ECONOMICS OF CHARCOAL PRODUCTION AND ITS IMPLICATION TO THE MANAGEMENT OF MIOMBO WOODLANDS IN KILOSA DISTRICT

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ABSTRACT

Tanzania is one among developing countries with increasing population growth. The increase of population is reported to contribute to the deforestation as most of the people depend on charcoal as primary source of energy in which the country produces and consume around 3% of global consumption. Most, of previous studies on charcoal provided empirical data on charcoal production, but consistency on productivity, costs incurred, benefits accrued and implication of the technology to woodlands is missing. This study was conducted to analyse the economics of charcoal production and its implication to the Miombo woodlands in Kilosa District, Morogoro region. The aim of the study was to get empirical knowledge for improving charcoal production and to strengthen the theoretical base necessary for supporting sound decision making in the study area. A sample of 120 charcoal producers in villages namely Nyali, Ulaya Mbuyuni, Dodoma Isanga and Ihombwe was used. Descriptive statistics and econometrics methods were used for data analysis. Cobb-Douglas production function was used to estimate charcoal yield per kiln and descriptive statistics of terciles were used to compare the socio-economic characteristics between producers groups. In analysing cost of charcoal production descriptive statistics were used in presenting the findings. Gross Margin analysis was used to estimate profit of charcoal production per kiln while multiple regression was used to analyse factors influencing profitability of charcoal business. For charcoal production technologies, findings show that charcoal producers using modern kilns had 40% yield higher than producers who used traditional kilns while producers who used medium size kilns ranging from 10.5cm^3 to 50.5cm^3 had 50% yield higher than producers who used small and large size kilns. In cost analysis results show on average cost of tree preparation per bag is about TAS 2000 per bag, kiln preparation about TAS 1000 per bag and kiln supervision about TAS 500 per bag. Profitability analysis the gross margin of 26%

implying that charcoal producers retain about 26% of each TAS 1 invested after selling charcoal also the results shows that producer with modern kilns have 44.5% profit higher compared to those with traditional kilns. It is concluded that modern kilns associated with high yield and more profit compared to traditional kilns. Modern kilns investment cost was relatively higher compared to traditional kilns. To achieve greater sustainability the study recommends policies in charcoal making should emphasize the use of modern kilns.

DECLARATION

I, Sachco Tatsumi, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and that it has never been nor concurrently being submitted for a higher degree award in any other university.

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DEDICATION

This Dissertation is dedicated to my lovely mother Helena Stephano. May the almighty God bless you.

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ABBREVIATIONS

FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
MEM	Ministry of Energy and Minerals
MNRT	Ministry of Natural Resources and Tourism
NAFORMA	National Forest Resources Monitoring and Assessment
NBS	National Bureau of Statistics
REDD+	Reducing Emissions from Deforestation and Forest Degradation
SDC	Swiss Agency for Development and Cooperation
TATEDO	Tanzania Traditional Energy Development Organization
TFCG	Tanzania Forest Conservation Group
TFS	Tanzania Forest Services Agency
WB	World Bank

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

National Forest Resources Monitoring and Assessment (NAFORMA) results show that the area under forests and woodlands in Tanzania mainland is 48.1 million ha. This is about 55% of total land area of Tanzania mainland. Woodlands alone account 44.7 million ha. The total wood volume is 3.3 billion m^3, out of which 97% is from natural forests and 3% from planted trees (MNRT/TFS, 2015). Deforestation, biodiversity loss and forest degradation are among major challenges identified to affect forests and woodlands in the Country. According to NAFORMA, the annual loss of forest area is 372,000 hectares. On a national basis, rural household energy demand (some 47 million m^3 in 2012) was roughly equal to national annual forestry yield outside protected areas. This indicates that the required house hold demand is being met in unsustainable way where by most of it taken in protected forest that are not legally allowed for wood harvesting (MNRT,2013; Ishengoma, 2013)

Tanzania is endowed with diverse sources of energy including biomass, hydro, natural gas, coal, geothermal, solar and wind (World Bank, 2010). The share of alternative energy sources are fossil fuels (6.6%), gas (1.5%), hydro (0.6%), and coal and peat, (0.2%) (MEM, 2011). However, more than 2 billion people in developing countries especially rural communities rely on wood fuel (charcoal and fuel wood) as their main source of energy (FAO, 2010). It is projected that in 2030, biomass energy will account for about two third of the total domestic energy in Sub-Saharan Africa (CIFOR, 2012). This shows wood fuel is important in meeting the energy requirements for most of the people. Wood fuel accounts for 90% of the total energy supply and demand in Tanzania (MNRT, 2013).

Majority of people consume charcoal and fuel wood for domestic purposes (households' sector), commercial, institutional and industrial consumption.

In Tanzania charcoal consumption is higher compared to other alternative energy sources mainly due to three reasons. Firstly, charcoal is perceived by both urban and rural users to be relatively cheap compared to other energy sources such as gas and electricity (Malimbwi, 2008). Secondly, charcoal is fairly easy to get in many places in rural areas compared to electricity or gas which need expensive installation in order to use (Luoga *et al.,* 2000; Kifukwe, 2013). Thirdly, most of people are simply just used to charcoal despite existence of alternative energy sources which require efforts to change their mindset to adopt other forms of energy sources (Kifukwe, 2013).

Globally, charcoal production was estimated to be 51 million tons in 2016 and it has increased by 4% since 2012; while Africa contributed 64% of global production (FAOSTAT, 2016). Regardless of the high charcoal production in African countries there is weak implementation appropriate policies to successfully manage the charcoal sector due to the fact that they tend to see the charcoal production and its use as an environmental health problem. Major obstacles to sustainable charcoal production in many African countries are the absence of enforcement legal frame work in charcoal sector which include low income for charcoal producers, lack of incentives to invest in highly efficient kilns, corruption and low capacity for policy implementation and enforcement (Onyango, 2015).

In year 2011, Tanzania was ranked 7th for overall charcoal production in the world, it accounts for about 3% of the global charcoal production (World Bank, 2009). This makes charcoal production to be the major cause of deforestation. This is attributed to the increase in charcoal demand and inappropriate technologies used in charcoal production (FAO, 2008). The use of traditional charcoal kiln accelerates the destruction of forest due to low efficiency (Müller *et al*., 2011). According to the World Bank (2009), Tanzania has lost between 100,000 and 125,000 hectares of forest due to the production of charcoal. Hence there is a need to look on the technology that is used in the process. However, in Tanzania the recent National policy is still focused on modern energy sources and there is very little debate on the potentials to modernize charcoal production. This will only lead to increase the negative impacts in charcoal sector, disempowering the environmental protection efforts and undermine the collection of revenue (Kifukwe, 2013).

Charcoal production is a labour-intensive process which is mostly carried out by men. Large number of people are employed at different stages of production which includes wood cutting, kiln preparation, carbonization and finally unloading charcoal from the kiln (FAO, 2010; CHAPOSA, 2002). The activity contributes to economic development through provision of rural incomes, tax revenue and employment (FAO, 2012). In 2012, charcoal and firewood generated about TZS 1.6 trillion in revenues for hundreds of thousands of rural and urban producers, transporters and wood energy sellers (NBS, 2013).In rural and densely populated areas charcoal production is one among few possible economic activities, requiring low capital investment and involving informal work conditions (Luoga *et al.,* 2000).Therefore a proper managed charcoal industry will generate substantial employment and income opportunities in Tanzania (Kifukwe,2013).

1.2 Problem Statement and Justification

Tanzania is one among developing countries with increasing population growth. According to the National census of 2012 Tanzania has a population of 44.9 million. The increase of population is reported to contribute to the deforestation as most of the people depend on charcoal as primary source of energy. Charcoal consumption is about 1 million tonnes, to meet this demand approximately 100 000 hectares of forest needs to be clear cut (Chidumayo and Gumbo 2013). Tanzania is one among top ten producers of charcoal world-wide, producing approximately 3% of the world's total (FAO, 2010). Charcoal production can either be done by traditional or improved methods. In some areas in Tanzania like Kilosa people have been trained to use improved basic earth kiln (555 producers trained in Kilosa) which improve charcoal production.

According to Chaposa (2002) a household can produce 43 bags of charcoal per month. A study done by Mndeme (2008) in Morogoro rural district shows that a producer can produce 28 bags of charcoal per month weighing 56kg. Moreover, Mndeme went further with estimation of different costs which are involved in the process whereby royalty which cost TAS 2000/bag, cess which cost TAS 1000/bag and annual registration fee of TAS 200,000. However, Camco (2014) revelled that charcoal production varies from 5 bags to 30 bags per month. Moreover Kazimoto (2015) also argues that a small-scale producer can produce 40 bags of charcoal per month. Kazimoto also revealed the cost of different equipment in charcoal production whereby Kazimoto found out the unit cost of axe and machete to be 7 and 9 respectively while that of hoe and spade were 5 and 3 respectively.

Although these studies provide empirical data on charcoal production, but consistency on productivity, costs incurred, benefits accrued and implication of the technology to woodlands is missing. The main research questions are: which main technologies are used, what unit of production is used, what amount of wood is felled per a unit of kiln, time used per activity, how much labour is involved, amount of other costs, the number of charcoal bags per kiln, what about of kg/bag of charcoal is produced per a unit kiln of charcoal, what is the prices.

