IMPACT OF WOOD FUEL PRODUCTION AND CONSUMPTION ON ZUKALA FOREST, LIBEN ZUKALA DISTRICT OF OROMIA REGIONAL STATE, ETHIOPIA

M.Sc. THESIS

BY: LEMLEM CHERINET WELDEYES

HAWASA UNIVERSTY WONDO GENET COLLEGE OF FORESTRY AND NATURAL RESOURCE, WENDO GENET, ETHIOPIA.

SEPTEMBER, 2020

IMPACT OF WOOD FUEL PRODUCTION AND CONSUMPTION ON ZUKALA FOREST, LIBEN ZUKALA DISTRICT OF OROMIA REGIONAL STATE, ETHIOPIA

BY: LEMLEM CHERNIET WELDEYES

THESIS SUBMITTED TO

THE DEPARTMENT OF GENERAL FORESTRY, WONDO GENET

COLLEGE OF FORESTRY AND NATURAL RESOURCES, SCHOOL OF GRADUATE STUDIES , HAWASSA UNIVERSTY,

WONDO GENET, ETHIOPIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN FOREST RESOURCE ASSESSMENT AND MONITORING

SEPTEMBER, 2020

Approval sheet I

This is to certifay that the thesis entiteled “Impact of Wood Fuel Production and Consumption on Zukala Forest,Liben Zukala District of Oromia Regional State, Ethiopia’’ submitted in partial fulfillment of the requirements for the degree of Master of Science in Forest Resource Assesment and Monitoring, the Graduate program of the Department /School of General Forestry and has been carried out by Lemlem Cherinet. Id. No MSC/FRAM/R012/11, under my/our supervision. Therefore, I/we reccommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

_____	_____	_____
Name of Major Advisor	signature	Date
_____	_____	_____
Name of co-advisor	signature	Date
_____	_____	_____
Head of Department	signature	Date
_____	_____	_____
Graguate program	signature	Date

Approval sheet II

We the undersigned members of the Board of Examiners of the final open defense by Lemlem Cherinet have read and evaluated her thesis entitled “Impact of Wood Fuel Production and Consumption on Zukala Forest,Liben District Oromia Regional State, Ethiopia” and examined the candidate.

This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Master of Science in Forest Resource Assesment and Monitoring.

_____	_____	_____
Name of the Chairperson	Signature	Date
_____	_____	_____
Name of Internal Examiner	Signature	Date
_____	_____	_____
Name of Major Adviser	Signature	Date
_____	_____	_____
Name of External Examiner	Signature	Date
_____	_____	_____
SGS Approval	Signature	Date

Final approval and acceptance of the thesis is continget up on the submission of the final copy of the thesis to the school of Graduate studies(SGS) through the department /school Graduate committee (DGC/SGC) of the candidate’s department.

Date ----------

Remark

ACKNOWLEDGEMENTS

First of all I would like to thank my almighty God for everything I have achieved until now in my life and for my success in education specially for this thesis and the cooperation and unreserved contribution of various individuals, group and organizations for the successful accomplishment of the study.

" I would like to thank my advisers Dr Tesfaye Ashine and Mr Getachew Demie (Assistant profeser) for their unreserved help throughout the thesis proposal preparation and write up"

Also I would like to thank all Liben Zukala District Administration , Agricultural office staff for their help and cooperation in any activities I did for this thesis in this district, and at the last but not the least I thank my family,my mather Desta Gezaw, my father Chernet Weldeyes, my sister Hana Chernet, my husband Eshetu Bekele, my sons Yoftahe Eshetu and Oliber Eshetu, they have been always with me in their spiritual pray and I like to thank all individuals who helped me and have good wishes for my successes.

TABLE OF CONTENTS

DEDICATION

I would like to dedicate this work to my beloved sons who sacrifice so many during the course of this study. This work is also dedicated to my family who tirelessly provided me with financial and moral support. I can never find words good enough to thank you, may God bless you.

ACRONYMS AND ABBREVIATIONS

KII	Key Informant Interview
HH	Household
FGD	Focus Group Discussion
BFEDO	Bureau of finance and economic development of Oromia
ZF	Zukala forest
AGB	Above ground biomass
BGD	Below Ground Biomass
MASL	Meter Above Sea-Level

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

IMPACT OF WOOD FUEL PRODUCTION AND CONSUMPTION ON ZUKALA FOREST, LIBEN ZUKALA DISTRICT OF OROMIA REGIONAL STATE, ETHIOPIA

Lemlem Cherinet Email, lemlemcher@gmail.com

ABSTRACT

Over three billion people throughout the world rely on traditional fuels such as fuelwood. In Ethiopia, 90 percent of energy consumption comes from biomass. Such heavy reliance on this form of energy is a threat to forest ecosystems. This study was carried out to assess amount of wood fuel consumption, factors affecting wood fuel consumption rate and assess the awareness of the community on the impact of wood fuel production and consumption on forest resource, in Liben Zukala district Oromia regional state, Ethiopia. The study was based on questionnaire from randomly selected households, focus group discussion and market survey. The inventory was conducted in Zukala forest to determine the biomass and volume of the standing trees in a systematically laid plot and compare with the household charcoal and fire wood consumption. In each plot, data were collected on tree species, plant height, diameter at breast height (DBH), number of sapling and seedling. The study revealed that 8,108.8 tons of fire wood and 6,472 tons of charcoal per annum had been extracted from the forest while the forest Biomass was 292 tons per ha on 3649.35 ha of total forest area implying that due to charcoal and fire wood 116.7 ha and 0.07 ha of forest degraded per annum, respectively. The regression result revealed that, family size and total land size owned were found to be significant and positively correlated with the probability of wood fuel consumption rate while total income was found to be 1% level significant and negatively correlated. The findings revealed that majority of people were unaware of how forest cover depletion as a result of wood fuel production and use. The most preferred and extracted tree species from the forest for charcoal were Acacia tortillis, Acacia Parasinata, Combretum terminalia and Cordia africana the species preferred for fire wood were Acacia tortillis, Juniperus procera, Olea eropaea, Erica arboria and Hypericum revolutum. In order to address the forest resource degradation of the area, use of efficient energy saving technologies, planting Eucalyptus and establishment of energy plantation are recommended.

Keyword*: wood fuel, wood fuel consumption and production, forest resource degradation and energy saving technology*

1. INTRODUCTION

1.1. Background of the study

Fuel wood and charcoal are the most globally used energy supplies. Wood is an important type of biomass, with annual global utilization of 3.3 billion m^3, of which more than half is used for energy (FAO, 2008). The use of natural wood charcoal is approximately dated back to 30,000 years ago commonly in cave (Van Beukering *et al*., 2007). Over 2 billion people globally rely on fuel wood as their main energy supply, especially rural households in developing countries (FAO, 2010). Global wood charcoal production in the year 2009, was estimated at 47 million metric tons; 9% increase since 2004 (FAO, 2009). Fuel wood and charcoal, provides more than 14% of the world's total primary energy and more significantly in developing countries (Demirbas, 2001). This demonstrates the importance of wood fuel plays in meeting the energy requirements of developing countries.

In Africa, the main source of energy for cooking and heating used by the majority of the urban and suburban population is wood-fuels (e.g., charcoal and firewood). These accounts, for 63% of the global charcoal production (FAO, 2011). As of between different countries, the extent and level of wood fuel dependency varies between rural and urban areas.

According to Bails *et al*. (2007), 94 % of the African rural population and 73 % of the urban population use wood fuel as their primary energy source. The urban area is heavily dependent on charcoal and rural area dependent on firewood (Seidel, 2008).

Similar to other African countries, more than 90 % of Ethiopian population also depends on biomass for its energy requirements (Mekonnen and Kohlin, 2009) of which fuel wood and

charcoal accounts for greatest proportion (FAO, 2005). According to Labarta *et al.* (2008) currently the production and utilization of these wood fuels have been growing in line with population growth which intern is changing the pace of deforestation in sub-Saharan Africa including Ethiopia.

About 35 % - 40 % of the land area of Ethiopia was once believed to have been covered by forest vegetation in the 1990s (EFAP, 1994). Since then, these forests have been destroyed at an alarming rate and reduced to only 2.4 percent in 1998 (EPA, 1998) due to anthropogenic impacts mainly due to extensive deforestation. FAO (2010) reported that Ethiopia's forest cover is 12.2 million ha 11%, puts Ethiopia among countries with a forest cover of 10-30%.

In Ethiopia,150,000 to 200,000 ha of forest cover is lost annually for charcoal production (Yigardu, 2003). Charcoal, fuel-wood and agricultural wastes provide for more than 86.8% of rural household energy, followed by urban household 8.2% and other sector about 5% requirements and contributes to about 87% of Ethiopia's final energy demand (Guta Dawit, 2012).

Charcoal industry has led to increased destruction of tree and vegetation due increased charcoal demand and inappropriate technologies used in charcoal production (FAO, 2008). Use of traditional charcoal kiln accelerates the distraction due to low efficiency (Muller *et al.*, 2011). For the success of the conservation efforts of the natural forests for their sustainability, accurate assessment and understanding the impact of charcoal and fuel wood production and consumption are important. In view of the above perspectives, it is worthwhile to conduct a study aimed at the impact of wood fuel consumption and production need to look at the technologies used in the district.

1.2. Statement of the problem

Global modernization and revolution in the energy sector has been significant although the majority of population in developing country still depend on wood fuel for day to day energy requirement (Smith *et al*., 2004). For long, Ethiopia had been losing its natural forests and woodlands for fuelwood, construction and expansion of agriculture. According to Ethiopia National Clean Cook Stoves Program, more than 99% of the rural households depend on firewood for cooking and heating purpose (NCCSPE, 2011).

The country biomass fuel consumption Charcoal, branches and leaves were about 105,172,465 tons per year and from 2000 to 2013 the charcoal consumption of the country increased from 48,581 to 4,132,873 tons/year (Geissler *et al.*, 2013). Therefore, the main reasons for initiating this research were: Cutting of trees for fuel wood without replacement has become serious problem contributing to land cover change in the study area and causing soil erosion. This reduces organic matter content and plant growth. Soils that decrease in organic matter cannot retain moisture. When the tree cover is lost, the soil becomes weak to the pounding effects of rain drops thereby increasing the rate of erosion and ultimately leading to low crop production. This heavy dependency on biomass fuel leads to degradation and deforestation.

In Liben Zukala district, the divestation of the forests has been going on for long time. Wood fuel production and consumption have also occurred at the area (FGRCP, 2010). Moreover, there are numerous streams that spring from the mountain ecosystems that are increasingly drying up. In the aftermath of degradation and deforestation in the area, there is a recent problem of erosion through excessive flooding during the rainy season. In addition, for quiet

some time, towns like Wenber and Adulala have been badly affected through intense rainstorm flooding.

In the District, no study has been conducted to investigate impact of wood fuel production and consumption on the forest and factors that determine households wood fuel consumption rate even though many other aspects of this forest have been thoroughly studied (Simie, 2007);(Girma and Sormesa, 2014). However, given the fact that forest degradation has been increasing by dependency on forest, it is important to asses how wood fuel consumption and production is influencing the forest. Therefore, in view of the literature gaps indicated above this research attempts to answer some of the issue of forest conservation, quantifying the forest loss due to wood fuel consumption and production as well as farmers awarenes on forest degradation essential for the purpuse of conservation of the forest resources in the area.

1.3. Objectives

1.3.1.General Objectives

The overall objective of the study was to assess the impact of wood fuel production and consumption on Zukala Forest resources of Liben Zukala District.

1.3.2. Spesific objective

The specific objectives of this study were

- To quantify the annual consumption of firewood and charcoal per household.
- To estimate the forest cover loss resulting from wood fuel production and consumption.
- To identify the driving factors that affect local community wood fuel consumption rate.

To assess the awareness of the people on the effects of wood fuel production and consumption on Zukala Forest.

1.4. Reasearch questions

The Study has tried to answer the following research questions

- How much fire wood and charcoal annualy consumed per household?
- How much forest lost dueto woodfuel production and consumption ?
- What are the driving facters that affect community wood fuel consumption rate?
- How farmers aware on impacts of wood fuel production and consumptionon on forest resource ?

