other alternative which was traditional kiln the gross margin of using improved kilns was calculated so as statistical comparison can be made.

2.5 Factors Influencing the Use of Improved Technologies

Individual adoption of a new technology depends on individual characteristics and physical needs of the production process that requires that technology (Talukder, 2012; Wale and Yallew, 2007)**.** An individual factor is one among important determinants of adoption to new technology because it refers to individuals' cognitive interpretation of the technology. According to Nkuba *et al.* (1999) individual factors including age, sex, experience, perceived usefulness and level of income influences individual's adoption of a new technology. Talukder (2012) also added training of usefulness of the technology and individual intersection with others who have used technology also influences the individuals' adoption to a new technology.

According to Nkuba *et al.* (1999) the decision to use or not use a new technology is a discrete choice. In literature there are several discrete choice models that can be used to analyse producers' technology choice decision. The models commonly used are Logit, Tobit and Probit models (Abebaw and Belay, 2001; Doss and Morris 2001 and Saha and Butler, 1995). However for the purpose of this study Logitmodel was used since it provides analysis of probability of a producer using or not use a technology as whole unlike Tobit or Probit models which use to calculate probabilities over certain range of interest values. Also logit model has an advantage of specifying variables as a linear function of the explanatory variables (Wooldridge, 2003).

The dependent variable of the Logit model used to be discrete where in this study was whether producer has used or not used improved kilns; explanatory variables was those hypothesized to influence adoption as mention by Talukder (2012) including producer characteristics variables (age, sex, level of education and marital status), producers socio-economic variables (level income, receiving training, membership to social networks) and producer perception variables (whether producer consider technology useful or not useful).

2.6 Variables and Expected Signs

2.6.1 Age

The coefficient of age of the charcoal producer is expected to have either positive or negative sign. It can be positive because producer's age is likely to enhance good decision making through accumulated wisdom from the life experiences; on the other hand it can be negative related to age young producers used to be more willing and likely to adopt to new technologies compared to old producers (Okaye *et al.*, 2008).

2.6.2 Sex

The sign of a coefficient of sex for a male producer is expected to be positive while for female is expected to be negative. In sub-Saharan societies according to Doss *et al.* (2011) women used to be disregarded in many aspects of life which limits them to the access to important resources such as land and credits. As a result of these social-cultural factors women used to have financial constraints compared to males which as a results hinders their ability to acquire new and relatively expensive technologies compared to male.

2.6.3 Education

The coefficient of education is expected to have a positive sign. More years of schooling by a producer are expected to increase her/his ability to efficiently acquire, synthesize and processing production information and become more likely to adopt improved technologies compared to less educated producers (Weir, 1999).

2.6.4 Experience

The coefficient of experience is expected to have a positive sign. Malimbwi and Zahabu (2007) argued that experience charcoal producers used to have better techniques, knowledge and exposure; due to this more years of experience in charcoal production is expected to increase the likelihood of producer being exposed to various production technologies and knowledge which make them more willing to adopt to new technologies such as improved kilns.

2.6.5 Income level

The coefficient of income level is expected to have a positive sign. According to Malimbwi and Zahabu (2007) the use of improved kilns need capital to be constructed; as income level increases the ability to purchase new and relatively expensive technology also increases. Producers with relatively high income are expected to be more willing to use improved kilns compared to producers with relatively low income level.

2.6.6 Charcoal producer received training

The coefficient of charcoal producer received training is expected to have a positive sign. According to Abdoulaye *et al.* (2014), producer training increases awareness and use of new technologies. Charcoal producer training on sustainable charcoal production by experts is likely to impact knowledge to producers on advantage of using improved charcoal kiln production and therefore increases the likelihood of producers using improved technologies.

2.6.7 Perceived usefulness of improved kiln

The coefficient of perceived usefulness of improved kilns is expected to have a positive sign. According to Talukder (2012) individual perspective may influence adoption of a new technology; the perspective can be influence by many factors such as social pressure including peers and people who their beliefs and opinions are important to the producer.

2.6.8 Social networks

The coefficient of a producer belonging to any charcoal social network is expected to have a positive sign. Social networks enable producers to interact with others which increase their exposer on various charcoal related issues including improved technologies (Talukder, 2012).

CHAPTER THREE

3.0 METHODOLOGY

This chapter presents methodology that was used to address the objectives of this study. The chapter starts with section describing the study area, followed by research design and sampling procedure and finally the chapter ends with description of how data was analysed.

3.1 Description of the Study Area

3.1.1 Location

The study was conducted in Kilindi district of Tanga region. The district is situated between 5.015^0 South and 6.005^0 South and longitude 37.05^0East and 38.05^0 East. It has a total area of approximately 6443.52 km^2 with 21 wards and 102 villages. The district has a population of 236 833 with density of 37 per km^2 (National Census, 2012). The altitude of this area ranges from 1000m-2400m above the sea level. As Figure 1 shows, in the east the district is boarded by Handeni district, to the south-east by Bagamoyo, to the west by Mvomero and Gairo, to the north Kilindi is boarded by Simanjiro and Kiteto to the north-west.