1.3 Justification of the study

Inefficiency of charcoal producing technologies causes charcoal producer to use more wood to produce one unit of charcoal because much of wood is lost in the process of charcoal production. This in turn deplete wood resources used in the process of charcoal production. The radius of the area from which raw materials are collected is steadily increasing, therefore charcoal makers needs to travel progressively further to obtain wood needed. Increase in distance from the main road has an effect to the price of charcoal whereby with longer distance there is increase in transportation costs which lead to higher prices of charcoal (MNRT, 2001). This increases the cost of producing charcoal for example the transportation cost of charcoal increases as charcoal producers move far away from the road site.

This study provides information on the charcoal yield per kiln, cost of charcoal production per kiln technology, benefits of charcoal production per kiln technology and on the factors influencing profitability of charcoal production. The information gives empirical knowledge for improving charcoal production technologies and practice and to strengthen the theoretical base necessary for supporting sound decision making. The overall inefficiency measurement are important for charcoal production firms facing a world of changing prices since the resultant loss has implications on managers' decision making

1.4 Objectives

1.4.1 Overall objective

The overall objective of this study was to assess economics of charcoal production technologies and its implication to the management of Miombo woodlands in Kilosa District, Morogoro.

1.4.2 Specific objectives

i. To estimate charcoal yield per kiln in the study area.

ii. To analyse the cost of charcoal production per bag in the study area.

iii. To estimate profit of charcoal production per kiln in the study area.

iv. To estimate factors influencing profitability of charcoal production in the study area.

1.4.3 Research Questions

i. What are the factors influencing charcoal yield per kiln in the study area?

ii. What are the costs of charcoal production in the study area?

iii. What are the benefits of charcoal production in the study area?

iv. What are the factors influencing the profitability of charcoal production in the study area

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Productivity of Charcoal per Kiln

In 2011, more than half of the annually worldwide logging volumes of roundwood (3.5 billion m^3) were used for fuel (FAOSTAT, 2014). Fuel wood production is difficult to estimate due to the informal character of its production. However, trends are obvious, in Africa there is an increase in fuel wood production whereas Asia experiences a decrease (FAO, 2013). Most charcoal producers in sub-Saharan Africa use traditional earth kilns, with wood-to-charcoal conversion efficiencies of 8-20%, so large quantities of wood are used per unit of charcoal produced (Liyama, 2013). The efficiency of the kiln depends on the construction (arrangement of the billets), moisture content of wood, the monitoring of the carbonization process and perhaps for the largest part on the skills of the producers. Attempts have been made to improve kiln efficiencies in many countries. In Tanzania, some of the proposed technologies and techniques include portable steel kilns, improved traditional earth kilns, and half-orange brick kilns as shown in Figure 1. Improved kilns could contribute substantially to production efficiency. However, in spite of their efficiency, the use of improved kilns has failed due to lack of capital for kiln construction (Chidumayo and Gumbo, 2010).

In Kilosa District there were about four types of traditional kilns which are used in charcoal production. These include the box type kiln, the rocket kiln, the *mdomo wa chupa* kiln and the msonge kiln (Sago, 2013). The kilns differ in shape and size but all can be classified as basic earth mound kilns. Besides the charcoal kilns already used in Kilosa, several other traditional (e.g. earth pit kiln), improved (e.g. improved earth mound kiln) and stationary (e.g. brick kilns or retort kilns) charcoal kiln types exist (ibid).

The yield from the basic earth mound kiln (BEK) varies depending on the construction, weather condition, wood species and the experience of the operator. Carbonization time is between 10- 14 days and cooling time is 24-48 hour on the average (Sago, 2013). On the other hand, there was introduction of improved basic earth mound kiln (IBEK) technology by Tanzania Traditional Energy Development Organization (TaTEDO) so as to increase the efficiency of charcoal production in Kilosa. The improved basic earth mound kiln (IBEK) technology is based on a range of several low-cost improvements of the traditional earth mound kiln aiming to increase the efficiency. The improvement includes the introduction of a chimney, an air circulation apron (arrangement of logs), as well as ensuring that wood used is adequately dried and cut into approximately similar sizes. During loading, plenty of small wood and branches is needed to fill the interspaces between logs so that oxygen supply becomes limited during carbonization (ibid).

Table 1: Type of kilns

Kiln type	Traditional kiln	Improved kiln	Efficiency (%)
Earth pit kiln	X		10-15
Portable steel kiln		X	20-25
Brick kiln		X	25-35
Cassamanceearth mound kiln		X	25-30
Earth mound kiln	X		10-20
Improved earth mound kiln		X	15-25

Source: van Beukering *et al.* (2007)

2.2 Cost of charcoal production

Charcoal-making process is resource-intensive as the harvesting of the feedstock is an intensive process, concentrated in small area as possible over as short a period of time as possible (FAO, 2010). Charcoal producers incur little expenses in charcoal making. It requires minimum capital input (axe, safety match, and a shovel). In addition, difficult work conditions associated with the extraction of wood, building the kiln and packing constitutes a significant individual investment of time (Jones, 2015). However, there is also lack of modern tools to use in the process of charcoal production. This results to the use of human labour throughout the entire production process. Labour has zero opportunity cost. As a result, despite growing scarcity of wood, charcoal generally remains under- priced by more than 20% to 50%, relative to its economic cost in most African countries (World Bank, 2009).

In charcoal production, kiln locations require enormous amounts of work to prepare. A wide range of interventions in many sub-Saharan Africa countries have tried to overcome this challenge by promoting more efficient kilns for charcoal production, but the adoption rate has been limited due to higher initial cost, manpower and skill required for viable management (Chidumayo and Gumbo, 2010). The need to process the billet into specific sizes and transport them to kiln sites is an added cost that is limiting adoption (*ibid*).These lead to disincentives for charcoal burners to adapt improved technologies in situations where they are not rewarded with increased prices or where the risk of discovery may require abandoning the production site (HEDON, 2010).

2.3 Profitability of Charcoal per Kiln

Charcoal production and trade contributes to incomes and employment opportunities for rural residents and benefits the national economy along the value chain (World Bank, 2011). In 2011, the charcoal sector in Africa was estimated to produce income of over US$ 10 billion, against the firewood's US$ 3.7 billion (World Bank, 2011; FAO, 2014). The charcoal business support basic needs, investments in other livelihood activities, and even act as a savings account for households to cope with shocks as charcoal can be stored strategically to provide for future spending as well as for price optimization (Schure *et al.*, 2014). On the other hand, the revenues are often neither enough to lift households out of poverty nor to provide them with incentives to adopt sustainable technologies (Zulu and Richardson, 2013; Schure *et al.,* 2014), as producers benefit least at the supply end of the long value chain where complicated regulations and vested interests squeeze profit margins.

In Tanzania, revenues generated by the charcoal industry for Dar es Salaam alone amount to TZS 350 billion (Agency, 2010). The charcoal sector worth TAS 300 billion in Kenya (KFS, 2013). In Uganda, more organized charcoal producers have some sort of a financial arrangement with the forest land owners based either on the number of bags of charcoal produced or the area of forest land being cleared. Given the producers' limited collective bargaining power, and also their lack of knowledge/incentive to increase production efficiency, the share of the total revenue per producer is fairly low, ranging from 5% to 10% (Basu, 2013).

A study of Luoga *et al.,* 2000 from Tanzania indicates that the charcoal producers perceived their profits to be positive because of their very low capital outlays to fell trees and construct earth mound kilns, their own ‘free’ labour, ‘free’ wood, and lack of concern about associated external costs. The perception of ‘free’ labour or the low opportunity cost of labour is attributed to the lack of alternative economic opportunities and low agricultural and market potentials prevalent in rural landscapes (Iiyama *et al*., 2014). The perception of ‘free’ wood is due to most costs being treated as free good because of lack of strictness of access to tree resources.

2.4 Factors Influencing Profitability of Charcoal Production

According to FAO (2010), the major determinants of charcoal profitability include technology in use, efficiency of operation, distance from major markets, low cost of inputs like labour used and the species of trees used. Each of the factor is discussed in subsections below.

2.4.1 Type of charcoal production technology

More advanced kilns enable higher charcoal yields. Under optimal conditions, surprisingly yields in the magnitude of 30% can be achieved from traditional technologies. In practice, however, yields from charcoal made from unimproved technologies are about 20% higher (Nturanabo *et al*., 2010). Improved technologies not only achieve higher yields but also are much more constant in the yields achieved.

2.4.2 Charcoal production efficiency

The efficiency of charcoal production determines the amount of charcoal that can be made per unit of wood biomass (Agency, 2010). The following factors affect charcoal production efficiency. First, relatively high efficiencies can be reached if an experienced producer follows best practice even when traditional kilns are used. Second, occasional charcoal producers achieve lower efficiencies than full-time charcoal producers. Third, illegal charcoal production might need to be performed in a quick way not allowing optimizing the charcoal production process (Liyama, 2013).