1.5. Significance of the study

The study has been its own rationalities both for study site in one way and for literatures. By analyzing the impact of wood fuel production and consumption on forest resource and driving forces behind the changes have occurred. Moreover, it can provide data to policy and decision makers to design appropriate policies and strategies for monitoring resource degradation and promote sustainable management of natural resources. Moreover, sustainable management of natural resources in turn can enhance agricultural productivity and builds the resilience of rural communities to shocks. A large number of government or non-government development agencies, researchers and local communities can benefit from the outputs of this research.

1.6. Scope and Limitation of the Study

The study was carried out in Liben Zukala District, East Shewa zone, Oromiya. The district consistis nineten kebeles of which three kebeles' selected for the study that cover an area of

approximately 13,649.13 ha. The study examined wood fuel consumption and production its impact on Zukala forest.

Although the research was carefully designed and followed accordingly to get the reliable data for best results, however, some limitations were encountered while performing the task. The major limitations of the study were, unwillingness of peoples, unavailability of necessary materials and lack of transportation service in the area.

2 .LITERATURE REVIEW

2.1. Operational Definition of Terms

Wood Fuel: includes all types of biofuel derived directly and indirectly from trees and shrubs grown on forest and non-forest land.

Charcoal: refers to a solid residue derived from the carbonization, distillation pyrolysis and rarefaction of wood (trunk and branches of tree) and wood by products, using continuous or batch system (pit, brick and metal kilns).

Household: comprises a person or a group of persons generally bound by ties of kinship who live together under a single roof or within a single compound and who share a community in that they are answerable to the same head and share a common source of food.

Fuel: is any material that is used predominantly for heat, light or power (i.e., Energy) by burning.

Deforestation is the long-term or permanent loss of forest cover and implies transformation into another land use

Forest degradation is the long-term reduction of the overall potential supply of benefits from the forest, which includes carbon, wood, biodiversity and other goods and services

Environment: is basically the circumstance or conditions that surround us. It comprised physical, ecological, social and economic environment.

Physical environment: is the section of the environment that has physical factors, for instance soil, water supply and climate. The term can also be defined as the material surroundings of a process, system or organism.

Ecosystem services: are the benefits people obtain from ecosystems which includes: provisioning service such as food and water, regulating service such as flood and disease control; cultural service such as spiritual, recreational and cultural benefit.

2.2. Wood fuel situation and charcoal consumption

The global wood production in 2000 reached approximately 3.9 billion m^3 where by 2.3 billion m^3 was used as wood fuels implying that approximately 60 % of world's total wood removal from forest and trees are used for energy purpose (FAO, 2008). In Africa over, 90 % of the wood taken from forest is wood fuel. The majority of wood is consumed as fuel wood; however varying but significant amount is transformed into charcoal, more than 80 % the fuelwood is consumed in urban area making charcoal the most important source of house hold energy in many African cities (Siedel, 2008). In Ethiopia 77% of annual biomass consumption is met from fuel wood followed by animal dung 13% and crop residue 9% respectively. Concerning regional distribution of biomass consumption, annually 88% of total biomass fuel is consumed mainly in three regions: Amhara 34%, Oromia 32% and SNNP region 22% (Faris, 2002).

2.3. Wood Fuels as Sources of Household Income

The trading of wood fuels provides an income for huge numbers of people. With a case of access both to the resource and markets, very large numbers of the landless and very poor gather and sell wood for fuel, and large numbers of farmers harvest and sell it as well. Much of wood fuel retailing is small scale and accessible to the urban poor too. Overall, it is a major source of income for the poor and can be one of the main sources from forest product activities. For some people engaged in wood fuel production, selling or trading, such

activities represent their principal source of income. This was found to be the case, for instance, for about 125,000 people producing or selling charcoal for use in the city of Dar es Salaam, Tanzania, in the 1990s (SEI, 2002). For others, fuelwood or charcoal provides a supplemental, transitional or seasonal source of income, or serve as a 'safety net' in times of hardship. Though urban demand usually is much larger, rural demand for purchased wood fuel is also growing. For instance, in Ghana in 1991– 92, 27 % of all fuelwood purchased by households and 13% of charcoal, was bought by households in rural areas (Townson, 1995).

2.4. Charcoal Production and Technologies

Charcoal production system is also characterized by the production technology that is used. charcoal can be produced by a range of methods, from simple earth kilns to brick or metal kilns. The three most common methods of charcoal production are earth kilns, masonry kilns and metal kilns. The earth kiln is the most common method of making charcoal in Ethiopia, as well as in the rest Sub Saharan Africa. Earth kilns are of various types but the most common are the traditional earth kiln, improved earth kilns and the Casamance kiln. Masonry kilns are usually of the bee hive and half orange type; they are recommended for charcoal conversion in areas where fuelwood is available for prolonged periods, such as in a large-scale land clearing or in fuelwood plantation. Metal kilns include the drum kiln, meko kiln and Mark v type in more industrialized settings, retorts can be used to capture condensable compounds, which can be redirected into the kiln and burned to generate needed for the charcoal making process.

In addition, some of the condensable compounds have value in other markets and can be extracted and sold (Demirbas, 2001). Improved charcoal production technologies have been

introduced in order to increase production efficiency and reduce the emission of potentially harmful pollution. However, the use of these technologies remains very low because of limited awareness, weak technical capacity and high risk to investment. Traditionally, charcoal is being made in mound or pit kilns (Amanor *et al*., 2002). This technology is still used in both developing countries and in industrialized countries (Chapopsa, 2002).

2.5. Charcoal trade and employment

Charcoal is more urban in use as compared to firewood. This could be attributed to the fact that it is easier to transport, efficient and produces a steady heat with little or no smoke compared to firewood (Melaku Bekele and Zenebe Girmay, 2013). It is also a convenient and accessible energy source for cooking at all times and at a reasonable cost compared to modern energy sources, such as electricity, kerosene and LPG. Therefore, with increasing urbanization, African populations are expected to increasingly shift from firewood to charcoal for domestic cooking and heating.

The trade involves a number of actors starting from the wood grower (missing in Ethiopia in most cases) the charcoal burners, transporters, wholesalers, retailers and then the end users, not to mention local chiefs, brokers, and check point controllers who are also involved in one way or another along the chain. As the charcoal trade in Sub-Saharan Africa, including Ethiopia is illegal in the majority of cases, the business seems to have created its own efficient mechanism to bring the item where the demand is. In this process, the most voiceless stakeholders among actors are the charcoal burners with little negotiating power (World Bank, 2010, Iiyama *et al*., 2015). The most powerful are those who organize the production and also who distribute the charcoal (wholesalers) to retailers.

2.6. Impact on composition and structure of woody species

The production of charcoal affects composition, density, diversity and dendrometric characteristics of woody species (Kouami *et al.,* 2009). In some cases, stumps are uprooted for the sake of charcoal production resulting in severe reduction in the potential for natural forest regeneration. Obviously, selective cutting can cause depletion of preferred species with adverse effect on the composition and biological productivity of forest resources (Arnold and Persson, 2006). Arnold and Persson (2006) also reported that charcoal production can materially alter the structure and productivity of harvested area and concluded that charcoal production can lead to transformation of woodland to bush, and bush land to scrubland over large areas. But, under severe wood depletion, even stumps left over from previous charcoal production may be dug and used to make charcoal which result in severe reduction in potential for natural forest regeneration and in some cases such circumstances lead to permanent deforestation accompanied by change to other land uses. The cutting of trees and shrubs for charcoal production can reduce forest density (Wezel and Bender, 2004; Oduori *et al*., 2011). Fuel wood, charcoal, crop residue and leaves with fuel wood occupying the leading position.

2.7 Consumption of wood fuels

Most of the developed world now gets the majority of its energy for cooking and heating from fossil fuel like coal and petroleum, wood fuels are still a major source of energy for people in developing countries. Here, wood fuels account for between 50 and 90 percent of the fuel used (FAO, 2010). Wood fuel is one of the main products of the forest. Approximately 60% of the World's total wood removals from forest and outside forests are used for energy purposes. Whilst the developed countries use only 30 % of wood produced

for energy, the developing countries use 80% for the same purpose (Energy commission). The extraction of timber for wood fuel accounts for 61% of the total wood removals (FAO, 2005; Herd, 2007). Energy provision is a basic human need and consumption is closely related to the level of a country's development. Fuel wood and charcoal production serve as a source of livelihood for most rural people and the increasing number of urban dwellers engaged in the charcoal and wood fuel trade (Anang *et al*., 2011). Woody biomass is part and parcel of rural livelihoods. According to Gelder and O'Keefe (1995) traditional economies can easily be defined as biomass economies. Rural livelihoods are intricately linked to the natural environment and this makes the charcoal problem a delicate one to solve (Anang *et al*., 2011).

2.8. Greenhouse gases emissions during carbonization

Charcoal from most earth-based kilns is produced in an oxygen poor environment that results in the formation of products of incomplete combustion, such as methane. Charcoal production therefore affects global warming through the production and emission of greenhouse gases, such as carbon dioxide (CO_2) and methane (CH_4). Although carbon monoxide is one of the products of incomplete combustion during charcoal making it is not listed as a greenhouse gas

by the IPCC as it is considered to be short-lived in the atmosphere (IPCC, 2007). Kammen and Lew (2005) have shown that emissions during charcoal production have a greater global warming contribution than emissions from charcoal burning.

2.9. Common livelihood systems and a general account of Deforestation in Ethiopia

The general picture of the farmlands in the northern and central highlands of Ethiopia is a bare and broken land that resembles a desert at high altitude. There is a rugged topography, which is washed by torrential downpour of rain, almost zero vegetation cover, backward land use practices and visible and traceable erosion (Abegaz, 1995). The cause for this had been designated as being the result of an almost national degradation. Degradation in Ethiopia occurs because of many and various reasons.

These are uncontrolled cutting for wood fuel consumption, arable land need by the peasant, fire and the creation of grazing lands and striping the barks of live trees for the construction of beehives and roofing (Melaku Bekele, 2003).

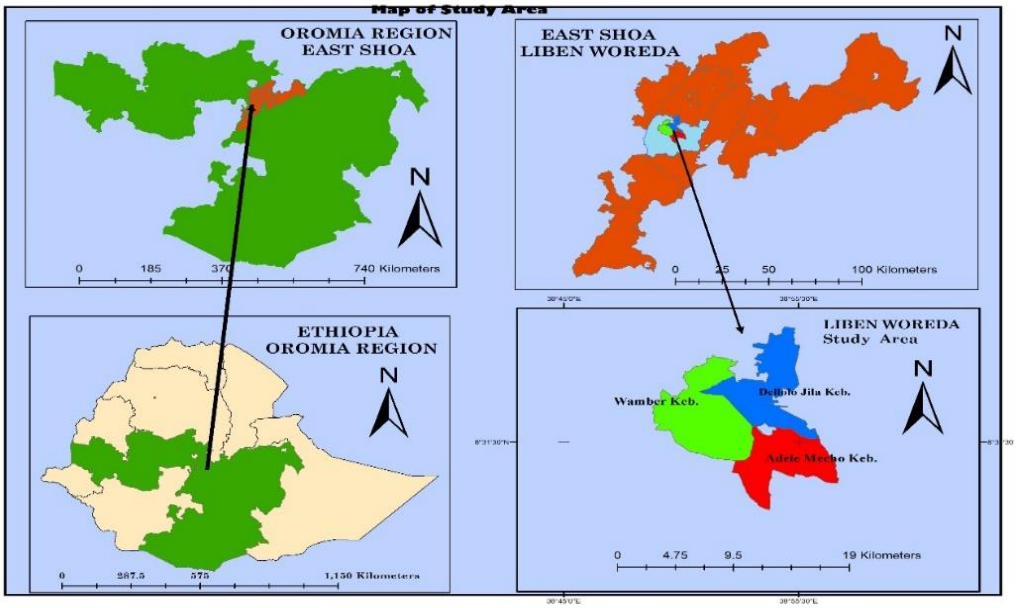
The most common type of land use pattern observable in most parts of Ethiopia is the animal traction dependent mono - cropping of teff for subsistence use. This system is characterized with an over-cultivation culture which suppresses the natural mechanisms of regeneration. The agricultural system is bedridden with food security in its production of annual mono - crop. This form of traditional agriculture, which is employed mostly in the north and central parts of the country contributed to the deforestation and depletion of the forest resources. Moreover, it is designated as a cause and associated with the population expansion from north to the southern part of the country (Melaku Bekele, 2003). The uneconomical way of using timber by the farmers of the north led to a shortage of Wood which opened the ground for the exploitation of tress growing on in accessible steep slopes which are marginal agricultural lands. The exposure of the hills and mountains in this manner to torrential showers which are characteristic to Ethiopia led to the degradation of the land by severe erosion (Chojnacki, 1963).