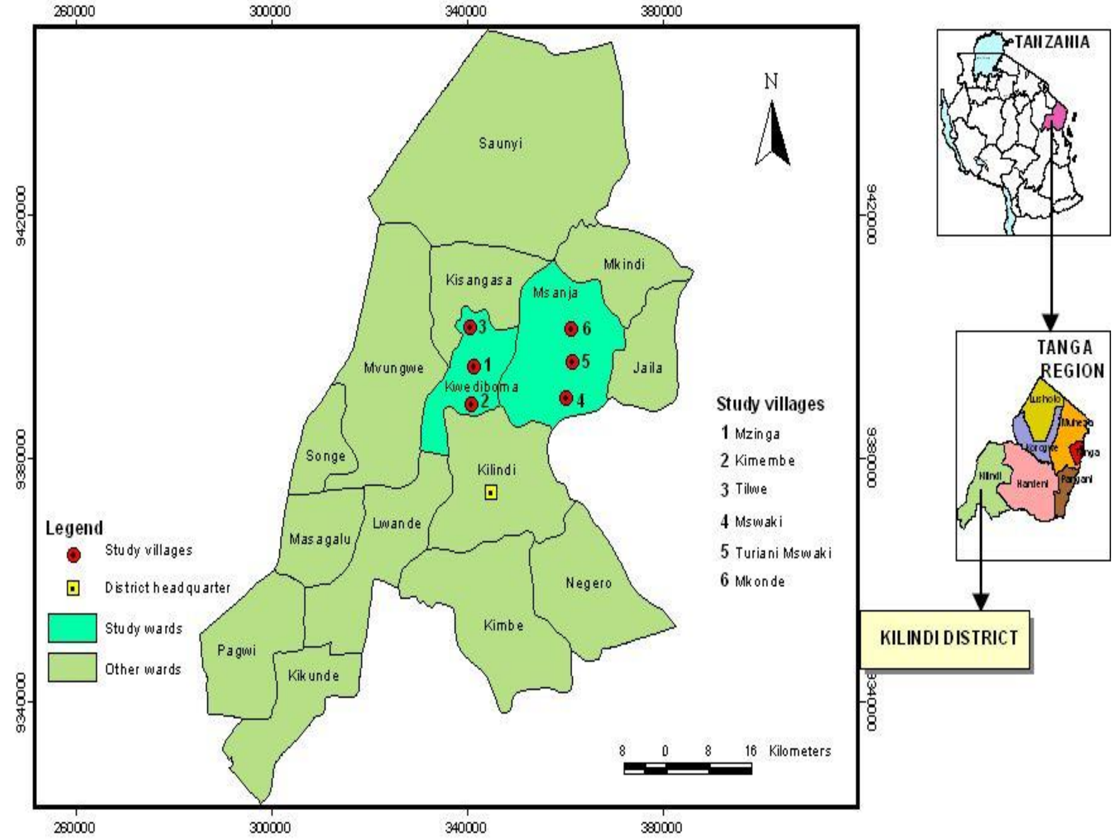

Figure 2: The map of Kilindi District showing study area

Source: GIS department of SUA

3.1.2 Climate

The climates range from hot and humid in dry plains to temperate in the mountains. The annual rainfall ranges between 500mm-800mm, the long rains are from February to May; and short rains from August to November (Hamilton, 1989). The temperatures of the area range from 21^{0}C to 24^{0}C.

3.1.3 Vegetation

Kilindi District is rich in indigenous and exotic tree species. It is characterized and dominated by woody plants, herbs, grasses and Miombo woodland respectively. However, natural vegetation cover has decreased in most parts due to human activities such as tree felling for timber and charcoal production, bush fires, new settlement establishment, shifting cultivation (slush and burn), as well as charcoal production which is a common practice (KDC, 2002).

3.1.4 Main economic activities

According to the 2012 Population and Housing Census, the major economic activities of the people in the study area are Agriculture and animal husbandry which employs about 77.4 percent of population. Other economic activities include mining, beekeeping, charcoal production, lumber and small trade. The main agricultural crops grown include maize, iris potatoes, banana, beans, spices, fruits and vegetables.

3.1.5 Research design and sampling procedure

A research design can be understood as the framework in which data is collected and analyzed (Bryman, 2008). Cross-sectional design was selected for this study because of its suitability whereby the design allows data collection at a single point of time from a large population therefore it is economic and flexible. A critical look at the research questions indicates that a pattern of association between and among the key variables which were sought and the cross-sectional design is a good choice in that regard. Cross sectional data was collected from a sample of charcoal producers in Kilindi district.

3.2 Sample Size and Sampling Techniques

3.2.1 Sampling techniques

The sample frame included charcoal producers in Kilindi district. The district was purposively sampled as a study area because a large number of people are involved in charcoal production for livelihood. Purposive sampling procedure was applied to select two wards of Msanja and Kwediboma from the list of 21 wards due to high charcoal production. One village was then selected from each ward purposefully namely Mswaki and Kimembe respectively from the list of villages based on charcoal production, marketing and accessibility to road. About 200 charcoal producers (both the users of improved and traditional kiln) were randomly selected for interview.

3.3 Data Collection

3.3.1 Primary data collection

Primary data were collected using household surveys, participant observation, key informant interview and focused group discussions.

3.3.1.1 Household survey

Detailed information for the study was collected during the household survey. Household surveys were used to identify characteristics of charcoal producers that influence their income in that particular activity. Other information collected were based on charcoal production (information on inputs, tools, types of kilns, shapes of kilns, size of the kilns, processes involved, costs and output), charcoal price and questions on perception of the charcoal makers on the usage of improved kilns. 200 households from two villages were randomly selected using village registers. The questionnaire survey was pre-tested

3.3.1.2 Researcher direct observation

Participant observation was another important data collection technique used to generate qualitative data. Through this technique first-hand information was obtained in relation to the various aspects of the research questions. Assuming my role as “observer-as-participant” (Bryman, 2008), I was immersed in groups in the communities over the extended period of two months, observed behaviour, listened to what is said in conversations and asked questions.

3.3.1.3 Key informant interview

Key informant interview by using checklist was used to collect supplementary information about charcoal production in Kilindi district. Key informant interviews are in-depth interviews of a select (nonrandom) group of experts who are most knowledgeable of the organization or issue. They often are used as part of program evaluations and needs assessments, though they can also be used to supplement survey findings, particularly for the interpretation of survey results.

3.3.1.4 Focus group discussion

Group discussions were conducted in each village with village leaders and charcoal buyers as stakeholders in charcoal production. These discussions focused on an overall picture of the charcoal production in the study area and how the charcoal producers benefit from the activity.

3.3.2 Secondary data collection

The study also used secondary data including publication, documents and statistics that were collected from the respective authorities.

3.4 Analytical framework

3.4.1 Characterization of charcoal production kilns in the study area

In this objective descriptive statistics were used for identification of different types of kilns used and other properties of those kilns such as shape and size. This objective also differentiated the number of charcoal producers who are using traditional kilns to improved ones. In addition, socio-economic characteristics of charcoal producers were presented and compared between charcoal producers who used improved kilns and traditional kilns. The comparison was made using chi-square test to see if there is any statistical difference in a given socio-economic characteristic and use of improved or traditional kilns.