2.4.3 Distance from major markets

Charcoal producer brings the charcoal in bags to the roadside from where it is transported by truck, other motorcycles or bicycle to the market by wholesalers or transporters, but they also work and sell their products individually (World Bank, 2009). As the distance from the production site to the market site increases the traders tend to keep the price low and as a result the profit to the producer remain minimum.

2.4.4 Charcoal Labour

In charcoal production, there is high use of household labour. Men carry out most of production activities like tree felling, cross-cutting and kiln building, women participate in breaking of the kiln after carbonization and recovering and bagging of the charcoal (CHAPOSA, 2002). They employ little labour to avoid cost of hiring them. This will lead to increase in profitability of charcoal production due to reduction of labour cost.

CHAPTER THREE

3.0 METHODOLOGY

This chapter presents methodology that was used to address the four objectives of the study. It starts by elaboration of the study area followed by research design and sampling procedure. Then, the chapter ends by a subsection that explain data analysis methods used to address each of the research objectives.

3.1 Description of the Study Area

3.1.1 Location

The study was conducted in Kilosa District, Morogoro. It covers 14918 Km^2. The District lies between Latitudes 6º South and 8º South and Longitudes 36º 30'East and 38º West. According to the 2012 Tanzania National Census, the population of the Kilosa District was 438 175 and the District is divided in thirty eight wards (Kajembe *et al.,* 2013).

As can be seen in Figure 1 Kilosa bordered to the North by Kiteto District of Manyara Region, to the northeast by Kilindi District of Tanga Region, to the east by Mvomero District, to the southeast by Morogoro Rural District, to the South by Kilombero District all of Morogoro Region, to the southwest boarded by Kilolo District of Iringa Region and to the west by Gairo District of Morogoro Region and Kongwa District of Dodoma Region.

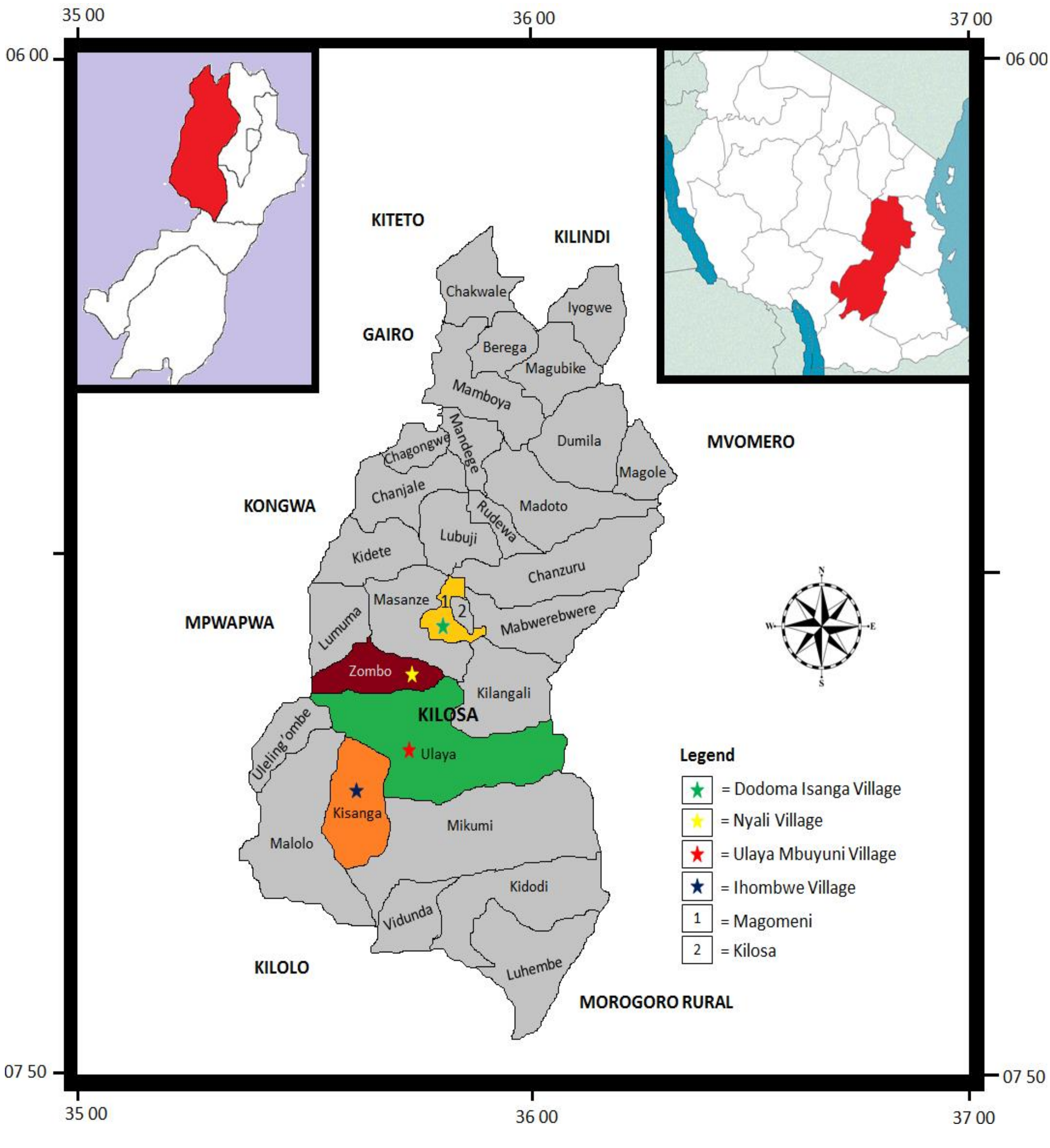

Figure 1: A map of the study area

3.1.2 Climate

The rainfall distribution is bimodal in good years, with short rains between October and January followed by long rains between March and May as shown in Figure 1 constructed using data from World Weather database. The mean annual rainfall ranges between 800 and 1400 mm. The mean annual temperature in Kilosa is about 25°C (World Weather, 2016)

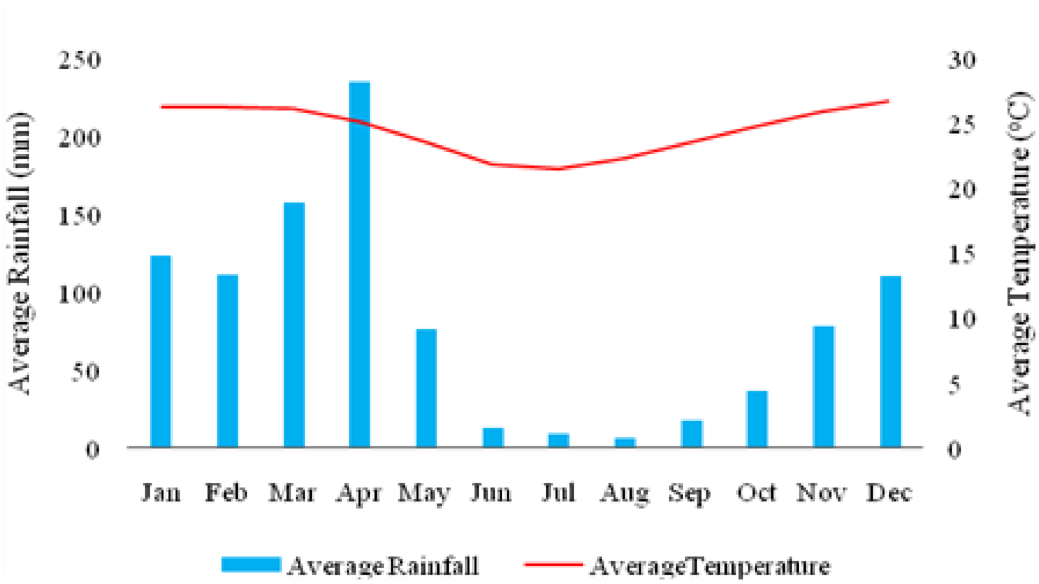

Figure 2: Monthly Average Rainfall and Temperature of Kilosa District (World Weather, 2016)

3.1.3 Vegetation

The vegetation in Kilosa District is characterized by both Mediterranean and tropical types, depending on altitude along the south-north exterior (Kajembe *et al.*, 2013). Typically it comprises of Miombo woodland, with grass and shrub covering the soils. Most of the forests are found in the western part of the district along the Eastern Arc mountain range of Rubeho (Kajembe *et al.*, 2013). The Eastern Arc Mountain range has several unique ecosystems with a variety of species and many of them are common in the area, which is internationally recognized as having an exceptional concentration of different species occurring nowhere else (EAMCEF, 2011). In addition, wildlife plays a significant role in Kilosa District through Mikumi National Park.

3.1.4 Social economic activities

In Kilosa District, charcoal production is the second economic activity after agriculture. Mainly small-scale farmers are involved in charcoal production to generate additional income. Charcoal is produced all year round, but the main production season is after the harvesting of the crops in the dry season. Depending on the financial situation of the farmer, also in the rainy season some charcoal is produced source.