3. MATERIALS AND METHODS

Materials used in the field were: digital camera, Note book, Caliper, Hypsometer, GPS and meters.

3.1 Description of Study Area and location

The study area is located in Liben Zukala District, East Showa Zone, Oromia. The district is one of the administrative territories with an area of 13,649.13 ha. Geographically, it is located between $38^{0}42'$ - $38^{0}55'$ E longitude and $8^{0}28'$N - $8^{0}35'$ N latitude. In the district, there are 19 kebeles out of which three kebeles are found in and around Mt Zukala forest. The capital city of the district is Adulala which has a distance of 32 km from Bishoftu and about 89 km from Addis Ababa. According to Liben Zukala District Administration Office (LZDAO) (2015), the total population of the district is 102,906, Male 39854 and Female 63,052.



Prepared by, Lemlem Cherinet

Figure 1: Map of the study area

Mount Zuqala, it is found in the district covered by afro-montane forest. This area (land surrounding the Crater Lake) has densely wooded vegetation at the top. The natural forest area is about 3649.35 hectares. Zukala's Forest (ZF) has numerous species of plants growing together. The dominant tree stand is however, *Juniperus procera.* The forest also serves as a habitat for wild life (Forest genetic resources conservation project, 2010). Physical infrastructures on the mountain and its surrounding are still at an insignificant scale of development. Considering the early date, they had been constructed and the nearness of the area to the capital, such infrastructures are still very deprived by even Ethiopia's standards.

3.1.1. Climate and Temperature

Most of the district (94%) falls under Weina Dega (Subtropical) agro-climatic zone (Forest genetic resources conservation project, 2010). However, one can find three traditional agro-climatic zones; Kola (Tropical Zone), Weina Dega and the Dega (cool zone) in the district.

At the base of mountain where the town of Adulala is found 1720 MASL. Since the Kola agro- climatic zone ranges between 1000 and extends to1800 MASL, the base of the mountain and its lower part is in the upper kola agro-climatic Zone. Most of the steep slope part of the mountain lies in the Weina dega (1800 -2400 MASL) agro climatic zone. One can observe starting from 2400 up to 3000 MASL the Dega agro- climatic zone extending right up to the top. The annual average minimum and maximum temperature is of 15^0c and 32^0c respectively.

3.1.2. Physical Features

There are five rivers namely Awash, Modjo, Akaki, Belbela and Wedecha (Forest genetic resources conservation project, 2010) in the district. The soil types are black, red, brownish

and gray in color. Each soil type is found in 63.7%, 3%, 9% and 24.3% out of the total respectively. The bed rock is a deposit from a volcanic ash and the lava flow had made the soil to be rich in nutrient content (Forest genetic resources conservation project, 2010).

3.2. Socio- Economic Characteristics of the District

Demographic condition

The total population living in the District is estimated at 102,906 out of which 39,854 are males while the remaining 63,052 are females. Available information about the district points that the area has been settled by the Oromo clans of Liben and Jida in the 17th century. The other ethnic group found in the area is the Amhara.

Economic characteristics

The population of the District depends on agriculture and other economic activity. The main form of agriculture is ox- drawn plowing system. A limited form of vegetable farming and sell from agroforestry is also practiced by the people of the area. Farming has intensified after the change of government in 1974 and 1991. There is also evidence that indicates starting at the beginning of the second half of the 20th century on the mountain.

The overall agricultural land in the District from previously surveyed data is only 161,056 hectares of land 74.2% is used as agricultural land while the forest lands are only 8.2 % (Forest genetic resources conservation project, 2010).

The major crops grown in the area are teff, burly and wheat. The agro- forestry products include Gesho (*Rhamnose prinoides*), cabbages, ‘tena dam’, split wood of *Olea africana* and

others. Domestic animals such as cattle, sheep, goats, donkeys, mules and poultry are raised by the peasants. Apiculture and honey production are also practiced by some of the farmers.

Rain Fall

The annual average rainfall is 630- 1150mm. The highest amount of rainfall occurs between the months of July and August (FGRCP, 2010). The current situation of deforested landscape had brought about excessive siltation in lands found below the slopes (Forest genetic resources conservation project, 2010). This happened since the rain that falls on top of the mountain fails to infiltrate due to the loss of a dense vegetation cover.

3.3. Research Design

This research was carried out in Liben Zukala District, East Shewa zone. Out of 19 kebeles, three kebeles which were near and around Mount Zukala forest were assessed for impact of wood fuel production and consumption on forest to have a clear idea for conducting conservation on the area. Therefore, both quantitative and qualitative methods of data collection were employed. Survey and field assessment, inventory and measurement were used to collect the relevant data.

3.3.1. Study site selection

Accordingly, before actual site selection, a reconnaissance surveys were carried out in order to obtain the general overview of the forest, to determine representative sample plot and to decide/identify the appropriate sampling method for the study area. During this visit, discussion have been done with experts and professionals of Liben Zukala District Agriculture and Natural Resource Office, Environment, Forest and Climate Change Authority and some

elders' people that properly know about the targeted study area.

3.3.2. Sampling techniques

Following a reconnaissance survey, probability and non- probability sampling techniques were used to select interviewers.

- The study area was selected purposively based on different outlooks such as the number of charcoal producers and closeness of zukala forest. Accordingly, out of 19 kebeles, three kebeles namely Wenber Zukala, Adele Mecha and DulolоJila were selected.

- The Snowball sampling technique was used to identify the wood fuel producers and sellers in the community. The technique was used due to the fact that there is no wood fuel producer and seller association. Therefore, a respondent selected recommends another respondent who was also involved in the process. However, to select wood fuel consumers a list of names of all house hold at each of the selected Kebeles were prepared to conduct a simple random sampling using the lottery method specifically.
- A stratified sampling method was employed to select the sample size with the help of key informant, KII, FGD, Agriculture and Natural Resource Office and Environment, Forest and Climate Change Authority experts.

3.3.3. Sample Size Determination

Even though there are several approaches to determine the sample size, this study applied a simplified formula provided by Yamane Taro (1967); with 93% confidence level.

$$n = \frac{N}{1 + N(e)^2}$$

n = sample size for the research use

N =5068 total number of HHs in selected kebele

e = margin of errors at 7 % According to the above formula, the total sample is 196 selected.

Table 1. Total household heads of the three kebeles and proportional sample size

Kebele	Total Household	Sample size
Wenber zukala	1689	60
DulołoJila	1988	72
Adele miecha	1391	64
Total	5068	196

Sources: Liben Zukala District Administration Office, 2020.

by using proportionate stratified Random sampling method, the sample size classified in to different

strata. $n_h = \left(\frac{N_h}{N}\right) \times n$

where n_{th} = sample size for h_{th} stratum N_h =population size for h_{th} stratum N=size of house hold n= size of entire sample.

$n_{\text{charcoal producer}} = (N_{\text{charcoal producer}}/N) * n$ n= (800 /5068) *196 = 31

$n_{\text{charcoal and fire wood business merchant}} = (N_{\text{charcoal and fuel wood business merchant}}/N) * n$

$$n = (250/5068) * 196 = 10$$

$n_{\text{wood fuel consumer}} = (N_{\text{wood fuel consumer}}/N) * n \qquad n = (4{,}000/5068) * 196 = 154$

$n_{\text{institutions}} = (N_{\text{institutions}}/N) * n \qquad n = (50/5068) * 204 = 2$

This study comprises 31 charcoal producers, 10 wood fuel business merchants, 154 Wood fuel consumers and 2 institutions were selected proportionally within three kebeles.

3.4. Method of data collection

To meet the objectives of this research, the data was collected from both primary and secondary data sources using focus group discussion, key informant interview, survey (field and market survey) and measurements discussed below.

3.4.1. Primary data

3.4.1.1 Household survey

Totally160 house hold were selected in order to generate first- hand and reliable data on various aspects of Wood fuel consumption; robust primary data was collected through administering questionnaires having both structured and non-structured forms. The questionnaire was pre tested and translated into Afan Oromo before the formal survey was conducted and modified slightly for clarity. The first part of the questionnaires was pertinent to household characteristics and socio-economic information of the households. The second part of questioners contains general information about the amount of fuelwood daily consumed, source of fuelwood, species preference and other information important for the

study. To quantify HHs wood fuel consumption, converted the amount of daily consumption into kilograms using method suggested by EPA (2003) and multiplied by 12 months (dry and rainy seasons) to reach in the yearly estimation of per household. Average annual household wood fuel production and consumption was calculated as follows:

- Average annual wood fuel consumption per household = (rainy season Ave. Wood fuel consumption ×30 days×3months) + (dry season av. Wood fuel consumption × 30 days×9 months)
- Total Average annual wood fuel consumption = (Ave. consumption per HH × Total population)
- Average annual charcoal production per producer = (Ave. rainy season production ×3months) + (Ave. dry seasons production ×9 months).
- Total Average annual charcoal production = (Ave. production per producer × Total Producer).

To identify and rank species preference for fuelwood, all mentioned species were ranked.

3.4.1.2. Key Informant Interview (KII)

To obtain in-depth information and to cross-check the data collected using a survey (field and market) key informant interviews were conducted. In this, one elder person from each sampled Kebeles, two district Natural Resource Conservation and Management Expert, one district Environmental and Land Administration Office Coordinator and one Kebele Administrator from each sample Kebeles were involved. Totally, 9 key informants were selected.

3.4.1.3, **Focus group discussion (FGD)**

Focus group discussions (FDG) are important tools to collect qualitative data by inter- changing ideas between groups of farmers in the sample kebeles. Two purposive criteria were used to select participants in FGD. The first was the age of the participants i.e. elder people who have lived a long time in the study area and had detailed information about the past and present situations.

A second criteria is the capability to understand the topics and express their feelings and opinions. The selection was performed purposively from both sexes with the help of the Development Agent (DA). Accordingly, a group containing one female and two male members were formed from each sampled kebeles. Totally 3 groups that have 9 members were formed. The FGDs were guided by a list of questions like a checklist. The aim of FGD was to assess and analyze the extent and trend of changes that discussants perceived to have occurred on the forest and driving forces behind such change.

3.4.1.4. Market Survey

In addition to the household survey, to get full data on rural fuelwood and charcoal consumption market survey was conducted. Four days selected and the counting was conducted from 07:00 Am to 9:00 pm per day at the major charcoal market and roadside of each kebele for 4-7 weeks during rainy and dry season. All fire wood and charcoal that is supplied by using a different mode of transportation from four major routes were recorded. The most common transportation ways were donkey load and horse - drawn cart. One donkey load of charcoal and firewood weigh an average of 38 kg and 25kg respectively. A market survey for inflow rate was recorded to estimate the supply to the local market.

3.4.1.5 Field Assessment and Measurement

In addition to the survey; field assessments, measurements and observations were made to assess and quantified the mass of produced wood fuel, technologies, inventory data, practices of production, common wood sources and tree used; location and local livelihood patterns in charcoal production areas among others.