3.4.2 Analysis of contribution of improved charcoal kilns to the household income

In this objective the analysis was conducted by examining the profit generated from charcoal production. In achieving this, profit analysis was derived using gross margins technique whereby the gross margin of charcoal producers using improved and traditional kilns was calculated separately. Later compared to see if there was any statistical difference and then find how much the producers retained as profit from selling charcoal. The gross margin was calculated by subtracting the cost from total revenue generated by the producer in their respective kilns. The formula that was used for gross margin is shown in equation 1 below.

$$G.M_k = \sum_i^j \left[\left(\frac{TR_{ik} - TC_{ik}}{TR_{ik}}\right)\right] x100 \qquad (1)$$

Where,

$G.M$ = Gross Margin, TR = Total Revenue, TC = Total Cost, n = Number of producers, i= i^{th} charcoal producer, k = 1 and 2, (where 1= traditional kiln and 2= improved kiln).

In computing gross margin the charcoal total cost was computed by including all components of costs which were involved in production of charcoal per kiln. According to a study by Mndeme (2008) charcoal production cost involves equipment's such as axe, hoe, rake, spade and machete costs, and production costs such as tree cutting, log processing, logs collection, logs transportation, kiln preparations, kiln supervision, unloading and packing the charcoal. The total revenue was calculated by getting total sells of bags from each kiln which is computed by taking number of total charcoal bags produced multiplying by its respective price.

After computing the gross margins of both improved kilns and traditional kilns, the comparison using student t-test statistics was conducted to determine if there is statistically significant difference between the two values.

In addition the share of different sources of income was presented to see contribution of each economic activity by a producer contributes to total income. The computation was conducted by finding the share of each economic activity of individual producer and later the aggregation from each individual was made to form the statistic for the whole study area. The economic activities that were used and common to the study area include own farm, wage labour, livestock, self-employment and charcoal production.

3.4.3 Factors influencing the use of improved charcoal kiln by charcoal producers

In this objective the factors influencing the use of improved charcoal was analysed by looking on what factors influences the charcoal producer to adopt the use of improved kilns. According to Wale and Yallew (2007) modelling producers decision on whether or not to adopt a technology constitute a discrete decision of whether or not to take up the technology. In number of adopting models assumes that producers are face with choice of two alternatives and a choice depends on identifiable characteristics of technology (Kaguongo *et al.*, 2010).

According to Kaguongo *et al*. (2010) modelling adoption following the random utility theory the decision of producers on whether or not to adopt the technology is guided by a utility maximizing objective which states that technology 2 (k_2) is preferred to technology 1 (k_1) only if the utility derived from new technology (k_2) is greater than the utility derived from old and existing technology (k_1).

The utility function ranking of i^{th} producer's' preference for technology is presented as shown in equation (2) below.

$$U(C_{ki}; A_{ki}) \ldots\ldots (2)$$

Where, C=Vector of production and producer specific attributes of the adopter, A= Vector of the attributes associate with the technology.

Technology adoption is defined by k with k_2 for new technology and k_1 for old technology. This implies the utility derived from adopting new technology depend on C and A. The variables C_{ki} and A_{ki} are not observable but a linear association is postulated between utility U derived from the t^{th} technology, a vector of observable production and producer characteristics X_i and a random disturbance term μ_k with zero mean as shown in Equation (3).

$$U_{ki} = \alpha_k X_{ki} + \mu_k \ldots\ldots (3)$$

Where, k =1 (traditional kiln), 2 (improved kiln) and i= 1,…,n

$U_{ki}$are random and therefore, the i^{th} producer will select the alternative kiln (k_2) if U_{2i}>U_{1i} or the latent random variable is as shown in Equation (4)

$$y^* = U_{2i} - U_{1i} > 0 \ldots\ldots (4)$$

A qualitative variable Y_i can represent the i^{th} producer's decision where $Y_i = 1$ if $U_{k2} > U_{k1}$ and new technology k_2 is adopted in adopting k_1 and $Y_i = 0$ otherwise.

The margin effect of a variable X_j on the probability of adopting new technology can be computed by differentiating P_i with respect to X_j as shown in Equation (5).

$$\frac{\partial P_i}{\partial X_{ij}} = f(Xi\beta).\beta_j \ldots\ldots (5)$$

Where, $f(.)$ is the margin probability density function of γ_j and j= 1,2,…J is the number of explanatory variables. The general form of the univariate dichotomous choice model is expressed as shown in equation (6).

$$P_i = P_i(Y_i = 1) = D(X_i, \theta) \ldots\ldots (6)$$

Where, i =a, 2, …n

Equation (6) states the probability that the i^{th} producer will adopt a specific technology is a function of the vector of explanatory variables X_i and unknown parameters vector θ. To specify D Logit model will be used.

The study was used the logit model to evaluate factors associated with charcoal producer's decision to use or not improved charcoal kilns. In the logit model, the probability of an individual farmer adopting improved kiln given a set of socio-economic and physical characteristics of (X) is given as shown in Equation (7).

$$P(k_2|X) = \frac{exp^{(\beta_0 + X_i\beta_i + \mu)}}{\left(1 + exp^{(\beta_0 + X_i\beta_i + \mu)}\right)} \ldots\ldots (7)$$

Similalry, the probability of not adopting the new kiln k_2 (continuing with traditional kilns k_2) is as shown in Equation (8) below.

$$P(k_1|X) = 1 - P(k_2|X) = 1 - \frac{exp^{(\beta_0 + X_i\beta_i + \mu)}}{\left(1+exp^{(\beta_0 + X_i\beta_i + \mu)}\right)} = \frac{1}{\left(1+exp^{-(\beta_0 + X_i\beta_i + \mu)}\right)} \ldots\ldots\ldots\ldots\ldots \text{(8)}$$

In this model the parameters are linear with normally distributed disturbance term.