3.1.5 The selection of Kilosa District

Tanzania Forest Conservation Group (TFCG) is implementing 'Transforming Tanzania's Charcoal Sector under Swiss Agency for Development and Cooperation (SDC) supports. TFCG has been supporting a community-oriented REDD+ project since 2009. The project focuses on woodland adjacent to the high biodiversity forests of the Rubeho and Ukaguru Mountains, a part of the Eastern Arc Mountains biodiversity hotspot. It has modelled a sustainable charcoal value chain into the community-based forest management process with aim of providing more security to charcoal producers; increased incomes to producers through production efficiency gains; significant village-level revenue from permit fees; and an environmentally sustainable harvesting approach. Villages were surveyed, demarcated and established land use plan. About 10% of the village forest that is allocated for sustainable charcoal production is subdivided into 24 units. The Project is being reported to establish a mechanism whereby royalty fee is being paid to the village government because they had been given the mandate to own the forest by the central government. Both Central and Local governments are reported to be supportive to the Project. The Project is being implemented in Kilosa District, involving 8 villages which are Msimba, Ihombwe, Kisanga, Ulaya Kibaoni, Ulaya Mbuyuni, Nyali, Dodoma Isanga and Kigunga. The selection process for the villages was based on three criteria: forest area, person active in charcoal production and remoteness which best reflect the range of social and environmental conditions. TFCG has received funding to expand the model to more villages in Kilosa and to more districts in Tanzania. Various kilns technologies introduced by the project provide relevant environment for this study.

3.2 Research Design and Sampling Procedure

3.2.1 Research design

A cross-sectional survey design was used in this study. The reason for choosing the design is because it is flexible, economic and easy to analyse data and information. The cross sectional data was collected from participants at the production level. The population of interest involved charcoal producers at Kilosa District.

3.3 Sampling Design and Sample Size

The sampling frame for the study was charcoal producers, particularly kilns technologies. Four villages were purposively selected out of 8 villages. The selected villages were Ulaya Mbuyuni, Nyali, Dodoma Isanga and Ihombwe. The villages were selected because they are involved in charcoal making activity also the TFCG Project started to operate in them.

Charcoal producers were stratified according to technologies used (modern and traditional) and size of kiln to produce charcoal. Modern charcoal producers were the ones who got the training and produce charcoal using modern kilns and in local charcoal producers were categorized into two: Those who did not get the training and produce charcoal using the local methods (local kilns) and the other category are those who got the training but they still using traditional kilns to produce charcoal.

Random sampling was used to select the sample within the strata. Modern and traditional kiln technologies were stratified into large, medium and small. Reconnaissance survey was conducted in the study area so as to be familiar and to be able to identify large, medium and small kilns as shown on Table 2. Moreover, pre-testing of the checklist was done so as to verify whether the questions were understood by the charcoal producers and also if they resemble with the actual situations in the field. In each stratum simple random sampling procedure was used to get five representatives' kiln in each category (large, medium and small) in both traditional and modern charcoal making technologies. A total of 120 respondents were interviewed in four villages, 30 respondents in each of the four villages were interviewed.

Table 2: Sampling

Types of Kiln Technologies	Capacity			
	Large	**Medium**	**Small**	**Total**
Modern	5	5	5	15
Traditional	5	5	5	15
Total	10	10	10	30

3.4 Data Collection and Analysis

3.4.1 Charcoal yield per Kiln

In analysing charcoal yield per kiln in the study area Cobb-Douglas production function similar to that of Fleisher *et al.* (2011) was used. The general function form of the study were formulated as shown below.

$Y_i = A_i L_i^{\alpha} K_i^{\beta} \mu_i$……………………………….………..(1)

Where,

i = i^{th} charcoal producer

Y_i = Total charcoal production by i_{th} charcoal producers which is expressed in kilograms per volume

A_i = Total factor productivity which represent the ability of i_{th} charcoal producers to transform raw materials into charcoal

L_i = Total amount of labour available for the activity (i_{th} charcoal producer man-hours worked in a period)

K_i = Capital input (the real value of all inputs used in charcoal production by i_{th} charcoal producer which included kiln preparation cost, equipment and tools)

α and β = Output elasticities of capital and labor, respectively. These values are constants determined by available kiln technology

μ_i = Disturbance term

By applying natural logarithm in equation (1) the expression becomes as shown below.

$\ln Y = \ln A + \alpha \ln L + \beta \ln K + \mu_i$………………………….. (2)

Household's characteristics also influence the efficiency of charcoal producers in transforming inputs into output. Hence the equation of total factor productivity is as shown below.

$lnA = \Sigma\gamma_j x_{ij} + \mu_i$…………………………..……………….. (3)

Where,

x_{ij}= Household characteristics affecting total factor productivity

And,

$\Sigma\gamma_j x_{ij} = \gamma_1 x_1 + \gamma_2 x_2 + \gamma_3 x_3 + \gamma_4 x_4 + \gamma_5 x_5 + \gamma_6 x_6 + \gamma_7 x_7 + \gamma_8 x_8 + \gamma_9 x_9 + \gamma_1 x_1 +$

$\gamma_1 x_1 + \mu_i$…….. (4)

Therefore,

$lnY = \Sigma\gamma_j x_{ij} + \alpha lnL + \beta lnK + V_v + \mu_i$……………………………… (5)

$$lnY = \alpha lnL + \beta lnK + \gamma_1 x_1 + \gamma_2 x_2 + \gamma_3 x_3 + \gamma_4 x_4 + \gamma_5 x_5 + \gamma_6 x_6 + \gamma_7 x_7 + \gamma_8 x_8 + \gamma_9 x_9 + \gamma_1 x_1 + \gamma_1 x_1 + V_v + \mu_i$$

Table 3 present definition of the variables used in formulating the model and their expected signs.

Table 3: Definition and expected signs of the variables

Variable		Description	Expected Sign
Charcoal yield	Y	Charcoal output per volume	
Capital	K	Capital invested in production of charcoal	+
Labour	L	Number of labour used per kiln	+
Young Age (1= 18 to 44 years), 0=otherwise)	x_1	A dummy variable indicating young age	+/-
Middle Age (1= 45 to 60; 0=otherwise)	x_2	A dummy variable indicating middle age	+/-
Sex (1=Male; 0=Female)	x_3	A dummy variable indicating sex of the charcoal producer	+
Education (1=At least primary school, 0=No school	x_4	A dummy variable indicating the level of education of the charcoal producer	+
Large size (1= 51.0cm^3 and above6; 0=otherwise)	x_5	A dummy variable indicating large size of the kiln	+/-
Medium size (1= 10.5cm^3 to 50.5cm^3; 0=otherwise)	x_6	A dummy variable indicating the middle size of the kiln	+/-
Kiln Type (1=Modern; 0= Tradition)	x_7	A dummy variable indicating the type of the kiln	+
Kiln Shape (1= Bottle, 0= otherwise)	x_8	A dummy variable indicating kiln shape	+/-
Kiln Shape (1=Box; 0; otherwise)	x_9	A dummy variable indicating kiln shape	+/-
Village 1 (1= Nyali; 0=otherwise)	V_1	A dummy variable indicating village 1	+/-
Village 2 (1= Ulaya Mbuyuni; 0=otherwise)	V_2	A dummy variable indicating village 2	+/-
Village 3 (1=Ihombwe; 0=otherwise)	V_3	A dummy variable indicating village 2	+/-
Error term	μ_i		

In addition to regression in this objective the study also the used to terciles to compare the profiles of charcoal by comparing the social-economic characteristics of charcoal producers with lowest yields and charcoal producers with the highest yields. The profiles were established by ranking yields per kilns of producers from the lowest to the highest and dividing them into 3 terciles of highest tercile, middle tercile and low tercile each having one third of the sample. Then the comparison was between the variables of the highest tercile and lowest tercile to see if there is any statistically significant difference. To compare continuous variables t-test was use and to compare qualitative variables chi-square test was used.

3.4.2 Costs of charcoal production

In this objective, similar to Mndeme (2008), cost of charcoal production was analysed by looking at the stages of charcoal production, costs of tools and to other related costs in production of charcoal. The costs included for charcoal production were kiln preparation (tree felling, tree processing, kiln site preparations, gather billets to the kiln site, arranging the billets, covering the arranged billets with grasses and soil). Other activities of which their costs were estimated included firing, monitoring the kilns, unloading and packaging. The labour used on kiln preparation and charcoal production were estimated in man-days. In the study area whole sellers are the one who buy charcoal at the production site. Costs data were summarized and analysed into mean, median, mode and standard deviation.

In addition, terciles were used to compare the cost profiles of charcoal producers by comparing the social-economic characteristics of charcoal producers with lowest cost and charcoal producers with the highest cost. The profiles were established by ranking cost per kilns of producers from the lowest to the highest and dividing them into 3 terciles of highest tercile, middle tercile and low tercile each having one third of the sample. Then the comparison was between the variables of the highest tercile and lowest tercile to see if there is any statistically significant difference. To compare continuous variables t-test was use and to compare qualitative variables chi-square test was used.

3.4.3 Profitability of charcoal production

In order to determine whether charcoal production is economically profitable the gross margin analysis was applied. Gross margin was calculated by deducting all cost from the total revenue generated from a kiln.