I. Inventory

The forest inventory plots were established by using a transects line with an average length of 400 m were laid at a distance of 200 m between transect lines at the Forest. In each plot, transects were determined using a compass. The first plot was laid at a100m distance away from the edges to reduce the edge effect for uniformity of sampled plots. On each line transect sample plots, measuring 20m × 20m($400m^2$), nested plot of 10m × 10m (100m2), 2m × 2m (4m2), were done along the transect line. A total of 30 plots were sampled in the forest. Within each rectangular sample plot, the number of individual seedlings, saplings and trees of different species was directly counted. For each plot all woody tree species with a diameter at breast height (DBH) > 5cm and height >3m were considered as a tree and they were measured for DBH and height. In the study tree species saplings were measured for DBH < 5cm and DBH > 2cm and 0.50 cm to 3m height. Similarly, seedlings were considered as those stems with DBH < 2 cm and height < 0.50m (Mengistu *et al*., 2005). Measurement was conducted to estimate the amount of wood fuel consumed by the households.

3.4.2. Secondary data collection

Secondary data was collected from various sources including District Environmental Protection

and Forestry Office, Trade and Industry Development Office, Agricultural and Natural Resource Office, journals, published and unpublished reports and relevant websites.

3.5. Data Analysis

The methodologies employed to analyze the collected data were descriptive statistics. With regard to data analysis, responses in the questionnaire and interview and vegetation measurements were entered into Statistical Package for Social Sciences (SPSSv 16) software. Percentage, Regression and arithmetic mean were also used to condense and study the variables for the purpose of analysis and interpretation. Furthermore, tables and graphs were used to facilitate the presentation of the result of the analysis and interpretation of data.

I. Estimation of forest cover loss

To estimate forest cover loss from charcoal production and use, the formula put forward by Chidumayo and Gumbo (2013), degradation in ha was calculated by using the following equation

$$\text{degradation (ha)} = \frac{Quantity\ of\ charcoal\ produced\ (t)\times 1/0.19}{Biomass\ (t/\ ha).} \quad \text{.....Eq. (3)}$$

The degradation caused by charcoal production was estimated using the amount of charcoal produced by producers. Where 0.19 is the wood-to-charcoal conversion rate for earth kilns in the tropics and biomass density in the forest biomass stocking rate.

II. Estimation of Above Ground Tree Biomass (AGTB)

The selection of the appropriate allometric equation is crucial in estimating above-ground tree biomass (AGBM). There are different allometric equations that have been developed by many researchers to estimate AGBM. These equations are different depending on the type of species,

geographical location, forest stand, types, climate Others. Therefore, the application of these equations to the study area is advantageous in a view of cost and time.

The equation used for the present study was a model developed by Chave *et al*. (2014).

The appropriate criterion for this model fits with the present study.

$$AGB = 0.0673 \times (WD \times DBH^2 \times Ht)^{0.976}$$

Where, AGB is above-ground biomass, WD is wood density, DBH is the diameter at breast height and Ht is tree height.

III, Estimation of Below Ground Biomass (BGB)

Below ground biomass estimation is much more difficult and time-consuming than estimating aboveground biomass (Geider *et al*., 2001). According to McMicken (1997), the standard method for estimation of below-ground biomass can be obtained as 20% of above-ground tree biomass i.e., root-to-shoot ratio value of 1:5 was used. Similarly, Pearson *et al*. (2005) describe this method as it is more efficient and effective to apply a regression model to determine belowground biomass from the knowledge of biomass aboveground. Thus, the equation developed by McMicken (1997) to estimate belowground biomass was used. The equation is given below:

$BGB = AGB \times 0.28$ ……. (equ.2)

Where, BGB is below ground biomass, AGB is above-ground biomass, 0.28 is the conversion factor (or 20% of AGB).

The volume of standing trees was calculated by Asrat zerihun (2020),

$V = 0.0001228*(dbh)^{2.5500000}$ ……. Eq. (4)

Where, v = volume of standing tree dbh = diameter of the tree

the volume of the standing tree was calculated to compare with the volume of the

fuelwood consumed by the households. The standing volume was converted into tones by

using the density of trees (Maltamo *et al*., 2004).

Multiple Regression Analysis

Regression analysis is a statistical technique for studding linear relationships. It assumes a general form for the relationship, known as the regression model:

$Y = \alpha + \beta_1 X_1 + ... + \beta_k X_k + \varepsilon$

Y is the dependent variable, while $X_1..., X_k$ are the explanatory variables or the independent variables. $\alpha, \beta_1..., \beta_k$ are partial regression slopes corresponding to respective X_i. ε_i is the residual variance in Y after taking into consideration the effects of the X_i variables included in the model. Regression analysis helps one to understand how the typical value of the dependent variable changes when any one of the independent variables varies, while the other independent variables are held fixed. The estimators, however, end up with almost the same standardized (marginal) impacts of independent variables (Pachauri *et al*, 2006). For this reason, the study has used the multiple regression model to identify the determinants of fuelwood consumption rate.

$Yi = \beta_0 + \beta_1 FAMSZE + \beta_2 LANDSZE + \beta_3 INCOME + \varepsilon i$

If the error term (ε) is taken into account the multiple regression model becomes:

$Yi = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... ++ \beta nXn + \varepsilon$

Where β_0 is an intercept that tells us the wood fuel consumption when the coefficients of all included explanatory variables are assumed to be zero, $\beta_1 \rightarrow$ n are slope parameters to be estimated in the model, respectively. The slope tells how the factors affecting wood fuel consumption as each independent variable change. Y_i is also referred to as the factors that affect the amount of wood fuel consumption.

Table 2. Explanatory Variables and their Hypothesized effect

Variable code	Variable type Variable	definition and Measurements	Expected Sign
FAMSZE	Continuous	Household size (total number of people in househ	+
LANDSZE	Continuous	Total area of land owned by household (in hectar	+
INCOME	Continuous	Total income of household	-

4. Results and Discussion

4.1. Socio- economic and demographic characteristics of the respondents

4.1.1. Age and Sex

The result of sex composition analysis indicates that among the total households 154 consumers were interviewed. Out of this female representing 70% and males representing 30%. From the total sample population, 31 producers were interviewed, 78.4% were males and the remaining 21.6% representing were females (Figure 2). The wood fuel production process is labor- intensive and requires much energy input during kiln preparation, especially breaking and arranging huge bulky wood stems, which attributes dominance of male and low engagement by females. This result agrees with (Luoga *et al*., 2000) process of charcoal production is labor- intensive, mainly carried out by men and bears some similarities to that in Kenya and Uganda.

The age structure analysis showed that the highest percentage (56.7%) of the household falls in the age range of 35 -39 years while a small percent (5.7%) was found in the highest age range of 50 -59. This implies that the majority of the respondents were economically active age group (Table 3). The production activity serves as a source of employment. They are forced to make a living due to the limited livelihood options available in the community.

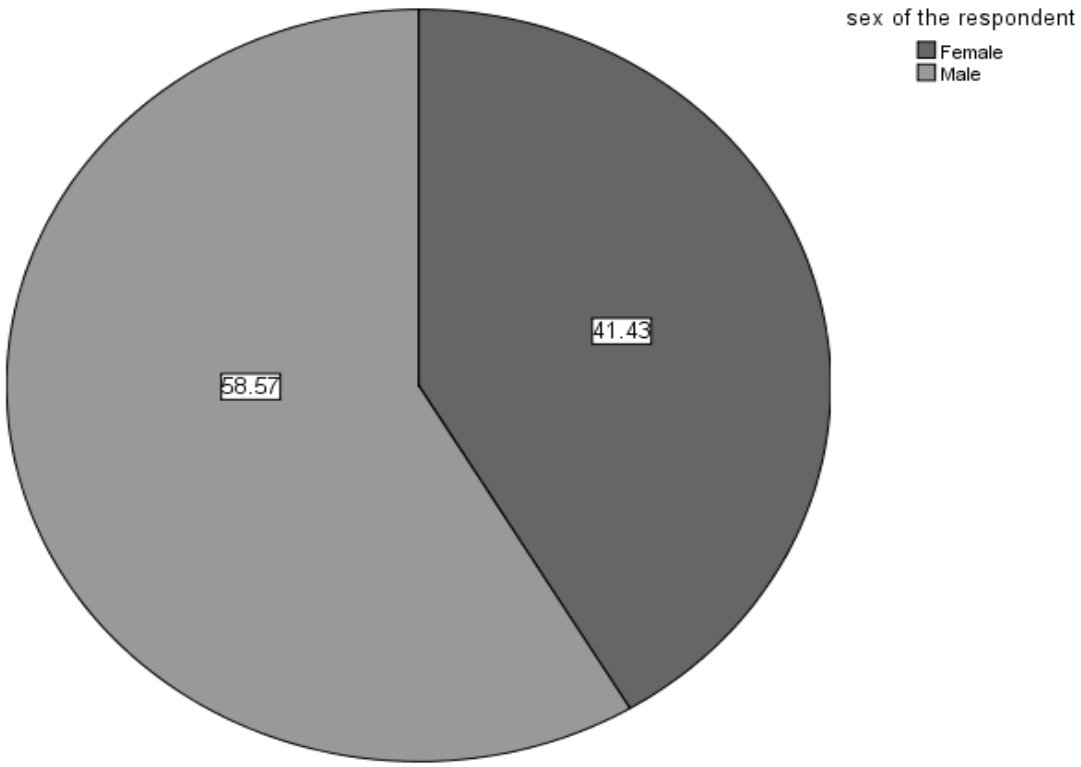


Figure 2. Sex composition of the respondent in the study area

Table 3. Age of the respondents

Age	Frequency	Percent
20-29	31	14.8
30-39	119	56.7
40-49	42	22.9
50-59	12	5.7
Total	204	100.0

source: social survey, 2020

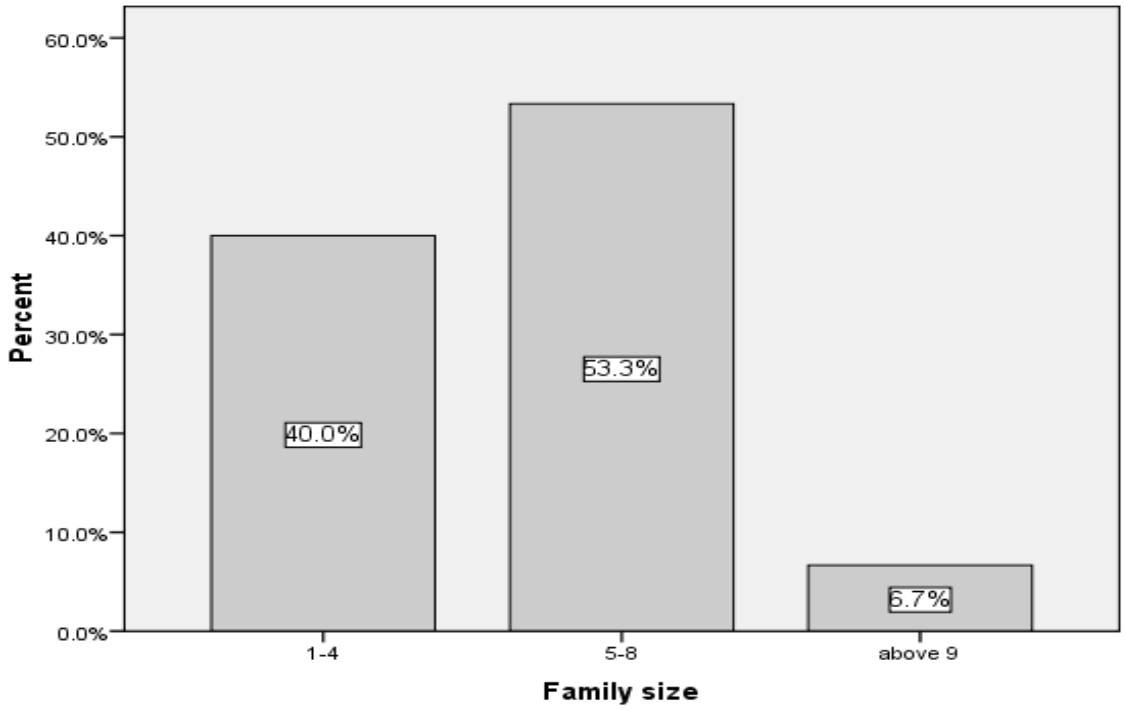
4.1.2 Family size and Agricultural land

Table 4. Family size and farmland of the study area.