Now dividing equation (7) by equation (8), gives the odds ratio in favour of adopting improved kiln by a charcoal producer as shown in Equation (9) below.

$$\frac{P(k_2|X)}{1-P(k_2|X)} = \frac{exp^{(\beta_0 + X_i\beta_i + \mu)}}{\left(1+exp^{(\beta_0 + X_i\beta_i + \mu)}\right)} \Big/ \frac{1}{\left(1+exp^{-(\beta_0 + X_i\beta_i + \mu)}\right)} = exp^{(\beta_0 + X_i\beta_i + \mu)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

(9)

By introducing natural logarithm in equation (9) results into Equation (10) as shown below.

$$L = ln\left(\frac{P(k_2|X)}{1-P(k_2|X)}\right) = \beta_0 + X_i\beta_i + \mu \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

(10)

Specific to this study equation (10) can be extended into equation (11) as shown below.

$$L = \beta_0 + X_1\beta_1 + X_2\beta_2 + X_3\beta_3 + X_4\beta_4 + X_5\beta_5 + X_6\beta_6 + \cdots X_n\beta_n + \mu \ldots\ldots\ldots\ldots\ldots\ldots \text{(10)}$$

Where, L= Dependent variable; X_1= Age; X_2= Sex; X_3= Education; X_4= Experience; X_5= Income level; X_6= Charcoal producer received training; X_7= Perceived usefulness improved kilns; X_8= Social networks; X_9= Marital status and μ= Error term

Table 1: Description of the variables used in a regression model

Variable		**Description**	**Expected Sign**
Dependent Variable			
The log of the odds ratio (1= Producer used improved kiln and 0 = Producer did not use improved kiln)	L	Dependent expressed in natural logarithm of probability of a charcoal producer using improved kilns ($P(k_2\|X)$) divided by probability of a charcoal producer not using improved kiln ($1 - P(k_2\|X)$). Where,	
Explanatory variables			
Age	X_1	Number of years of the charcoal producer	+/-
Sex (1= Male; 0 = Female)	X_2	Gender of the charcoal producer	+
Education (0= No school; 1=Primary school; 2= Secondary school; 3= Post-secondary school)	X_3	Formal Education level of the charcoal producer	+
Experience	X_4	Number of years a charcoal producer has been operating	+
Income level	X_5	Monthly estimated income is Tanzanian shillings of a charcoal producer	+
Charcoal producer received training (1= Yes; 0 = No)	X_6	Producer receiving any training on charcoal production improved technologies	+
Perceived usefulness of improved kilns (0= Not useful, 1= Moderate useful, 3= Very useful)	X_7	Perspective of charcoal producer on how useful improved charcoal kilns are in production process	+
Social networks (1=Yes; 0= No)	X_8	Charcoal producers membership to any charcoal production network	+
Marital status (1= Married; 0=Not married)	X_9	Charcoal producer marital status	+

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

This chapter presents the results and discussion of the study. It starts by describing characteristics of charcoal production in the study area; this followed by analysing the contribution of improved charcoal kilns to the household income. The chapter ends with determination of the factors influencing the use of improved charcoal kilns by the charcoal producers in the study area.

4.1 Characterising Charcoal Production Kilns in the Study Area

4.1.1 Type of kiln and charcoal producers characteristics

Table 2 shows the characteristics of charcoal producers in the study area where it was revealed that, about 45.5% of charcoal producers were less than 35 years old while 54.5% were 35 years and above. Statistically there was a significant difference between age group and use of particular kiln, and can be seen that for age group less than 35 years less proportion use improved kilns compared to age group 35 years and above who relatively large proportion use improved kilns. This implies there is positive association between age and using of improved kilns.

In the study area 32% of the producers are female while 68% of producers are males. Statistically there is no significant difference between sex of the producer and use of a particular kiln.

In the study area 17.5% live single while 82.5% are married. Statistically there is no significant difference between marital status and use of a particular kiln.

In the study area 11% of charcoal producers had no any formal education, 79% had primary school and 10% had secondary school and above. Among those with no school 6.5% use traditional kilns while 4.5% uses improved kilns, those with primary school 48% uses traditional kilns while 31% uses improved kilns while for those with secondary school and above 6% use traditional kilns while 4% use improved kilns. Statistically there was no significant difference between education level and use of particular kiln type.

In the study area 7% of producers have less than a year experience in charcoal production while 69.5% had 1 to 5 years of experience while 23.5% had over 5 years of experience. Statistically there is a significant difference between experience and use of particular kiln. For instance there were a higher proportion of producers using improved kiln for those with 5 years and above implying that more years of experience a likely to adopt to improved kilns.

In the study area 41.5% of charcoal producers had no training on charcoal production while 58.5% had training on charcoal production. Statistically there is a significant difference between receiving training and type of kiln used, as can be seen large proportion of producers with training used improved kilns implying that training increases awareness on advantages of improved kilns over traditional kilns.

Table 2: Charcoal producers characteristics by type of kiln used in percentage

Variables	Traditional Kilns	Improved Kilns	Total	$\chi 2$-test
Age				
Less than 35 years	30.5	15	45.5	0.054
35 years and above	30.0	24.5	54.5	0.068
Sex				
Female	22.0	10	32.0	
Male	38.5	29.5	68.0	
Marital Status				
Single	9.0	8.5	17.5	0.154
Married	51.5	31	82.5	
Education Level				
No school	6.5	4.5	11.0	0.988
Primary	48.0	31	79.0	
Secondary and above	6.0	4	10.0	
Experience in charcoal production				
Less than a year	5.0	2	7.0	0.050
1 to 5 years	46.0	23.5	69.5	
Above 5 years	9.5	14	23.5	
Training				
Charcoal producer did not receive training	37.0	4.5	41.5	0.000
Charcoal producer received training	23.5	35	58.5	
Total	60.5	39.5	100	

4.1.2 Kiln types and extent of use in the study area

In the study area as can be seen in Figure 2 about 60% of charcoal producers reported to use traditional kilns while 40% reported to improved kilns. This implies that in the area still a large number of people are using traditional kilns which are associated less efficiency and lower yields (BTG, 2010); and fewer producers uses improved kilns despite economic benefits that associate with them including less defiled charcoal and improved carbonisation which increase yield which translates to increased profit (Dobie *et al.,* 2015).This finding is similar to many studies such as Monela *et al.* 1999 and Chidumayo and Gumbo 1988 where in many places in a country producers uses traditional inefficient kilns with conversion rate ranging from 8 to 20 percent.