Total revenue was computed by taking the number of bags produced multiplying by price sold, while total cost was calculated by summing up all of the corresponding cost which were incurred during producing that output which included tool costs, food cost, kiln preparation costs and fees cost. The computation was done at a producer level regardless of the type of the kiln they used.

$$Gross\ Margin\ (GM) = \Sigma_i^n \left[\frac{R_i - C_i}{R_i} \Big/ n \right] x100\% \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(5)}$$

Where,

GM = Gross margin (TZS /kiln)

R_i = Total revenue (TZS /kiln)

C_i = Total variable costs (TZS)

n = Number of observations

3.4.4 Factors influencing profitability of charcoal production

Different information on factors influencing profitability was collected. Information on the level of education and experience of charcoal producer was collected, labour cost was collected through the use of the checklists and personal observation. Moreover, information on the size of the kiln was collected through measurements. A multiple regression similar to Burja (2011) and Kazimoto (2015) was used to assess the determinants of profitability in charcoal production.

$$P = \alpha + x_1\beta_1 + x_2\beta_2 + D_1\beta_3 + D_1\beta_3 + D_1\beta_3 + +D_1\beta_3 + D_1\beta_3 + D_1\beta_3 + D_1\beta_3 + D_1\beta_3 + D_1\beta_3 + V_1\beta_3 + V_1\beta_3 + V_1\beta_3 + \varepsilon_i$$

Where,

P = Profitability of charcoal producer as measured from net profit margin in TZS

χ_1 = Labour

χ_2 = Size of the kiln

χ_3 = Volume of the billets

χ_4 = Education level of charcoal producer

χ_5 = Sex of the charcoal producer

β_i = Coefficients of predictors

ε_i = Random error

Table 4 present definition of the variables used in formulating the model and their expected signs.

Table 4: Definition and expected signs of the variables

Variable		**Description**	**Expected Sign**
Volume of billets	x_1	Volume of billets loaded in the kiln	+
Labour	x_2	Number of labours used per kiln	+
Young Age (1= 18 to 4 years), 0=otherwise)	D_1	A dummy variable indicating young age	+/-
Middle Age (1= 41 to 60; 0=otherwise)	D_2	A dummy variable indicating middle age	+/-
Sex (1=Male; 0=Female)	D_3	A dummy variable indicating sex of the charcoal producer	+
Education (1=At least primary school, 0=No school	D_4	A dummy variable indicating the level of education of the charcoal producer	+
Large size (1= 51.0cm^{3}and above6; 0=otherwise)	D_5	A dummy variable indicating large size of the kiln	+/-
Medium size (1= 10.5cm^3 to 50.5cm^3; 0=otherwise)	D_6	A dummy variable indicating the middle size of the kiln	+/-
Kiln Type (1=Modern; 0= Tradition)	D_7	A dummy variable indicating the type of the kiln	+
Kiln Shape (1= Bottle, 0= otherwise)	D_8	A dummy variable indicating kiln shape	+/-
Kiln Shape (1=Box; 0; otherwise)	D_9	A dummy variable indicating kiln shape	+/-
Village 1 (1= Nyali; 0=otherwise)	V_1	A dummy variable indicating village 1	+/-
Village 2 (1= Ulaya Mbuyuni; 0=otherwise)	V_2	A dummy variable indicating village 2	+/-
Village 3 (1=Ihombwe; 0=otherwise)	V_3	A dummy variable indicating village 2	+/-
Error term	ε_i		

Volume of the billets: Volume of the billets were calculated in cm^3 by using Huber's formula. First, the length of each billet was measured by the use of tape measure and diameter of each billet was measured at bottom middle and end side by using calliper. The expected sign is positive because a person who use more trees is expected to have more yield than the one who use a smaller number of trees. This in turn will lead to high profitability.

Labour: Labour was calculated as total man days supplied in charcoal production. The total working hours per day in charcoal production was 9 hours. The expected sign of labour is positive as increase in labour will increase in amount of yield and hence in profitability of charcoal.

Age: The age of charcoal producers was categorized into three main group namely young age with age of 18 to 44 years and middle age with age of 45 to 60 years while old age was used as a reference to avoid dummy variable trap. The expected sign is positive because men engage more and are getting more profit compared to females.

Sex: This shows the sex of charcoal producers which can either be male or female. The expected sign is positive because males tends to be favoured by traditional and male dominated system which used to be in their favour due to this they are expected to have higher profits compared to females.

Education: This was categorized into two groups of those with at least primary school and those with no education. The expected sign is positive because education is important in charcoal production and hence in profitability.

Size of the kiln: Three categories of size were created. The medium size of 10.5cm3 to 50.5cm3 and the large size of 51.0cm3 and above. The small size was used as reference to avoid dummy variable trap. The expected size of the kiln is either positive or negative because in both large and medium size the profit can either be high or low.

Kiln type: Two categories of kiln type were observed. The modern one and the traditional kiln. The expected sign of the kiln type is positive because those who use modern kiln are expected to get more profit than those using traditional kiln.

Kiln shape: Three types of kiln shape were identified. These include bottle shape, box shape and pyramid shape. However two kiln shapes which are bottle and box were used in analysis and the third was used as a reference to avoid dummy variable trap. The expected sign is either positive or negative because the shape of the kiln does not determine the amount of charcoal that will be produced hence its profitability.

Village: Village as a dummy variable included three villages namely Nyali, Ulaya Mbuyuni and Ihombwe village. The third village which is Dodoma Isanga was used as a reference to avoid dummy variable trap. The expected sign is positive as anyone from each village can get high or low profit depending on how well he or she has utilized the factors of production and his or her experience.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Charcoal Yield per Kiln

4.1.1 Characteristics of charcoal producers in the study area

Table 5 below presents the characteristics of charcoal producers in the study area.

Table 5: Characteristics of charcoal producers in the study area

Variable	Percentage
Age	
Young age (18-44 years)	63%
Middle age (45-60 years)	28%
Old age (above 60)	10%
Sex	
Male	38%
Female	62%
Level of education	
No school	28%
Primary school	67%
Secondary school	5%
Type of kiln	
Modern kiln	44%
Traditional kiln	56%
Shape of kiln	
Box shape	41%
Bottle shape	48%
Pyramid shape	11%
Villages	
Nyali	25%
Ulaya Mbuyuni	24%
Ihombwe	25%
Dodoma Isanga	26%

As can be seen in Table 5 about 63% of the producers were males and 38% are females, in many studies in Tanzania and other sub-Saharan countries such as Doss (2011) males used to dominate production because the traditional and cultural system used to favour males over females on land ownership and decision making. This implies that women are not actively engaged in charcoal production, according to interview this might be caused by the nature of production which requires masculine activities in preparation of billets, kiln construction and unloading the kilns. On the other hand, women are required to perform domestic activities which limits their active participation in charcoal making business.

Also, in the study area as can be seen in Table 5 about 63% of charcoal producers were in young age group ranging 18 to 44 years, 28% were in the middle age group ranging 45 to 60 years and 10% were in the old age group ranging 60 years and above. In the study area majority of producers are in the young age group. According to Okaye *et al*. (2008) young producers are energetic and more likely to adopt to new technologies than their older counterparts. This implies young age group are expected to be more correlated with high yield.

Moreover, as can be seen in Table 5 about 28% of the charcoal producers have no formal education, 67% have primary education and 5% have secondary education. The findings show most of producers have no a very little education. Expose to schooling enhances producers' ability to efficiently acquire, synthesize and processing production information and respond to various production challenges Weir and Knight (2000). This implies that yield is expected to be correlated with producers with more education.

Similarly, in the study area as shown in Table 5 about 44% of charcoal producers used modern kilns while 56% used traditional kilns. The percentage of traditional kilns being slightly higher than modern is because of relatively high capital needed to construct modern kilns compared to traditional kiln. In the study area about 11% of producers used pyramid shaped kiln, about 41% used box shaped kilns and 48% used bottle shaped kilns.

4.1.2 Factors influencing charcoal yield per kiln

Results of the factors influencing charcoal yield per kiln are presented in Table 5. From the results the R-squared is 0.810 implying that the regression model accounts for about 81% of the variation on the response data.

The results show that most of the variables that were hypothesised to influence charcoal yield per kiln showed to have significant effects. The two important factors of production labour and capital both show positive significant effects on charcoal yield per kiln. Addition of one labour in charcoal production process resulted in a 0.24% increase in the yield per kiln. The results are consistent with that of Neufeldt *et al.* (2015) where addition to labour in charcoal production process resulted in an increase in the production since the activity is labour intensive. Similarly, addition of a unit capital in charcoal production process resulted in a 0.19% in the yield per kiln. This correspond to the study of Menemencioglu (2013) where addition of capital in production increases yield despite of this activity not necessarily needing a lot of capital to initiate.

Household characteristics such as age, sex and education also showed very high significant effect on the charcoal yield per kiln. The findings show that a kiln that was operated by a male yield were 53 % higher compared to that operated by a female holding other factors constant. These results concur with Fletcher and Kenney (2011) who argued that in African countries women are facing many constraints which hinder their productivity such as limited access to capital, fear of indebtedness, lack of information as a result of taboo relating to interactions between people of opposite sex such as women attending meetings outside home.