Item	Minimum	Maximum	Mean +SD
Farm land(ha)	0	1.5	0.4+0.4
Family size	2	15	6.8 + 1.9

The mean family size of all the respondents was calculated to be 7 persons/HH. This result is greater than the mean family size of 6 and 6 persons/HH recorded from Bure of Amhara regional state and Dale district of SNNP regional states of Ethiopia respectively, both of which are higher than the national average of 5 persons/HH (CSA, 2015); the Amhara regional average of 5 persons/HH and SNNP regional state average of 5 persons/HH (CSA, 2015) were recorded. Hence, heavy dependence on available natural resources and the need for generating extra household income takes pressing importance in their life. It also has a direct negative impact on the resource of the area (Muys, 2000; Demel *et al*., 2001).

The overall average landholding of the respondent was 0.4 ha/HH (Table. 4). This is lower than the total land holding /household (1.1±1.26 and 1.4±1.25 ha) in Ada'a and Lume districts of East Shewa, Ethiopia, and also lower than the national average landholding of 1.02 ha (CSA, 2010). Wood fuel production on farms can be economically viable and sustainable options for small holder farmers who struggle to satisfy subsistence needs and meet energy demand, while maximizing resource efficiency through allowing the reallocation of labor from wood fuel collection to agricultural production and off-farm income activities (FAO, 2010).



Source: Based on a social survey, 2020

Figure 3: Household size of the respondents

4.1.3. Occupational distribution of respondents

The various occupations identified included charcoal and firewood production, farming and trading. Although the major occupation identified was farming and wood fuel production (41.4%), a closer look as illustrated in Figure, 4 revealed that the producers were predominantly farmers who engaged in charcoal and firewood to supplement incomes earned through farming.

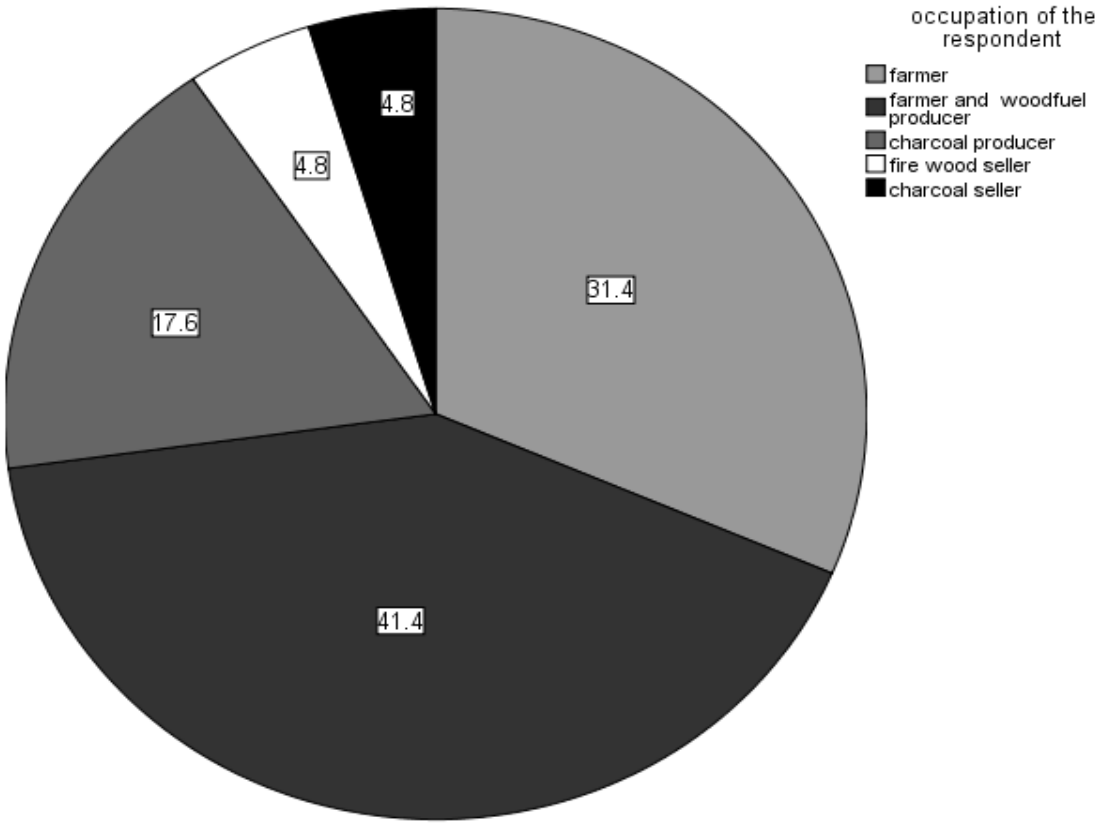


Figure 4. Occupational distribution of respondents

4.1.4. Educational background of respondents

The educational background of the respondents ranged from the basic level, elementary, secondary, Diploma and those who have had no formal education. It was realized that, a total of 196 (26.2%) respondents attended basic education and hence they can read and write, while the remaining 52.3% had no education whilst the remaining the heads of households attend varying level of educational qualification ranging from elementary school to a high-level Education (Table 5). This result is less than the Oromia National Regional State enrolment rate 61% in 2005 (MOE, 2005). From the study, 52.3 % of respondents are illiterate.

This leaves them with limited employment avenues due to no or little skills. So due to free access to forest their levelly hood activity depends on the forest. Farming is not viable in this district because of shortage of agricultural land coupled with limited livelihood opportunities. In their bid to survive, the forest was degraded in the process.

Table 5. Educational background of respondents

Educational level	Frequency	Percent
Basic	55	26.2
Primary	34	16.2
Secondary	5	2.4
Diploma	6	2.9
Illiterate	104	52.3
Total	204	100.0

Source: Based on social survey, 2020

4.2. Charcoal production techniques

A higher proportion of the charcoal production` in the district was done using traditional techniques and earth mound kiln type (figure 5). Traditionally, charcoal is being made in mound or pit kilns (Amanor *et al*., 2002). This traditional technique is still used in both developing and industrialized countries (Chapopsa, 1969). This finding is in line with the findings of Nejnga *et al*. (2013) who found that almost all of the charcoal in Kenya was produced using traditional kilns which are very inefficient. This is especially so as more wood is needed to produce a small quantity of charcoal with a negative consequence being

the depletion of the forest cover, with a significant breakdown in its environmental services. This view is supported by Njenga (2013); Bailis and Kammen (2005) hold that the charcoal carbonization process involves large portions of wood being lost in kilns with only 10% efficiency (Mugo and Gathui, 2010). The critical effect of this technique of charcoal production as held by (Pennise *et al.*, 2001) is carbon emissions and forest cover depletion.

Figure 5. Traditional Charcoal production system

4.3. Sources of energy for cooking

The result of the survey showed that firewood, leaves, charcoal, animal dung and electricity are sources of energy in the study area. Large proportions of the households in the study area were dependent on traditional fuels(biomass). The result shows that 92% of households were used wood fuel as a source of energy for baking and cooking (boiling water, wot making, tea and coffee) followed by animal dung 6% and leaves 2%.

The use of modern energy like electricity as a source of energy was at its infant stage showing that it was used by very few households only in Adulala town**.** This high dependence on biomass source as respondent listed were mainly due to lack of access to modern energy

sources and due to open access of natural forest, lack of awareness on the alternative energy sources, smokes from the fuelwood helps in heating their houses and also as repellant for insects and snakes took the lead reason for the community of the area.

About 60.3 % of the respondents reported that they have been collecting fuel wood from the forest (Table 6). This result indicated that majority of people collect fuelwood from the forest. About 83.3% of the community uses the three-mold inefficient traditional cooking stoves while only 16.7% use the efficient cooking stoves (lakech) (Figure 6). This aggravate forest degradation in the area.

Table 6. Source of wood fuel for the community

Source	Frequency	%
Market	40	23
Forest	123	60.3
Farm plot	33	16.7
Total	196	100

Source: Based on field survey, 2020

Figure 6. Types of cooking stoves in the study area

4.4. Ready market for wood fuel produce

From the study, it was revealed that the majority of the producers mainly sell their produced wood fuel at Adulala, wenber market and roadside. Wholesaler of charcoal is carried out at market centers where retailer and individual consumers obtain their supplies or delivery. The supply of these goods is done either by the producers themselves or through intermediate men from whom customers acquire smaller units.

(photo by Lemlem Cherinet, 2020)

Figure 7. Wood fuel sold in Adulala market

4.5. Community preference of tree species for wood fuel production and consumption

According to household survey, different species of tree and shrubs were identified to be collected from the nearby forest area as a source of energy. The most preferred and used tree species were;

Table 7. Preferable Species for charcoal and fire wood production and consumption

Species preferred for charcoal	%	Species preferred for fire wood	%	Reasons for species preference
Acacia tortillis	33.0	*Acacia tortillis*	27.3	Good quality and availability (burn slowly embers, long lasting flame, no spark,)
Acacia parasinata	30.7	*Juniperus procera*	25	Good quality (burns slowly, long lasting embers)
Combretum-terminalia	20.5	*Hypericum revolutum*	6.8	Availability
Cordia africana	15.9	*Erica arborea*	2.3	Availability
		Olea europaea	38.6	
Total	100		100	

Source: Based on field survey, 2020

As indicated on table 6, most of the households prefer four plant species for charcoal production. *Acacia tortillis, Acacia Parasinata, Combretum terminalia* and *Cordia africana*. According to three kebele leaders, development agents and FGD agreed that species like *Acacia tortillis, Juniperus procera, Olea europaea, Erica arborea* and *Hypericum revolutum* were highly preferred species for fire wood consumption. This finding is in line with the findings reported by Gebreslassie *et al.* (2014) from Northern Ethiopia. According to them *O. europaea* and *Juniperus procera* were the most preferred fuel wood species from the forest. The respondents described a number of attributes or factors that they considered to be important for good wood fuel. The most important attributes were availability and quality

of the species. According to respondents, if the wood species have good quality, the wood fuel should have a hot flame, a flame that is long lasting, produce long lasting embers, and be easy to split and ignite. In addition, the preferred species would have to burn without producing much smoke, and have a flame that does not produce sparks. This situation was also proven by observing from the weekly supply of charcoal for domestic consumption and to the market for sale. The dependency of the community on those species for wood fuel was also a daily need of the community, so that it creates high pressure on degrading the status of the species in the forest.

Tree density of Zukala forest

Stocking averaged 200 trees per hectare of *Erica arborea*; 187 tree/hectare *Hypericum revolutum*, 335 trees per hectares of *Juniperus procera* and 1162.44 different trees/ha at Zukala forest, with *Juniperus procera* the dominant species.

Evans (1992) reported that the mean annual increment of forest in tropics ranges from 100 to 300m^3 per hectare which is equals to 67 to 206 ton/ha. The author also argued that the yield may vary based on the tree species, site quality, spacing, management activity, age, climate etc. The annual fuel wood consumption in the area 6472 ton/year implies that the fuel wood collection and consumption is one of the main causes for aggravating deforestation in the study area.

Table 8. Forest stock of Zukala Forest

Zukala forest	Unit	total stock
Stock density	tree/ha	1162.44
Volume	ton/ha	263.07
Saplings	number	2757.57
Seedlings	number	3614
Total standing forest	Ton	960,034.30

Source field data, 2020

Volume of the Zukala forest

The data collected during the vegetation survey revealed that the average volume of the Zukala forest is 14.6 m^3/0.04 which is equal to 263.07 tons/ha. The total forest area is 3649.35 ha. Therefore, the total standing forest at Zukala forest was 960,034.3 tons (Table 8). In general biomass production in the form of removal of wood for fuel has far-reaching negative outcomes for the proper functioning of the ecosystems (FAO, 2010).