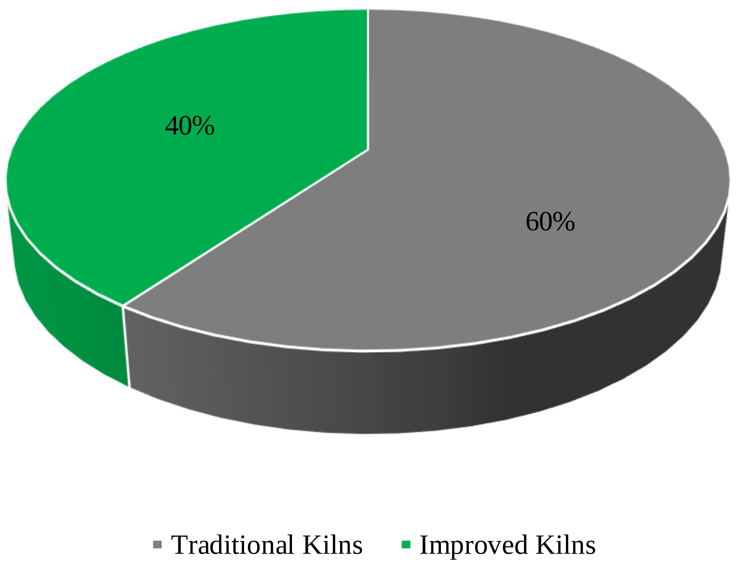

Figure 3: Charcoal kilns in the study

4.1.3 Kiln shape

The main type of the kiln used in the study area is rectangular shape which is used with 95% producers while few about 2% and 3% uses pyramid and bottle shaped kilns as shown in Figure 3. These findings are similar to that of Monela *et al.* 1999 where similar proportions were found. Regardless the shape traditional kilns used to be earth mould and made by covering billets with earth followed by carbonization process under limited air supply while improved kilns in addition used to have wire mesh or metal sheet to reduce contamination of charcoal and chimney to enhance control of the carbonization process.

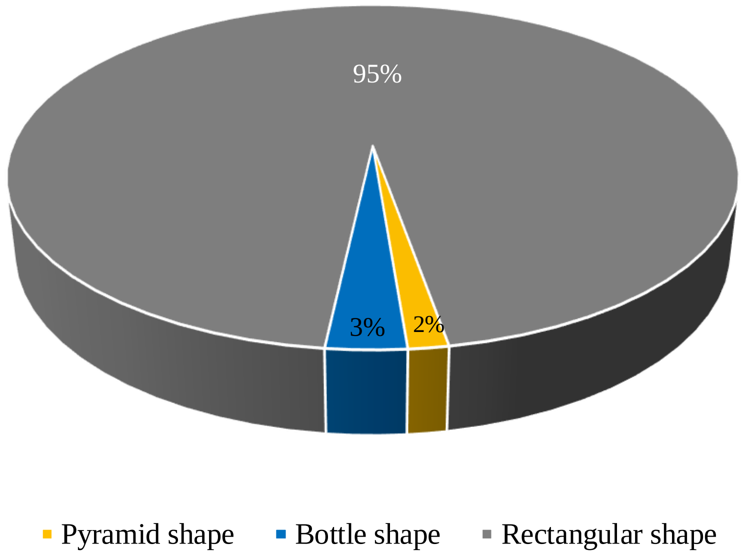

Figure 4: Kiln shapes

4.1.4 Kiln volume

Volume of kilns as can be seen in Figure 4 are divided in three categories of large volume ranging from 50m^3 and above, medium volume ranging from 10m^3 to less than 50m^3 and small volume which is less than 10m^3. In the study area 29% of improved kilns and 56% of traditional kilns are of large volume; 33% of improved kilns and 24% of traditional kilns are of medium volume while 33% of improved kilns and 20% of traditional kilns are of small volume. According to KFS, 2014 large volume used to involve high requirement of wood and transportation cost and when managed properly returns used to be high as well.

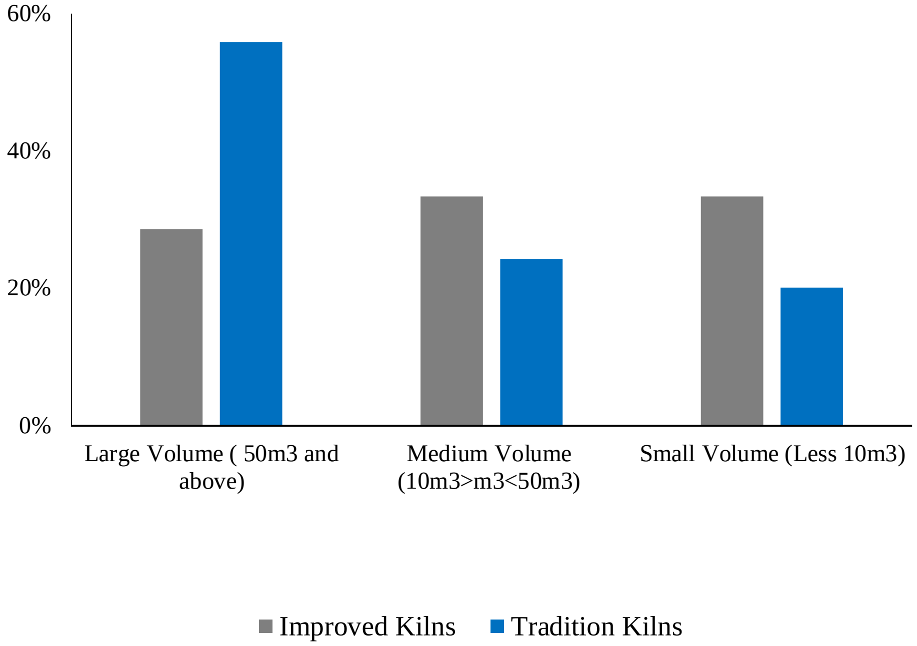

Figure 5: Kiln Volume

4.1.5 Tree species

As can be seen in Figure 5 there are various tree types used by charcoal producers in the study area. Approximately 29% of the producers in the study area use *Combretum molle*; according to Adeniji *et al.*, 2015 apart from looking on factors such as availability, producers used to select these tree basing on the hardness of the wood where hardwoods used to give higher yield than softwood and charcoal produced from hardwoods used to be non-bristling which translates to higher profits.