Similarly, the findings show that the kiln that had a producer with at least primary school education the yield was 76% higher compared to kiln which producers with no school.

According to Weir (1999), education enables producers to interact and manage more efficiently both systemic and idiosyncratic shocks during production and hence they become more productive.

Furthermore, for the age variable, kiln that was operated by the young age group ranging from 18 to 44 years the yield was 76% higher than middle age and old age. Similarly, the kiln that was operated by middle age group ranging from 44 to 60 years the yield was 39% higher than old age group ranging from 60 years and above. Young age groups have more productive as they are more energetic and more easily to adopt new technologies (Odhiambo and Nyangito, 2003).

The variables related to production technology including kiln type, kiln size and kiln shape showed mixed results some being significant and some not. The type of kiln showed significant effects where a modern kiln was having a yield 40% higher than traditional kiln. For kiln size the results were significant only for medium size kiln were the yield from medium size kiln was 50% higher compared to other kiln sizes. The kiln shape variables were all not significant implying that shape of the kiln did not have any significant effects on the yield. This result is similar to that of Falcao (2008) where the study found producers who used technological advanced kiln had more significantly higher yield compared to those who did not.

In capturing unobserved heterogeneity such as infrastructure and local village factors to avoid biased estimates of unknown parameters, village fixed effects were controlled as presented on village variables. As can be seen in the table some were significant implying that location in the study area influences yield, for instance a producer in Nyali village was having yield 56% compared to other villages holding other factors constant while a producer in Ulaya Mbuyuni village was having 33% higher holding other factors constant.

Table 6: Factors influencing charcoal yield per kiln

Variable	Coefficient	p>|t|
Labour	0.2401	***0.000
Capital	0.1994	**0.031
Sex (1=Male; 0=Female)	0.5321	***0.000
Education (1=At least primary school, 0=No school	0.7978	***0.000
Young Age (1= 18 to 44 years), 0=otherwise)	0.7570	***0.000
Middle Age (1= 45 to 60; 0=otherwise)	0.3856	*0.057
Medium Size (1= 10.5cm^3 to 50.5cm^3; 0=otherwise)	0.5013	**0.031
Large (1= 51.0cm^3 and above; 0=otherwise)	0.4370	*0.077
Kiln Type (1=Modern; 0= Tradition)	0.3998	***0.003
Kiln Shape (1= Bottle, 0= otherwise)	0.2661	0.369
Kiln Shape (1=Box; 0; otherwise)	0.1101	0.685
Village 1 (1= Nyali; 0=otherwise)	0.5591	***0.001
Village 2 (1= Ulaya Mbuyuni; 0=otherwise)	0.3338	**0.038
Village 3 (1=Ihombwe; 0=otherwise)	0.2246	0.128
Constant	-7.1942	***0.000
Number of observation		61
F (12, 48)		14.03
Prob > F		0.000
R-squared		0.810
Statistical significance level		5%

(*= significant at 10% level; **=significant at 5% level; ***=significant at 1% level)

4.1.3 Yield per kiln profiles of charcoal producers

In addition to regression, the analysis of factors influencing charcoal yield per kiln was further examined by comparing social-economic characteristics of the lowest and the highest terciles of yield per kiln. The yield per kiln of all individuals were ranked from the highest to the lowest and divided into terciles and statistical comparison was made. Table 6 and Table 7 presents the terciles of qualitative and continuous variables respectively.

Table 6 presents the comparison of yield per kiln using qualitative variables. As can be seen from the table, the proportion of female compared to male is lower in the highest tercile kilns compared to the proportion of compared to proportion of female to male in the lowest tercile kilns, the results shows from 35% of producers composing the highest tercile kilns female are only 3% while male are 32%; while from 32% of producers composing lowest tercile kilns the proportion of women is 16% and males 16% significant at p-value of 0.014. This implies that males producers had more yield per kiln compared to females. The findings are consistent with that of Kazimoto (2015) where by charcoal production is largely undertaken by male, the findings show that about 65.8% of charcoal production was done similarly Doss (2011) communities in sub-Sahara African societies including Tanzania are male dominated system which side-line women in various social issues such as education, land and wealth ownership as a result woman become less productive.

For education variable, the proportion of producers with at least primary school is higher in the highest tercile kilns compared to the lowest tercile kiln, the results show from 35% of producers composing highest tercile kilns producers with at least primary school is 32% and only 3% were with no school; while from 31% of producers in the lowest tercile kilns only 6% of producers had at least primary school while 25% had no school significant at p-value of 0.000. This implies producers who attended at least primary school have more yield per kiln compared to those with no school at all. This is consistent with results of Jones (2015) which shows despite charcoal production being dominated by less educated producers, charcoal producers who are educated are more productive relatively to with less educated.

For type of the kiln used, results show the proportion of producers using traditional kilns is lower in the highest tercile while the proportion of producers using tradition kilns in the lowest tercile being significantly high. The results show from 35% of producers in the highest kiln 19% used modern kilns while 16% used tradition kilns; while from 31% of producers in the lowest tercile 25% used traditional kilns and only 6% used modern kilns significant at 0.011. This implies that using modern kilns producers derives more yield compared to traditional kilns. Similar to Kazimoto (2015) charcoal producers who used traditional kilns are less efficient in converting charcoal into wood which result to lower yield per producer. According to Van Beukering et al. (2007) traditional kiln wastes about 70% of wood caloric value which accelerates deforestation.

As can be seen in Table 7 there is a significant difference between volume of the billets use for a producer in the lowest tercile compared to the producer in the highest tercile, a producer in the lowest tercile approximately uses 23 000cm^3 of billets compared to 11 000cm^3 of billets in the highest tercile kiln, the difference being significant with p-value of 0.001. This implies that despite large volume used by producers in lowest tercile kilns their yield is lower compared to those in the highest tercile kilns who use less volume but obtaining greater yield.

In contrary to volume of billets, the number of bags produced by lowest tercile kilns were significantly less compared to the number of bags producer by the highest terciles kilns, a producer in the lowest tercile kiln produce approximately 15 bags compared to 36 bags in the highest tercile kiln the difference being significant at p-value of 0.000.

Moreover, the producers in the highest tercile kilns use more trees compared to the producers in the lowest tercile kilns where, a producer in the highest tercile uses about 8 tress compared to 4 trees used by the lowest tercile kilns significant at p-value of 0.000. The results implies that high yield producers uses more trees and still there are more efficient compared to the low yield producers.

On the side of primary factors of production of labour and capital the results show significant difference for both. The producers in the highest tercile kilns use more cost compared to the producers in the lowest tercile kilns, a producer in the highest kiln approximately used TZS 120 000 compared to TZS55 000 in the lowest tercile kilns. This implies that the high yield producers significantly invest more in production by purchasing various inputs such as tools, food and others which increases their efficiency compared to the lowest tercile producers. Similarly producers in the highest tercile kilns use more labour hours compared to the lowest tercile kilns, a producer in the high yield kiln use about 67 labour hours compared to 38 labour hours in the lowest tercile kilns. This implies that there is more use of labour in the highest tercile kilns compared to the lowest tercile kilns.

Table 7: Comparison of proportion qualitative variables

	Variable	Lowest Tercile	Middle Tercile	Highest Tercile	Total	Chi-square
Sex	Female	16	10	3	29	
	Male	16	24	32	71	***0.014
Total		32	33	35	100	
Age	Young Age	14	22	25	62	
	Middle Age	10	6	10	25	
	Old Age	8	5	0	13	0.127
Total		32	33	35	100	
Education	No school	25	3	3	32	
	At least primary school	6	30	32	68	***0.000
Total		31	33	35	100	
Kiln Type	Tradition	25	22	16	44	
	Modern	6	11	19	56	***0.011
Total		31	33	35	100	
Shape	Bottle	14	19	10	43	
	Box	16	13	22	51	
	Pyramid	2	2	3	6	0.399
Total		32	34	35	100	

(*= significant at 10% level; **=significant at 5% level; ***=significant at 1% level)

Table 8: Comparison of means for continuous variables

Variables	Lowest Tercile			Middle Tercile			Highest Tercile			p-value
	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	
Volume of billets	23032	17993	13667	14940	14730	928	11329	12811	759	***0.001
Bags	15.3	11.5	2.4	27.9	27.5	2.2	35.7	38.0	2.1	***0.000
Number of trees	3.9	3.0	0.5	6.6	7.0	0.6	8.0	9.0	0.6	***0.000
Capital	55245	58050	5517	146375	96500	30623	119252	108500	9347	***0.000
Labour	37.5	27.5	6.6	73.4	55.0	15.0	67.4	64.0	9.3	***0.000

(*= significant at 10% level; **=significant at 5% level; ***=significant at 1% level)

4.2 Cost of Charcoal Production

In this objective the analysis of charcoal production per bag was conducted by observing different processes and items involved in charcoal production and from apiece contribution of to the cost of bag was calculated.