Regeneration of woody species in Zukala forest

From the analysis of seedling and sapling data, the total population of seedlings, saplings and trees were 3,614, 2,757.57 and 1162.44 per ha respectively (Table 8). The distribution of seedlings and saplings was greater than mature tree individuals per hectare. This indicates that the regeneration status of the forest is at better status if appropriate sustainable forest management schemes are put in place to allow for the growth of the seedlings and sapling into a matured tree population. The number of seedling and saplings are considered the regeneration potential of the species. The presence of good regeneration potential shows the stability of the species to the environment. Climatic factors and biotic interferences influence

the regeneration of different species in vegetation (FAO, 2010). Higher seedling density values get reduced to sapling due to biotic disturbances and competition for space and nutrients. The data analysis revealed that the density values for seedlings and saplings of the population structure of the forest are higher than the mature population. This is an indication that there is a continuous removal of matured trees from the forest resource of the area for different purposes, among which consumption as fuel wood is the major one.

4.6. Degradation associated with wood fuel production and consumption

Wood fuel activity was the first in its negative contribution for forest loss in (Figure 8) Liben Zukala district is known for lack of adequate agricultural land and absence of sufficient agricultural production. Other drivers of forest loss in the study area are settlement and Agricultural activity. It is also evident that the local people totally depend on construction materials harvested from the natural forest to construct their shelters and also for making different household utensils and farm implements, which also aggravates the problem of degradation. Tree cutting for fuel and construction purpose cause deforestation of the natural forests of Ethiopia, (Degefa and Baudouin, 2004).

This result is in line with the results reported from South Africa where wood fuel production has largely been responsible for the loss of the wood land, together with agriculture, for large scale deforestation that has occurred over time (Chapos, 2002; Malimbwi *et al*., 2001).

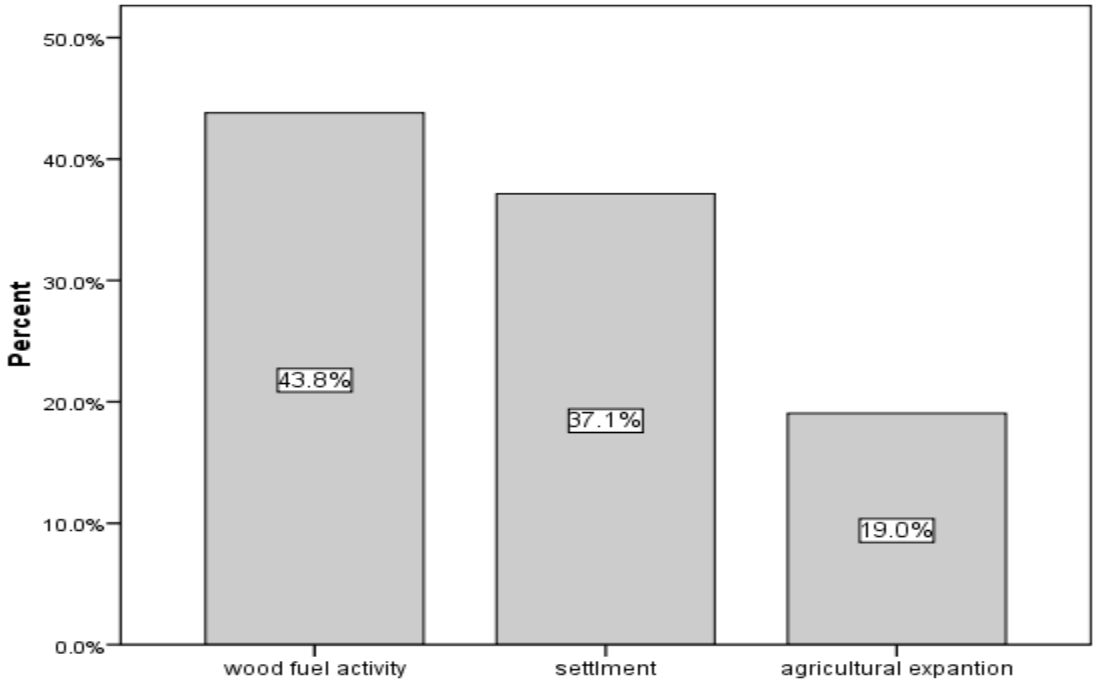


Figure 8. Cause of deforestation in Liben Zukala District

Further interrogation of participants about the past status of forest in area, at a focus group and key informant discussion made possible to understand that about the past 10 years before the area was largely covered by natural forest with large trees and with big wild animals like lion were part of the forest resource. Venturing into the forest was a risk affair due to wide range of predator and even crossing over to the near kebele was discouraged amongst young children as it was dangerous. According to Liben Zukala district Environmental Protection and Forestry Office and Agriculture Office due to high dependency on biomass without tree planting for wood fuel production and consumption activities, settlement and agricultural expansion were a facture responsible for forest loss in the area.

Liben Zukala district is heavily reliant on rainfed agriculture as majority (100 %) of the respondents talked of ever declining rain fall amount as compared to past relatively high amount of rainfall experienced in the area before clearance of the lands, the respondent also

listed some of the impacts they experience directly or indirectly as a result of deforestation including reduce rain fall 45.7%, Climate change 31.4%, loss of biodiversity 8.1% and erosion 14.8% as Shown in Figure 9 .

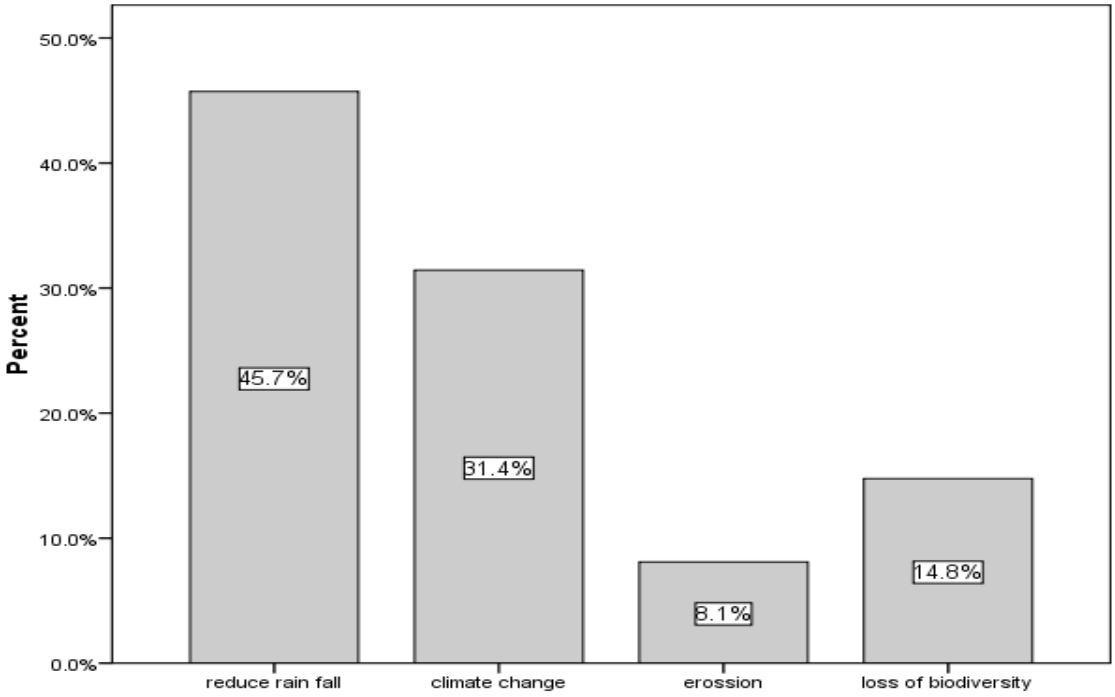


Figure 9. Consequences of forest degradation

4.6.1. Fire wood consumption of household

According to the respondents in the study area fuel wood is the common and major household energy source for home-based activities (baking, cooking and heating). The average fuel wood consumption per day per household in the study area was 5.5kg (SD = 1.6) for rainy season (June -August) and for dry season (September- May) was 4kg (SD=1.4). The average annual household consumption in the study area is 1.6 metric tons per year per household. The result was in consistent with study conducted Elisabeth *et al*. (2014) in Kaffa region which was 1.6 tons/household. The total domestic firewood consumption in Liben Zukala district was 8,108.8 tones / year and average per capita firewood consumption was

1.6 ton / HH per year. Seasons and climate significantly influence the firewood consumption pattern (Nagothu, 2001). In the study area rainy season fire wood consumption was greater than dry seasons, due to additional requirement of fuels to keep their houses warm and due to schools are closed and children have time to collect more fuel wood for their family.

Fuelwood consumption in Liben Zukala District is very high compared to Jogogudedo water shed Ethiopia 0.6 ton /household. Other rural regions in Sub-Saharan African such as, Uganda and Kenya, where mean annual consumption was estimated at 0.5 ton/household, (Robecca, 2015) and 0.6 ton/household (Sylvie *et al*., 2011) respectively. But this result is smaller than fuelwood consumption in Arsi Negele 6.5 ton per household which was conducted by Nijeb Muhamad (2008). This indicates that our finding result has difference or slight deviation with the national energy consumption estimation. And also, smaller than annual fuelwood per capita consumption of Woina Dega (subtropical) Zone of Ethiopia 1.7 tones (MME, 2013).

4.6.2. House Hold Charcoal Consumption

Result of the survey indicated that about 7.6% of the charcoal produced is sold at the nearest town where as about 87.6 % and 4.8% is sold inside the district and both outside and inside the District, respectively (Figure 10).

The average charcoal consumption per household in the study area was 4kg/day in the rainy season (June -August) and 2kg/day for dry seasons (September- May). The average annual household consumption in the study area was 1.2 tons per year per household.

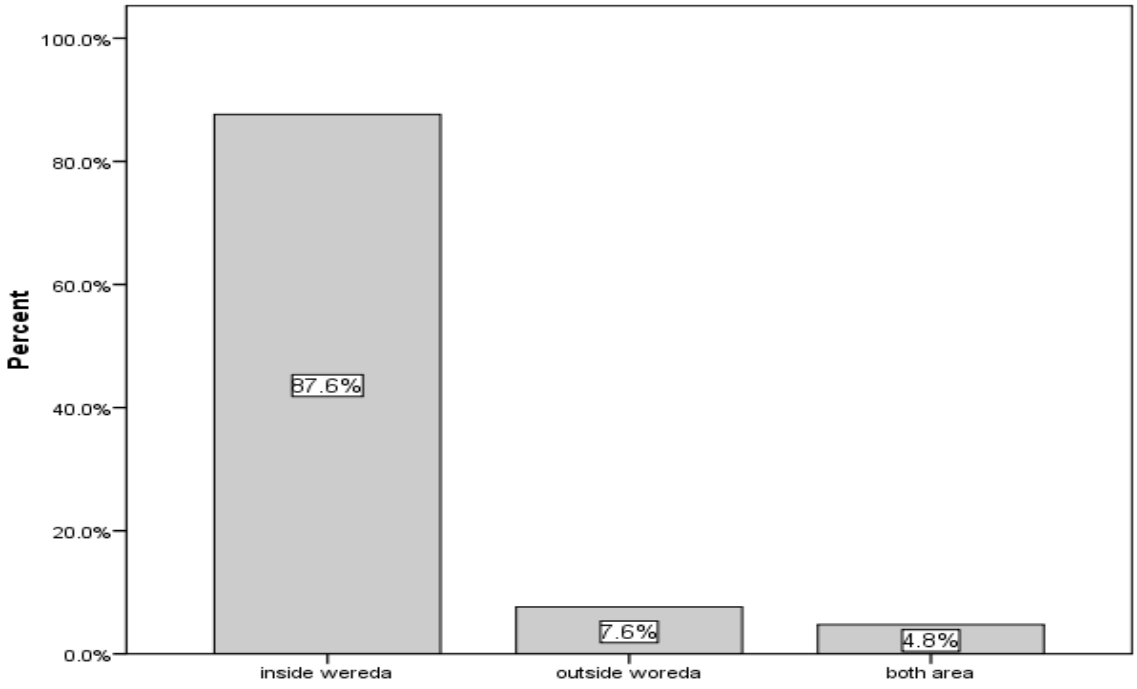


Figure 10. Market place of wood fuels produced from Zukala forest

4.7. Loss of forest due to wood fuel production and consumption

Charcoal production in this District is practiced throughout the year, but very high production was observed in dry seasons rather than rainy season. Wood fuel source for the most producers were Zukala Forest. This study revealed that on average 14 bags (532 kg) of charcoal in rainy season and 19 bags (722 kg) in dry seasons produced per month per production. The average annual charcoal production is 8.09 tons of charcoal per producer per year.