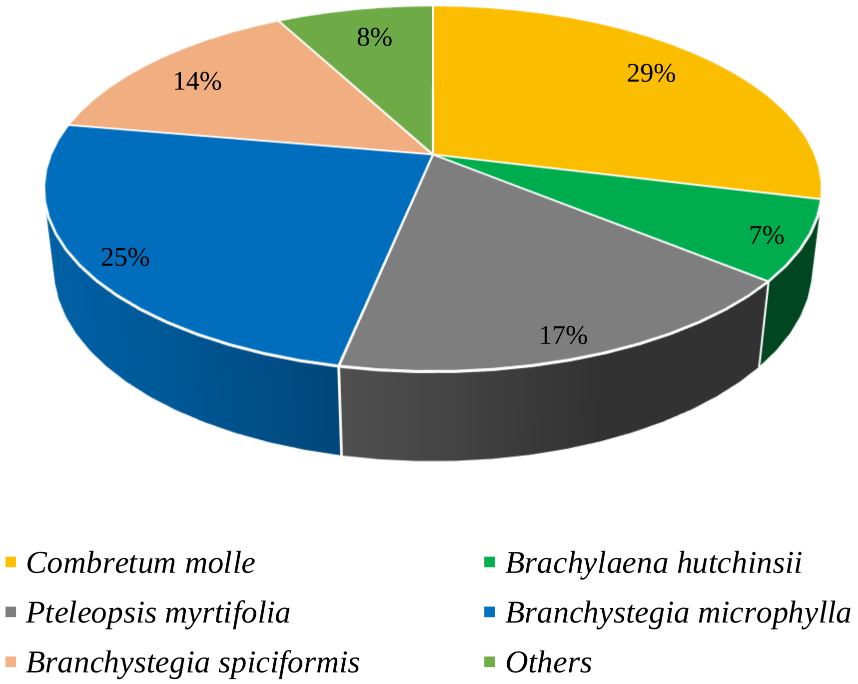

Figure 6: Type of trees used by charcoal producers

4.2 Contribution of Improved Charcoal Kilns to the Household Income

This section identifies contribution of improved charcoal kilns to the total household income in the study area. In the study area there were mainly five common sources of income to household including income from charcoal production, income from own farm, income from wage labour, income from livestock and self-employment as shown in Figure 6. Charcoal production activities contributes about 82% of the total household income followed by income from own farm activity which contributes about 16%. Other economic activities including income from wage labour, income from livestock and income from self-employment contributes only 1% of the total household income.

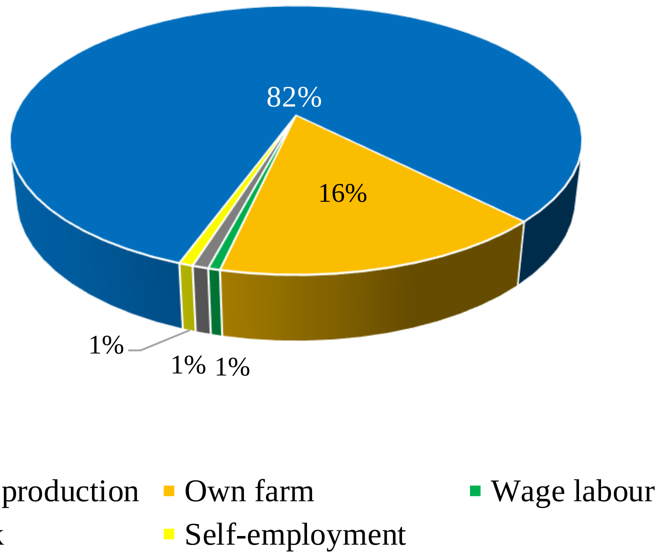

Figure 7: Income contribution from various household economic activities

As can be seen from Figure 6 income from charcoal production contributes a large portion of the total household income. In determining by how much actually the charcoal producer profits between each kiln type in the study area Table 3 presents results of gross margin analysis which was performed for producers who used improved kilns and producers who used traditional kilns separately followed by statistical comparison using t-test.

Table 3 show that average revenue from charcoal producers who used improved kilns is about TZS 1.35 million per kiln while average cost incurred during the process is around TZS 507 000 per kiln. The gross margin from using improved kilns in the study area is 62% implying that for each TZS 10 000 sells charcoal producer retains TZS 6200 as a profit. Similarly for charcoal producers who used traditional kilns average revenue was approximately TZS 730 000 while the average cost was around TZS 387 500.

The gross margin from using traditional kilns in the area is 47% implying that for each TZS 10 000 sells charcoal producers retains TZS 4700 as profit. According to t-test this difference in gross margin is statistically significant at p-value of 0.02 inferring that charcoal producers who used improved kilns in the study area generates more income from charcoal production compared to those who used traditional kilns. These finding concurs to several studies including that of Dobie *et al.*, 2015 and Liyama *et al.*, 2014 in which traditional kilns are often inefficient with efficiency of only 9 to 15% suggesting there is a biomass loss of 85 to 91% during the process; while improved kilns can reach efficiency up to 40% wood to charcoal conversion efficiency (Ishengoma and Ngaga, 2000).

Due to this significant loss in biomass, producers who use traditional kilns tend to waste a lot of resources and efforts because of inefficiency which leads to lower returns since the large value of material invested in construction of traditional kilns are wasted unlike producers using improved kilns who have relatively higher value of material invested being turned into output.

Table 3: Gross margin of improved kilns versus traditional kilns

Variables	Improved Kilns (n=79)	Tradition Kilns (n=121)	t-test
Revenue	1350000	730000	
Tools cost	80000	27500	
Kiln construction cost	360000	300000	
Food cost	27000	20000	
Cost of empty bags	40000	40000	
Average cost	507000	387500	
Gross Margin	**62%**	**47%**	**0.024**

4.3 Factors Influencing the Use of Improved Charcoal Kilns by Charcoal Producers

This section analyses the factors influencing the use of the improved kiln by a charcoal producer in the study area. Logistic regression was used and results are presented as shown on Table 4 below. In model summary below numbers of observations used in the logistic regression were 200 producers. The p-value of 0.000 of prob>chi^2 implies at least one of the regression coefficients in the model is not equal to zero. The value of Pseudo R^2 of 0.393 implies the model has a strong goodness of fit because from the rule of thumb logistic model with strong goodness of fit have value of Pseudo R^2ranging between 0.2 and 0.4.