4.2.1 Cost per bag for different stage of production

Table 8 presents cost for of each process from the study area. For tree preparation stage, on average 4 labour were used for 6 days costing of TAS 37 800 this was equivalent to TAS 2877 per kiln and TAS 1874 per bag. For kiln preparation on average 4 labour were used for 6 days costing about TAS 20 236 this was equivalent to TAS 1269 per kiln and TAS 864 per bag. Lastly average 3 labour were used during supervision stage for 6 days making costing about TZS 14 143, this was equivalent to TAS 1646 per kiln and TAS 502 per bag.

Table 9: Cost per bag for different stage of production

Variable	Mean	Median	Mode	SD	Min	Max
Days used for tree cutting and billet preparation??	6	6	7	4.18	1	30
Number of labour used in tree preparations	4	3	3	2.52	1	12
Total labour days for tree preparations	20	16	12	13.35	2	70
Tree preparation cost	37800	21000	5000	57292.25	500	350000
Cost per kiln (tree preparation)	2877	1250	333	4127.27	24	16667
Cost per bag (tree preparation)	**1874**	**955**	**500**	**1671.00**	**50**	**7000**
Days used for kiln preparations	6	6	7	3.00	1	28
Number of labour used in kiln preparation	4	3	2	2.00	1	10
Total labour days for kiln preparations	23	20	15	18.81	2	140
Kiln preparation cost	20236	12500	10000	14363.00	6200	60000
Cost per kiln (kiln preparation)	1269	607	1429	1593.80	204	5400
Cost per bag (kiln preparation)	**846**	**667**	**1000**	**715.02**	**200**	**3000**
Days used for supervision of the kiln	6	6	7	3.24	1	21
Number of labour used in supervision of the kiln	3	3	2	1.98	1	10
Total labour days for supervision of the kiln	18	15	10	12.10	2	84
Kiln supervision cost	14143	14000	5000	7861.90	5000	25000
Cost per kiln (kiln supervision)	1646	500	500	2029.49	208	5000
Cost per bag (kiln supervision)	**502**	**467**	**-**	**304.99**	**167**	**909**

4.2.2 Cost per bag for equipment in charcoal production

In each stage of charcoal production mentioned there are several basic equipment, including axes, hoes, rakes, spades and machetes; the cost of buying these equipment were calculated to capture the cost of continuous use them for charcoal production. Table 9 presents equipment cost, an axe used for tree cutting have average purchasing cost of TZS 4000 with a lifespan of 2 years. During the lifespan of 2 years average of 240 bags are produced making a unit cost of producing a bag being TZS 133. Similarly, a machete used for tree cutting have an average purchasing price of TZS 4 000 with a lifespan of 2 years. During the lifespan of 2 years average of 240 bags were produced making a unit cost of producing a bag using machete being TZS 67. For hoe, rake and spade have average purchasing price of TZS 4 000, TZS 7 000 and TZS 8 000 respectively. Their respective lifespan was 1 year, 2 years and 2 years with 120 bags produced per hoe, 240 bags for rake and 240 bags for spade. Due to this the unit cost for producing a bag was TZS 67 for a hoe, TZS 38 for a rake and TZS 133 for a spade.

Table 10: Cost per bag for equipment in charcoal production

Type of equipment	**Purchasing price** (TZS)	**Life time in use (years)**	**Number of charcoal bags produced per year**	**Total number of charcoal bags produced per equipment**	**Unit cost per bag per equipment** (TZS)
Axe	4000	2	120	240	**133**
Hoe	4000	1	120	120	**67**
Rake	7000	2	120	240	**38**
Spade	8000	2	120	240	**133**
Machete	4000	2	120	240	**67**
Total					**438**

4.2.3 Other cost per bag related to charcoal production

In addition to basic production cost, there other cost that producer incurred. The cost includes food cost which can vary from one producer to another and annual registration fees which all producers have to pay to the government and it is same to all producers regardless the number of bags all kilns produces during the year.

As can be seen in Table 10 in the study area average food cost in charcoal production is about TZS 48 603, this cost is corresponding to TZS 1 704 per bag and TZS 12 781 per kiln. For annual registration fees as can be seen is fixed amount of TZS 261 000 and depending on the production of individual producer in the study area registration fees per bag was TZS 4 049 and TZS 74 041 per kiln.

Table 11: Other cost per bag related to charcoal production

Variable	Mean	Min	Max	SD	Observation
Average food cost	48603	0	228800	48601	120
Food cost per bag	1704	0	13538	1895	120
Food cost per kiln	12781	0	176000	19732	120
Annual registration fees per producer	261000	261000	261000	0	120
Registration fees per bag	4049	621	29000	4274	120
Registration cost per kiln	74041	26100	261000	32518	120

4.2.4 Cost per kiln profiles of charcoal producers

In addition to studying cost per bag in charcoal production, the analysis compared socio-economic characteristics of producers. The tercile analysis was used to compare producers in lowest and the highest terciles of cost per kiln. The terciles were formed by ranking all producers from one with lowest cost per to the highest cost per kiln and statistical comparison was made. Table 11 and Table 12 presents the terciles of continuous and qualitative variables respectively.

From Table 11 there is a significant difference between average cost used in the lowest tercile compared to the highest tercile, on average a producer in the highest tercile uses about TZS 104 594 while the in the lowest tercile uses about TZS 33 723 significant at 0.000. Average cost is a proxy to investment made by a producer in the charcoal production and this result implies that producers in with lowest tercile invest less compared to producers in the highest tercile. This is consistent with Malimbwi and Zahabu (2007) investing in charcoal production technology specifically improved kilns used to contribute significantly in efficiency, therefore producers using more capital obtain more yield compared to those who lack capital.

As can be seen in Table 11 there is a significant difference between the number of trees used by producer in the lowest tercile compared to the producer in the highest tercile, a producer in the lowest tercile uses about 5 trees compared to 8 trees in the highest tercile significant at p-value of 0.001. This implies that producers with more cost per kiln uses more trees. Similarly, for number of bags producer there is a significant difference between the lowest cost per kiln tercile and the highest cost per kiln tercile, a producer in the lowest produce average of 24 bags compared to 35 bags in the highest significant at p-value of 0.001. This implies that producers with more cost per kiln producers significantly higher number of bags. The results are consistent with NLA (2010) argued that charcoal is poor mans’ business with limited resources which results into low usage of inputs as well as production of output.

Table 12 presents the comparison of cost per kiln using qualitative variables. As can be seen from the table the proportion of producers with at least primary school is high in the highest tercile compared to the lowest tercile, results show from 34% of producers composing the highest tercile 31% had at least primary school while only 3% had no school. This implies that producers with schooling are likely to invest more compared to those with no school.

For type of kiln used there is a significant difference between producers used traditional and modern kilns in the lowest and highest terciles, results show from 34% of producers in the highest tercile 24% use modern kilns while 10% use traditional kilns while among 33% from the lowest tercile 11% used modern kilns while 22% used tradition kilns. This result implies that in investing in high yield kilns requires relatively high investment consistent with Mndeme (2008) where modern kilns need higher investment.

For other qualitative variables such as sex, age, shape of the kiln and village were did not show significant difference between the highest cost kiln and the lowest cost kiln.

Table 12: Comparison of costs between low, middle and high cost kilns: Continuous variables

Variable		**Lowest Tercile**			**Middle Tercile**			**Highest Tercile**		
	N	**Mean**	**SD**	**N**	**Mean**	**SD**	**n**	**Mean**	**SD**	**p-value**
Total cost	40	33723	12234	40	75350	10320	40	170090	104594	***0.000
Number of trees	40	5	3.05	40	6	3.40	40	8	3.59	***0.001
Volume of billets	40	10425	14667	40	7806	8545	40	7650	7577	0.286
Number of bags	40	24	13	40	27	17	40	35	15	***0.001

(*= significant at 10% level; **=significant at 5% level; ***=significant at 1% level)

Table 13: Comparison of socio-economic profile between low, middle and high cost kilns

Variable		Lowest Tercile	Middle Tercile	Highest Tercile	Total	Chi-square
Sex	Female	13	12	8	32	
	Male	20	22	27	68	0.243
Total		33	33	33	100	
Age	Young Age	18	23	23	63	
	Middle Age	11	8	8	28	0.739
	Old Age	4	3	3	10	
Total		33	33	33	100	
Education	No school	12	13	3	28	
	At least primary	21	20	31	72	***0.005
Total		33	33	33	100	
Kiln Type	Tradition	11	15	24	50	
	Modern	22	18	10	50	***0.003
Total		33	33	33	100	
Shape	Bottle	18	13	18	48	
	Box	11	17	13	41	0.645
	Pyramid	4	3	3	11	
Total		33	33	33	100	
Village	Nyali	4	8	13	25	
	Ulaya Mbuyuni	8	8	8	24	0.140
	Ihombwe	12	8	5	25	
	Dodoma Isanga	9	9	8	26	
Total		33	33	33	100	

(*= significant at 10% level; **=significant at 5% level; ***=significant at 1% level)

4.3 Profitability of Charcoal Production

This section analyses the profitability of charcoal production per kiln in the study area by using gross margin. Gross margin was calculated by deducting all cost from the total revenue generated from a kiln. Total revenue was computed by taking number of bags produced multiplying by price sold, while total cost was calculated by summing up all the corresponding cost which were incurred during producing that output which included tools cost, production costs, food and fees cost. The computation is presented in Table 13 below.