The total domestic wood fuel production and consumption of the district were 8,108.8 tons fire wood and 6,472 tons of charcoal per year. The amount of charcoal produced depends on factors related to carbonization and types of kilns used to burn charcoal. By using the Zukala forest Biomass Density (BD) in average 292 ton/ha and the total quantity of charcoal

produced during dry and rainy seasons were 6,472 ton/Year, and applying this quantity to the model of Chidumayo and Gumbo (2013), totally 116.7 ha/year of forest was degraded due to charcoal and 0.07 ha of forest was degraded due to fire wood production and consumption .

4.8. Driving factors for wood fuel consumption and production

I, The subsequent factors that account to the high patronage of wood fuel consumption

Three variables used in the model significantly affected the consumption of wood fuel by households in the study area (Table 9; $P < 0.01$).

This regression result showed that fuel wood consumption is positively correlated with Family size and land size of house hold head. However, the result reveal that wood consumption is negatively correlated with monthly Income of household.

Table 9. Regression coefficient estimates of socio-economic factors influencing wood fuel consumption

Variables	Unstandardized Coefficients	Standardized Coefficients			
	B	Std. Error	Beta	T	Sig
FAMSize	0.7	0.06	0.59	10.6	0.000***
ALSize	0.5	0.16	0.23	3.4	0.001**
INCOME	3.93	0.22	-0.35	-5.54	0.000***

. Source: Based on field survey, 2020

Note: *** indicate the level of significance at 1 %, and 0.1 %.

$R = 0.5$ $R^2 = 0.35$ Adjusted $R^2 = 0.34$

Family size: House hold family size significantly affects the probability of wood fuel consumption with p value and β coefficient of 0.000 and 0.59 respectively. Family size of household positively affect fuelwood consumption. This beta coefficient indicates that the probability of wood fuel Consumption is 59% higher for households with large family size than those with small family size. This might be due to the fact that large family members in a household demand more energy for cooking and heating in most rural areas and possibly more labor supply for fuel wood collection. The finding of this study is in line with result of Abaynesh *et al*. (2015) and Sylvie *et al*. (2011) found that family size is the most significant factors influences amount of fuel wood consumption level.

Income: Income of the household significantly affects amount of fuel wood consumption with p value 0.000 and coefficient - 0.35. The coefficient result indicates that the probability of consuming fuel wood for high income is 35% lower than household who have low income. This means that household with large income consume less fuel wood. This might be associated with the use of improved stoves that could reduce the probability of using more wood fuel. In addition, households that own large income have the possibility of purchasing other alternative energy sources like solar energy device, kerosene and LPG for their domestic purposes.

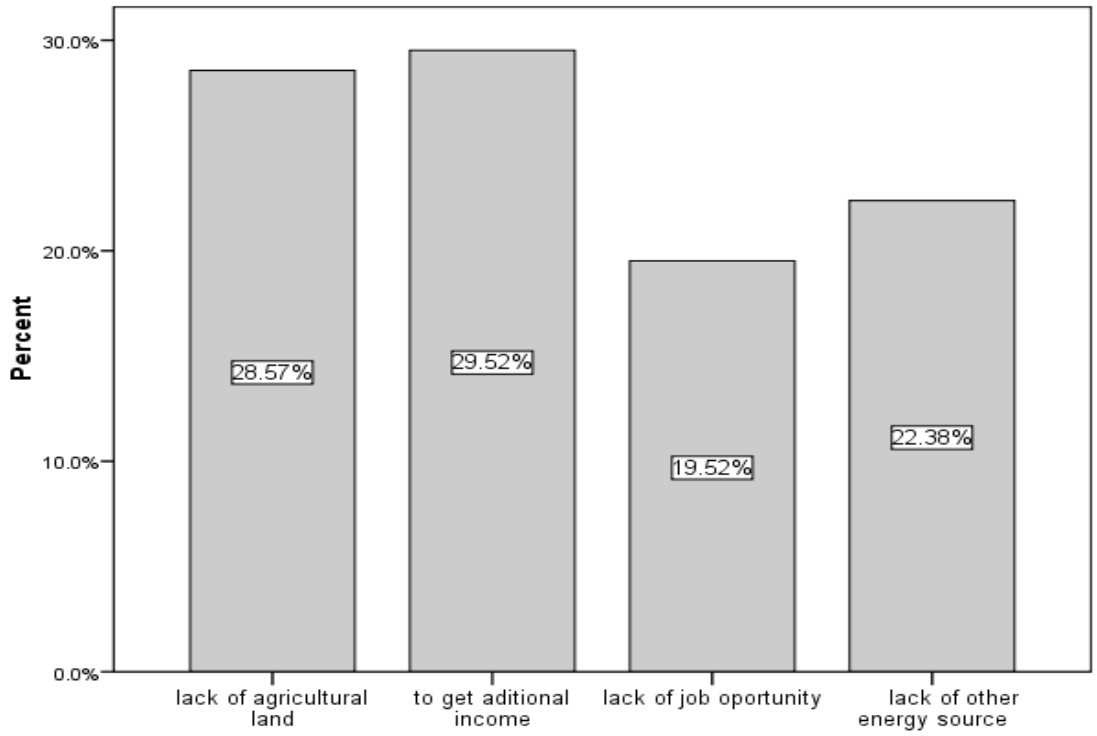
Land size: As it was expected, land size owned by households significantly affects wood fuel consumption with p value of 0.001 and β coefficient 0.23. this indicates that, the likelihood of fuel wood consumption of household with larger land size is 23% higher than those who

has few land sizes. It suggests that, larger land size holder is to cover different agricultural activities like farm land ploughing, sowing, weeding, harvesting and threshing they need labors because of this additional food prepared with more fuel wood consumption. This is in line with the findings of Dawit (2010) conducted in Northern Ethiopia, which revealed that next to agricultural land expansion by farmers, the most leading factors for high deforestation is using fuel wood as source of energy in Ethiopia.

II, The subsequent factors that account to the high patronage of wood fuel production.

The income earned by individual producers in the course of production is a major influential factor of steadiness of the activity. Rural livelihoods are intricately linked to the natural environment, making the charcoal problem a delicate one to solve (Anang *et al*., 2011). The high incidence of poverty and food insecurity in the district is as a result of the single rainfall regime which supports one season rain fed agriculture. As a coping strategy, the households living in these areas have diversified their livelihood sources. Commercial wood fuel production is thus a significant source of livelihood providing incomes to support households especially during the long dry seasons (Songsore, 2003; Agyeman et al., 2012). Producer of wood fuel also aim at profit maximization. During the study, according to the respondents the average price per bag of charcoal and a bundle of fire wood was higher especially in the rain season and hence a motivating factor for an individual producer to produce more. Producer engaged in other activities such as farming and trading among others but the wood fuel production is seen as the fastest way to income generation especially during the rainy seasons when price of charcoal and wood fuel are higher. The result of the study indicated that 29.52% of respondents are engaged in wood fuel production to get additional income

while 28.5% are engaged due to lack of agricultural land, 22.38%, lack of other energy source and 19.52% due to lack of other job opportunity (Figure 11).



Source: Field data, 2020

Figure 11. Driving forces of wood fuel production in Liben Zukala District

4.9. Respondents awareness on the effects of wood fuel production and consumption

Figure 12 and Tables 9 below present the level of awareness of the population in the study area on the effects of wood fuel production and use of the forest. Of the total sampled wood fuel producers, traders and users (Figure 12), 62.9% of them were not aware of the effect of wood fuel production and use on the Forest, while 37.1% were aware that wood fuel production and use affect forest resource. This implies majority of people were unaware of how forest cover depletion as a result of wood fuel production and use (Table 9). Jeremiah *et al.* (2014) also reported attitude, awareness and social status to be important in decisions

on forest management and hold that if the population is not well-informed conservation efforts are in a challenge.

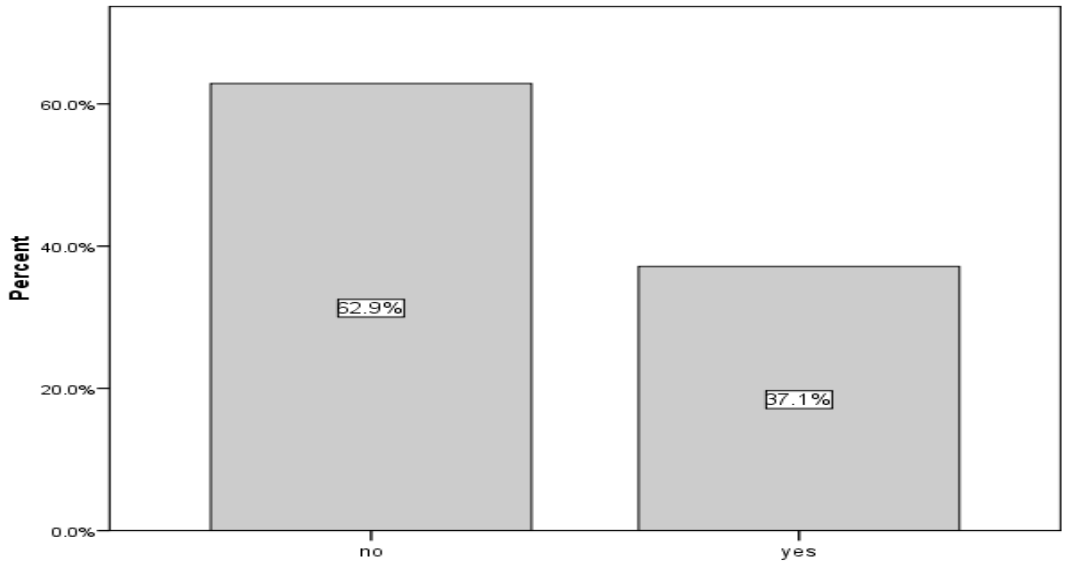


Figure 12. Respondents awareness on the effect of wood fuel production and consumption

Table 10. Respondents awareness on the effects of wood fuel production and consumption

Effect of Wood fuel production and consumption	No %	Yes %
reduce rain fall	64.6	35.4
climate change	60.0	40.0
leads erosion	46.2	53.8
loss of biodiversity	58.1	41.9

Source: Based on field survey, 2020

From the above findings, it could be observed that 62.9% of the respondents were not aware of the effect of wood fuel production and use on the forest. These tie squarely with the findings of Pawar and Rothkar (2015) who found that most of the charcoal users and

producers were not aware of the effects of their action on the environment and on their wellbeing. However, this finding is in contrary to the findings of Gumbo *et al*. (2013) in charcoal scoping study carried out in Zambia, where it was reported that most people were getting to be aware of the negative

effects of charcoal production to the environment and forest in particular. According to Environmental Protection, Forest and Climate Change Office, a few numbers of the population were aware of the environmental effects of wood fuel production and use, but they cannot do much since they consider wood fuel as the most affordable source of household energy due to a cheaper option. This sentiment supports the reports of Njenga *et al*. (2013), where charcoal was on high demand and use as a result of energy costs at low income household.