Table 4: Factors influencing the use of improved charcoal kiln

Variables	Odds Ratio	Coefficient	P-value
Age in years	4.4605	1.4953	0.001***
Sex (1= Male; 0= Female)	0.9334	-0.0689	0.880
Marital Status (1= Married; 0= Not married)	0.1998	-1.6106	0.005***
Education level (1= At least primary school; 0= No school)	0.4552	-0.7871	0.200
Experience in charcoal production in years	1.0981	0.0936	0.124
Membership to charcoal social networks (1= Yes; 0= No)	11.4621	2.4390	0.002***
Income level in Tanzanian shillings	1.0000	1.8e-07	0.039**
Perception very useful (1= Yes; 0= No)	19.2018	2.9550	0.011***
Perception not useful (1= Yes; 0= No)	13.2192	2.5817	0.029**
Producer had training (1= Yes; 0= No)	8.9580	2.1926	0.002***
Number of observations			200
Prob> chi2			0.000
Pseudo R^2			0.393

In the logistic regression model seven out of ten variables hypothesized to influence the use of improved kilns over traditional kiln were found to be significant. The coefficient of age has a positive sign indicating positive association between age and use of improved kilns; for the age variable a unit increase in age of producer by one year, the odds of producers using improved kilns increase by 4.46 given other factors constant.

This implies as producer age increases the chances of using improved kilns increases by 4.46 times. According to Okaye *et al.,* 2008 producer's age is likely to enhance good decision making through accumulated wisdom from the life experiences.

The coefficient of marital status has a negative sign indicating negative association between marriages and using improved kilns, for married producers the odds of using improved kiln are 0.1998 less than producers who are not married. This implies that in the study area producers who are not married are more likely to use improved kilns comparing to married producers.

The coefficient of membership to charcoal social networks has a positive sign as expected. For a charcoal producer who is a member in charcoal production social network the odds of using improved kilns are 11.46 times larger than those producers who are not members. According to Talukder (2012) individual adoption of improved technology used to be influenced by social pressure especially individuals whose belief and opinions are important including peer and people in social networks. Therefore producers who are in charcoal producers social networks are likely to use improved kilns compare to those who are not.

The coefficient of income is positive has a positive sign as expected. However the value of coefficient is a very small number, a unit increase in income of a charcoal producer, the odds of producer using improved kilns increases by 1 times. This implies that in the study area factors other than income have association on producer choice of using improved kilns.

The coefficient of producer having training has a positive sign as expected. For a charcoal producer who had training the odds of using improved kilns are 8.958 times larger than those producers who had no training. According to Abdoulaye *et al.* (2014) training increases producers' awareness on better production practices including the usage of new technologies. For instance charcoal producer training on sustainable charcoal production by experts is likely to impact knowledge to producers on advantage of using improved charcoal production and therefore increases the likelihood of producers using improved technologies.

The coefficients of producers' perception have positive sign. However for producers who considered using improved kiln is very useful have higher odds of using improved kilns compared to those who considered otherwise, for charcoal producer with perception that using improved kilns is useful the odds of using improved kilns are 19.2 higher than those who perceived otherwise while for a producer with perception that using improved kiln is not useful the odds of using improved kilns are 13.2 time higher than those who perceive otherwise. In a way similar to social network according to Talukder (2012) perception towards technology depends from experience of the user from peer, people he or she trust and experience from using. The perception building will influence whether or not a producer to be likely to use improved kilns.

In addition to regression results, to ensure the model was correctly specified, model fitting well data and independence of explanatory variables, different tests were carried out; the tests included link test for checking specification, Hosmer and Lemeshow's test for checking goodness of fit and t test to check multicollinearity. Results from test are presented in Appendix 2 and are showing the ordinary least squares assumptions are fulfilled and the model is correctly specified.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

The main objective of the study was to analyse contribution of improved charcoal kilns to the income of charcoal producers in Kilindi district of Tanga region. The study was interested with improved kilns due to its advantages mentioned in literature of being efficient in conversion which translate to better use of wood resources and more profit to producers. Specific objectives of the study were to characterise charcoal production in the study area, to analyse contribution of improved charcoal kilns to the household income and to examine factors influencing the use of improved charcoal kilns by charcoal producers in the study area.

5.1 Conclusions

The findings shows that large number of charcoal producers in the study area uses traditional kilns despite advantages existing from using improved kilns; and producers in the study area have kilns of different sizes regardless the type of kiln whether traditional or improved kilns.

The findings show that charcoal production is the main contributor to the income of the household in the study area and therefore charcoal production is very important to the livelihood of its producers in the study area compared to other economic activities such as farming, livestock keeping and other activities. Furthermore, findings show that for producers who use improved kilns in the study area retain slightly more than a half of sales (TZS 6200) to their income after deducting production costs while for charcoal producers who used traditional kilns retain just a quarter of the sales (TZS 4700) to their income after deducting cost involved during production. Therefore in the study area the use of improved kilns is more profitable compared to the use of traditional kilns.

Moreover the findings from the logistic regression show that in the study area age, membership to charcoal social networks, income level, training and perception increases the likelihood of a producer using improved kiln while marital status decreases the likelihood of a producer using improved kilns during charcoal production process.

5.2 Recommendations

The following section presents recommendation based on the findings of the study in Kilindi district of Tanga region.

i. Charcoal producers should put more emphasis on the use of improved charcoal kilns since they have shown significant effects on the income of the households involved in charcoal production in the study area.
ii. Charcoal producers should be encouraged to form charcoal production social networks which will help to communicate and sharing various knowledge regard charcoal production since social networks has shown to have significant effect on the decision of producer choice of improved kilns.
iii. Local governments through forests authorities should conduct training on advantages of using improved charcoal kilns among charcoal producers in the study area since it has shown a positive influence towards using improved kilns for charcoal producers who received training.
iv. Academic institutions and other stakeholder organisations should conduct further research in the study area to find out why married charcoal producers have shown to be less likely to use improved charcoal kiln in the study area compared to those who are not married.

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APPENDICES

Appendix 1: Regression diagnostics

According to econometric procedure there are regression assumptions that have to be fulfilled in order to have meaningful results. The diagnostics ensures that the model and variables are correctly specified. The following are diagnostics results to check for logistic regression.

Specification Error

To determine if the model is correct specified; link test was used to determine is the model is correctly specified to see if the model have all the relevant predictors and if the linear combination is sufficient.

Null hypothesis: The model is correctly specified

Alternative hypothesis: The model is not correctly specified

Table 5: Link test for specification error

Kiln type	**Coefficient**	**P>z**
Hat	1.12406	0.000
Hat squared	0.08205	0.131
Constant	-0.14157	0.521
Number of observation		200
LR chi2(2)		107.3
Prob> chi2		0.0000
Pseudo R2		0.3998

Since the p-value of hat squared is not significant, there is no sufficient evidence to reject the null hypothesis that the model is correctly specified. Therefore, the link test show that the model is correctly specified and the model have all relevant predictors and linear combination is sufficient.