Table 14: Charcoal production gross margin

Variable	Modern Kiln	Traditional Kiln	Mean
Average tool cost	25283	26697	25990
Average food cost	38285	57403	47924
Average fixed cost	67342	72101	69722
Total variable cost	81772	102678	92225
Average price	10267	10700	10483
Total Revenue	275100	323633	299367
Gross margin	**28%**	**25%**	**26%**

Charcoal production gross margin was 26% implying that in the study area on average the charcoal producers retains about 26% of each TAS 1 they earn after selling their charcoal. For charcoal producers who used modern kilns the gross margin was 28% implying that for charcoal producers using modern kilns retains about 28% of each TAS 1 they earn after selling charcoal; while for charcoal producers using traditional kiln the gross margin was 25% implying that for charcoal producers using traditional kilns retains about 25% of each TAS 1 they earn after selling charcoal. As can be seen in the findings, production using improved kilns retains more profits compared to production using traditional kilns.

4.4 Factors Influencing Profitability of Charcoal Production

Results of the factors influencing profitability of charcoal production in the study area are presented in Table 14. From the results the R-squared is 0.4942 indicating that the regression model accounts for about 50% of the variation in the response data.

From production and technology variables labour and kiln type were significant while others were not. From the results a producer who used a modern kiln had TZS 0.45 profit higher than those who used traditional kilns holding other factors constant. For labour an additional of unit labour in charcoal production increase profit by TZS 0.0047 holding other factors constant. The result is similar (Neufeldt *et al.*2015) where improved kilns produces higher profits.

The findings show for household characteristics variables age was statistically significant while sex and education were not. For age variable a producer within young age group had TZS 1.15 profit higher than other age groups holding other factors constant. For a producer within middle age group had TZS 1.10 profit higher than other age groups holding other factors constant.

In addition, for capturing unobserved heterogeneity such as infrastructure and local village factors to avoid biased estimates of unknown parameter village fixed effects were controlled as presented on village variables. As can be seen in Table 14 a producer in Ihombwe village had TZS 0.45 profit higher compared to other villages holding other factors constant. Other village variables were not significant.

Table 15: Factors influencing profitability of charcoal production

Variable	Coefficient	p>|t|
Young Age (1= 18 to 44 years), 0=otherwise)	1.15244	***0.001
Middle Age (1= 45 to 60; 0=otherwise)	1.10489	***0.001
Sex (1=Male; 0=Female)	0.37014	*0.095
Education (1=At least primary school, 0=No school	0.24869	0.349
Volume of billets	0.00002	0.175
Large size (1= 51.0cm^3 and above6; 0=otherwise)	-0.35858	0.360
Medium size (1= 10.5cm^3 to 50.5cm^3; 0=otherwise)	-0.05952	0.869
Labour	0.00469	*0.018
Kiln Type (1=Modern; 0= Tradition)	0.44525	**0.033
Kiln Shape (1= Bottle, 0= otherwise)	0.32785	0.439
Kiln Shape (1=Box; 0; otherwise)	0.16139	0.688
Village 1 (1= Nyali; 0=otherwise)	0.01945	0.941
Village 2 (1= Ulaya Mbuyuni; 0=otherwise)	-0.15883	0.534
Village 3 (1=Ihombwe; 0=otherwise)	0.45274	*0.058
Constant	-2.32144	***0.003
Number of observation		61
F(12, 48)		3.21
Prob > F		0.0014
R-squared		0.4942
Statistical significance level		5%

(*= significant at 10% level; **=significant at 5% level; ***=significant at 1% level)

4.5 Implication of Charcoal Production Technologies to Management of Miombo Woodlands

Based on the findings, improved kilns technology has shown advantages both in terms of profitability to the producer as well as yield compared to traditional kilns. As the results shows, it infers that an individual investing one Tanzanian Shilling in charcoal business by using modern kiln will be using less wood by 40% and make profit 0.45 cents higher than an individual who is using traditional kiln who use the same amount of investment. This implies that, in order to manage Miombo Woodland sustainably without compromising much on the welfare of charcoal producers, the use of improved modern kilns should be emphasized.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

The main objective of the study was to analyse charcoal production technologies and its implication to the Miombo woodlands in Kilosa district in Morogoro region. The study focused various aspects of production including yield, cost, gross margin and profitability. In doing so various variables related to affecting production including producer individual characteristics, production technologies, inputs, and location of production were used in the analysis. The specific objectives of the study were to analyse charcoal yield per kiln in the study area, to analyse the cost of charcoal production per bag in the study area, to analyse profit of charcoal production per kiln in the study area and to analyse factors influencing profitability of charcoal production in the study area.

5.1 Conclusion

The findings from the first objective show that in the study area producers who used modern kilns were deriving more yield compared to those who used traditional kilns while other production technology variables such as shape and size of the kiln were not significant. Producer characteristics such as age, sex and education were highly significant with respect to yield obtained in production process.

The findings from the second objectives identified and examined number of cost that associated in charcoal production. The findings show three main cost are incurred: production costs, tools cost and other cost including food and registration cost. Also through tercile analysis the study showed there is a statistically significant difference between social-economic variables of producers between the highest cost producers and the lowest cost producers.

The findings from the third objective showed that in the study area the gross margin for charcoal producers using improved kilns was about 28%, this indicates that in the study area producers earn profit from production process where in each TZS 10 000 selling of charcoal bag they remain with TZS 2 800 as profit after deducting all the cost.

Lastly, the findings from the fourth objective showed producers for charcoal production technology variables producers who used modern kiln were more profitable compared to those who used traditional kilns while other technology variables were not significant. Similarly, producer characteristics variables such as age and sex were significant while others such as education were no significant.

5.2 Recommendations

Based on the findings the following are recommendations:-

First, to achieve greater sustainability of Miombo woodland in the study area, policies toward harvesting forest should emphasize the use of modern kilns as they have showed greater advantage in yield, cost and profitability. Therefore in doing so investing in capacity building and training are needed to make producers aware on the use of modern kilns and their advantages.

Secondly, in order to enable most of the producers to use modern kilns, government should prepare ways which will enable producers to obtain enough capital such as credits and subsidy (subsidy such as removing annual registration fees for producers who opt to use modern kilns) to enable producers to construct modern kilns as have been seen that modern kilns used to be associated with high cost (investment) therefore removing this cost obstacle will not only help the producers but also will help in improved management of Miombo woodlands.

Lastly, since education seemed to be significant in yield, cost and profitability government should promote education among charcoal producers and encourage more educated people to engage themselves in sustainable charcoal production. This is important because according to Neufeldt *et al.* (2015) about 40% of charcoal makers have no formal education, due to this the activity attracts more people to join which have negative consequences in the Miombo woodlands. Therefore encouraging educated people in charcoal production activity will have positive effect on managing Miombo woodlands as educated people are more aware on environmental issues compared to uneducated ones.

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APPENDIX

Appendix 1: Checklist (for charcoal producers)

Checklist (for charcoal producers)

1. How many members do you have in your charcoal making group?
2. What are the preferred tree species for charcoal making?

Local name	Botanical name	Use frequency	Mean Dbh	Tree volume

3. What type of kiln do you use for making the charcoal ………………………….?
4. What is the shape of kiln?...
5. What is the cost of constructing the above mentioned kiln?

Activity	Cost
Tree cutting	
Logs processing	
Logs collection	
Transportation to the kiln site	
Kiln preparation	
Supervision	

6. What are steps of kiln construction……………………………..?

7. Kiln size

Length(m)	
Width(m)	
Height(m)	
Radius(m)	

8. Source of labour for charcoal making

Labour source	Village

9. If it is hired labour how much do you pay per kiln construction/activity...............?

10. Tools used in charcoal production

Tool	Ownership	Rent	Purchasing price (TAS)	Lifespan in (years)
Axe				
Hoe				
Rake				
Spade				
Others				

11. Number of days required for different charcoal making activity

Activity	Number of days required
Wood cutting	
Kiln preparation	
Carbonisation and supervision of the kiln	
Unloading the charcoal	

12. How many bags of charcoal are obtained per kiln (traditional or improved technology)……………………………………..

13. Efficiency of charcoal production

Size of the kiln	Number of billets/kiln	Billets size (cm)	Average (cm)	Measured kiln volume (m^3)	Measured biomass (kg)	Number of bags/kiln	Average bag weight (kg)	Charcoal weight	Eff. (%)kg

14. What is the average price of charcoal?

Charcoal at different places	Price of charcoal(Tsh/bag)
At the production site	
At kilosa road	
At the high way	
Morogoro urban price	

15. Costs/km for different modes of transport

S/N	Mode of Transport	Number of bags	Number of trips	Distance from the production site to the road site(km)	Distance from the road site to the market(km)	Time taken to the market(hrs)	Cost pertrip or perbag (TAS)
1	Lorry						
2	Canter						
3	Pickup						
4	Tractor trailer						
5	Motorcycle/Bicycle						
6	Others						