Goodness of Fit

To determine if the model fits well the data Hosmer and Lemeshow's goodness of fit test were conducted.

Null hypothesis: The model fit well the data

Alternative hypothesis: The model does not fit well the data

Table 6: Hosmer and Lemeshow's goodness-of-fit

Group	Prob	Obs_1	Exp_1	Obs_0	Exp_0	Total
1	0.0127	0	0.1	20	19.9	20
2	0.0389	1	0.4	19	19.6	20
3	0.0933	2	1.1	18	18.9	20
4	0.189	1	2.9	19	17.1	20
5	0.3562	8	5.6	12	14.4	20
6	0.5041	6	8.6	14	11.4	20
7	0.6673	13	11.8	7	8.2	20
8	0.7348	12	14	8	6	20
9	0.8631	16	15.9	4	4.1	20
10	0.9786	20	18.5	0	1.5	20
Number of observations	200					
Number of groups	10					
Hosmer-Lemeshow chi2(8)	8.63					
Prob> chi2	0.3741					

With a p-value of 0.37, there is no sufficient evidence to reject the null hypothesis that the model fits well the data.

Multicollinearity

Multicollinearity occurs when two or more independent variables in the model are approximately determined by a linear combination of other independent variables in the model. The variance inflation factor test was conducted to see if there is multicollinearity problem.

Table 7: Multicollinearity Test

Variable	VIF	VIF	Tolerance	Squared
Age in years	1.09	1.04	0.918	0.082
Sex (1= Male; 0= Female)	1.15	1.07	0.87	0.13
Marital Status (1= Married; 0= Not married)	1.08	1.04	0.9238	0.0762
Education level (1= At least primary school; 0= No school)	1.07	1.03	0.9387	0.0613
Experience in charcoal production in years	1.22	1.11	0.817	0.183
Membership to charcoal social networks (1= Yes; 0= No)	1.29	1.14	0.774	0.226
Income level in Tanzanian shillings	1.26	1.12	0.7905	0.2095
Perception very useful (1= Yes; 0= No)	3.67	1.92	0.2725	0.7275
Perception not useful (1= Yes; 0= No)	3.06	1.75	0.3269	0.6731
Producer had training (1= Yes; 0= No)	2.86	1.69	0.3495	0.6505
Mean VIF	1.78			

From the rule of thumb multicollinearity occurs when the value of VIF is greater than 4, since there is not variable with VIF greater than 4 and average VIF being 1.78; therefore there were no multicollinearity problem in the explanatory variables.

Appendix 2: Questionnaire

SOKOINE UNIVERSITY OF AGRICULTURE
COLLAGE OF FORESTRY, WILDLIFE AND TOURISM
(Questions to be answered by the Head of the Household or other responsible party

Questionnaire Unique ID: ________________________ Phone: ______________

Ward: ________________________ Date: ______________

Village: ________________________ Time: ______________

PART A:
HOUSEHOLD INFORMATION

A1	Name of the head of the household	----------------------------------
A2	Age of the head of the household	----------------------------------
A3	Sex of the head of household a. Male b. Female	------------
A4	Marital status a. Single b. Married c. Widow d. Separated e. Divorced	------------
A5	Education level of the head of the household a. No school b. Primary School c. Secondary School d. Post-secondary school	------------
A6	Experience in charcoal production in years	------------
A7	Are you a member of any charcoal production association/network? a. Yes b. No	------------
A8	Occupation a. Charcoal production b. Agriculture on own farm c. Agriculture wage labour d. Livestock keeping e. Self-employed in non-farm activities f. Other economic activities (mention) *(Start with main occupation followed by secondary occupation(s)*	-------,-------,-------,-------,----

A9	What is your average monthly income? a. Charcoal production b. Agriculture on own farm c. Agriculture wage labour d. Livestock keeping e. Self-employed in non-farm activities f. Other economic activities (mention) g. Total	a. ____________________ b. ____________________ c. ____________________ d. ____________________ e. ____________________ f. ____________________ g. ____________________
A10	Are you aware of improved charcoal kilns? a. Yes b. No	------------
A11	How do you perceive the usefulness of using improved kilns in charcoal production? a. Very useful b. Moderate useful c. Not useful	------------

PART B:
CHARCOAL PRODUCTION

B1	How many charcoal kilns do you produce per year?	
B2	Type of kiln used a. Improved kilns b. Traditional kilns	
B3	Shape of the kiln used a. Box b. Pyramid c. Bottle d. Other shape (mention)	------------
B4	Volume of the kiln 1. Height 2. Length 3. Width 4. Diameter	1. ________________________ 2. ________________________ 3. ________________________ 4. ________________________
B5	Type of tree used	a. ________________________ b. ________________________ c. ________________________ d. ________________________
B6	How many times do you produce a year?	------------
B7	How many charcoal bags do you produce per year?	------------

PART C:
EQUIPMENT

	Tool	**Ownership** **0. No** **1. Yes**	**Lifespan of a tool** *(Years)*	**Purchasing price of a tool** *(Tanzanian Shillings)*
C1	Machete			
C2	Axe			
C3	Spade			
C4	Rake			
C5	Wheelbarrow			
C6	----------------------------			
C7	----------------------------			
C8	----------------------------			
C9	----------------------------			
C10	----------------------------			

PART D:
KILN PRODUCTION COST

	Item	Number of Labour	Cost per Labour *(Wage)*	Number of Labour Days
D1	Tree cutting			
D2	Tree processing			
D3	Site preparation			
D4	Billets pilling			
D5	Kiln construction			
D6	Kiln firing			
D7	Kiln monitoring			
D8	Kiln unloading			
D9	Charcoal Packing			
D10	----------------------------			
D11	----------------------------			
D12	----------------------------			
D13	----------------------------			

PART E:
OTHER COST

	Item
E1	Food cost per kiln E11. Food price per unit labour ____________________________ E12. Number of labour supplied with food____________________________ E13. Total food cost ____________________________
E2	Fees/permits E21. ____________________________ E22. ____________________________ E23. ____________________________
E3	Empty bags E31. Price of empty bags ____________________________ E32. Number of empty bags purchased ____________________________
E4	Transportation Cost E41.Do you transport output from production site to markets? 1. Yes; 0. =No _____ E42.Number of bags transported ____________________________ E43. Cost per bag ____________________________