5. CONCLUSION AND RECOMMENDATIONS

CONCLUSION

The results of this study revealed that charcoal production in Liben Zukala District use traditional earth mound kiln method. This technology and wood fuel consumption has got negative impact on the forest. The most common source of energy by households in study area were firewood, charcoal and animal dung. The most preferred tree species resource for the fire wood were *Acacian parasinata, Acacian tortillis, Juniperus procera, Olea and Erica arborea for charcoal Acacia tortillis*, Acacia *Parasinata*, Combretum *terminalia* and *Cordia Africana*. These species are mostly extracted from the forest for energy sources for cooking and heating. The result of present study shows that 94% of the households depend on wood fuel as source of energy for baking and cooking (boiling water, wot, tea and coffee) followed by animal dung 6 %. In assessing status of wood fuel consumption in the study area 94% of households in the area use wood fuel from natural forest. The study result revealed that estimated total annual fuelwood and charcoal production and consumption was 8,108.8 tons and 6,472 tons per household per year respectively. More wood fuels were consumed in rainy season than dry season this could possibly rainy season is cold time that household needs more wood fuel to keep their houses warm. Total income is factor that could negatively influence wood fuel consumption, whereas land size owned and family size determine wood fuel consumption positively. In general, the result of the finding indicates that, major of households dependent on wood fuel was due to shortage of agricultural land and lack of job opportunity in the district. Market survey result show that high amount of wood fuel extracted for supply to local market for sale. The heating and cooking are done using three mold inefficient traditional cooking stove and the level of awareness of the population on the

forest effects of wood fuel production and use is relatively low. The consequences of uses of biomass energy sources may lead to forest degradation, deforestation, and lands degradation all are severe environmental and socio- economic problems.

.

RECOMMENDATIONS

The following recommendations forwarded based on the findings were;

- Decreasing dependency on biomass through the provision of improved production inputs and alternative modern energy supplies such as LPG, Biogas, and Solar.
- Strengthening of Natural Environment Trust Fund allocation system and creation of degraded forest and woodland environment rehabilitation programs.
- Active involvement of community leaders' forest management through voluntary patrolling of the production site to avoid indiscriminate felling of tree for wood fuel.
- Capacity building and empowerment of communities to take full responsibility of managing their environmental resource.
- Stakeholders involve in forest resource conservation should emphasized on collaboration with local people in forest conservation.
- Adoption of efficient modern charcoal production technologies and stove.
- Increase efforts in conservation especially through widely used improved charcoal stove and charcoal production technologies.
- Boosting of wood supply through agro forestry farming by introducing own farm and community woodlots.
- Increase or Expand electricity supply and distribution.

REFERENCES

Abaynesh Kebede, Achalu Chimdi and Akhila S. Nair, 2015. Effect of Firewood Energy Consumption of Households on Deforestation in Debis Watershed Ambo District, Oromia Regional State, Ethiopia. Ambo University, College of Computational and Natural Sciences, P. O. Box: 19, Ambo, Ethiopia.

Abegaz, F., 1995, May. Effect of sub-surface drainage system on groundwater table, soil salinity and crop yield in Melka Sadi pilot drainage scheme. In on: proceedings of the 1st and inaugural conference of the Agronomy and crop Physiology society of Ethiopia (pp. 139-148).

Amanor, K.S., 2002. Bush fire management, culture and ecological modernization in Ghana.Bulletin,33(1), pp65-74.

Anang, B.T., Akuriba, M.A. and Alerigesane, A., 2011. Charcoal production in Gushegu District, Northern Region, Ghana: lessons for sustainable forest management. International Journal of Environmental Sciences, 1(7), pp.1944-1953.

Arnold J.E.M, Köhlin G and Persson R., 2006. Wood fuels, lively hoods, and policy interventions: changing perspectives World Dev. pp596–611.

Asrat, Z., 2020. Modelling and quantifying tree biometric properties of dry Afromontane forests of south-central Ethiopia.

Bailis, R., Ezzati, M., and Kammen, D. M., (2005). “Greenhouse Gas Implication of Household energy technologies in Kenya.” Environmental Science and Technology 37(10):20512059.

Bailis, R., Berrueta, V., Chengappa, c., Dutta, K., Masera, O., Patara, S., (2007). Performance testing a tool to monitor improved stove intervention: Experiences of the shell Foundation house hold energy and health project. Energy for sustainable Development.

Chaposa, 2002. Charcoal Potential in Southern Africa. Final Report, Stockholm, Environmental Institute, International Cooperation with Developing Countries.

Chave, J., Réjou-Méchain, M., Búrquez, A., Chidumayo, E., Colgan, M.S., Delitti, W.B., Duque, A., Eid, T., Fearnside, P.M., Goodman, R.C. and Henry, M., 2014. Improved allometric models to estimate the aboveground biomass of tropical trees. Global change biology, 20(10), pp.3177-3190.

Chidumayo EN and Gumbo DJ. 2013 The environmental impacts of charcoal production in tropical ecosystems of the world: A synthesis. Energy Sustain Dev; 17: pp.86–94.

Chojnacki, S., 1963. Forests and the forestry problem as seen by some travelers in Ethiopia. Journal of Ethiopian Studies, 1(1), pp.32-39.

Guta, D.D., 2012. Assessment of biomass fuel resource potential and utilization in Ethiopia: sourcing strategies for renewable energies. International Journal of Renewable Energy Research (IJRER), 2(1), pp.131-139.

Dawit, H., 2010. Ethiopian energy systems: Potentials, Opportunities and Sustainable utilization MSc. Thesis Uppsala University, Sweden.

Degefa Tolosa and Baudouin, A., 2004. Access to natural resource and conflicts between farmers and agro-pastoralists in Borkena wetland, north-eastern Ethiopia. Norsk geographic Tidsskift-norwegian Journal of Geography Vol. 58, pp.97-112.

Demel, J., Buchberger, W. and Malissa Jr, H., 2001. Multiclass/multiresidue method for monitoring widely applied plant protecting agents in air during field dispersion work. Journal of Chromatography A, 931(1-2), pp.107-117.

Demirbaş, A., 2001. Biomass resource facilities and biomass conversion processing for fuels and chemicals. Energy conversion and Management, *42*(11), pp.1357-1378.

Environmental Protection Authority (EPA), 1998. National Action Program to Combat Desertification. Addis Ababa: Environmental Protection Authority,1, 158p.

Elisabeth, D., Martin, H., Louis, V., Robert, M and Ben, D. V. 2014. Fuelwood Savings and Carbon Emission Reductions by the Use of Improved Cooking Stoves.

EPA, 2003. State of Environment Report in Ethiopia: The Federal democratic republic of Ethiopia Addis Ababa, Ethiopia.

Ethiopia Central Statistical Authority (CSA), 2015. Ethiopia Welfare Monitoring Survey, Ethiopia Central Statistical Agency, Addis Ababa, Ethiopia.

Ethiopian Forest Action Program (EFAP), 1994. The challenges for Development Ministry of Natural Resources, Addis Ababa.

Evans J. 1992. Plantation forestry in the tropic .2nd ed. Oxford University press Inc. New York.

FAO, 2005. Global Forest Resources Assessment.

FAO, 2008. http://www.fao.org/copyright-en.htm.Accessed on 20/11/2013

FAO (Ed.), 2009. Livestock in the balance, The state of food and agriculture.

FAO, 2010. Global forest resources assessment- Forestry Department Food and Agriculture Organization of the United Nations. FRA2010/065 Rome, Italy.

FAO, 2011. State of The World's Forest Rome. Retrieved from; www.fao.org/docrep/013/12000e/12000e00.Htm.

Faris, K., 2002.Survey of indoor air pollution problems in the rural communities of Jimma, Southwest Ethiopia, Ethiopian Journal of Health Sciences.

FGRCP (Forest Genetic Resources Conservation Project), 2010. Socio-Economics participatory Rural appraisal Report of Zukala Monastery Forest. Institute of Biodiversity Conservation and Research in cooperation with GTZ.

Food and Agricultural Organization (FAO), 2010. State of the world's forests report 2010.

Gebreslassie Teklay, Hagos Gebraslassie and Abraham Mehari, 2014. Assessing Households' Fuel Wood Tree Species Preference: The Case of Desa'a Afro Alpine Forest, Tigray Natural resource management department, Adigrat University, Adigrat, Ethiopia.

Geider, J.R., Delucia, H.E., Falkowsk, G.P., Finzi, C.A., Grime, P.J., Grace, J., Kana, M.T. and Roche. 2001. Primary productivity of planet earth: biological determinants and physical constraints in terrestrial and aquatic habitats. Global Change Biology 7: pp.849-882.

Geissler S, Dietmar Hagauer PM, Alexander H, Michael K, Peter S, (2013). Biomass Energy Strategy Ethiopia., AMBERO Consulting Gesellschaft mbH Immanuel-Kant-Str. 41, 61476 Kronberg.

Gelder, B.V. and O'keefe, P., 1995. The new forester. London (UK), Intermediate Technology.

Girma, A., Sormesa, T., 2014. Forest Carbon Stocks in Woody Plants of Mount Zuqala Monastery and Its Variation along Altitudinal Gradient: Implication of Managing Forests for Climate Change Mitigation.

Gumbo, D. J., Moombe, K. B., Kandulu, M. M., Kabwe, G., Ojanen, M., Ndhlovu, E., and Sunderland, T.C.H., 2013. Dynamics of the charcoal and indigenous timber trade in Zambia: A scoping study in Eastern, Northern and Northwestern provinces. Occasional Paper 86. CIFOR, Bogor, Indonesia.

Herd, A.R.C., 2007. Exploring the socio-economic role of charcoal and the potential for sustainable production in the Chicale Regulado, Mozambique. A dissertation presented for the degree of Master of Science University of Edinburgh.

Iiyama, M., Neufeldt, H., Dobie, P., Hagen, R., Njenga, M., Ndegwa, G., Mowo, J.G., Kisoyan, P. and Jamnadass, R., 2015. Opportunities and challenges of landscape approaches for sustainable charcoal production and use. Climate-smart landscapes: multifunctionality in practice, 195, p.209.

IPCC.Climate change, 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

Jeremiah, R. J., Mbwambo, J. S., and Dos Santos, A. S., 2014. Attitudes of local communities towards REDD+ Initiatives in Tanzania. A case of selected communities in Kilwa district. International Journal of Physical and Social Sciences, 4 (4), 255.

Kammen, D.M. and Lew, D.J., 2005. Review of Technologies for the Production and Use of Charcoal; Energy and Resources Group and Goldman School of Public Policy

Renewable and Appropriate Energy Laboratory Report. University of California: Berkeley, CA, USA.

Kouami, K., Yaovi, N. and Honan, A., 2009. Impact of charcoal production on woody plant species in West Africa: A case study in Togo. Scientific Research and Essays, 4(9), pp.881-893.

Labarta, R.A., White, D.S. and Swinton, S.M., 2008. Does charcoal production slow agricultural expansion into the Peruvian Amazon rainforest. World Development, 36(3), pp.527-540.

Liben Zukala district Administration Office (LZWAO), 2015. Physical and socio-economic profile of Liben Zukala district assessment result report.

Luoga E. J; Witkowski, E.T.F. and Balkwill, K., 2000.Economics of charcoal production in miombo woodlands of eastern Tanzania: some hidden costs associated with commercialization of the resources. Ecological Economics,35: pp.243-257.

McMicken, K.G., 1997. A Guide to Monitoring Carbon Storage in Forestry and Argo-forestry Projects. In: Forest Carbon Monitoring Program. Win rock International Institute for Agricultural Development, Virginia, Pp. 87.

Malimbwi, R.E. and Mugasha, A.G., 2001. Inventory report of Kitulangalo forest reserve in Morogoro, Tanzania. Forest and Beekeeping Division, Dar es Salaam (unpublished).

Maltamo M, Eerikäinen K, Pitkänen J, Hyyppä J, Vehmas M., 2004. Estimation of timber volume and stem density based on scanning laser altimetry and expected tree size distribution functions. Remote Sens. Environ. 90(3): pp.319-330.

Mekonnen A, Köhlin G (2009). Determinants of household fuel choice in major cities in Ethiopia.http://www.rff.org/files/sharepoint/WorkImages/Download/EfD-DP-0818.pdf

Melaku Bekele, 2003. Forest Property Rights, the role of the state and Institutional Exigency: The Ethiopian Experience. Doctoral dissertation. Sweedish university of Agricultural Science. Uppsala, Sweden

Melaku, B., Zenebe, G., 2014. Reading through the charcoal industry in Ethiopia: Production, Marketing, Consumption and Impact. Forum for Social Studies, Policy Brief 31: pp.1-4.(FAO,2005)http://www.fssethiopia.org/publicationfile/policy%20brife%2031%20english.pdf.

Mengistu T, Demel T, Hultén H, Yemshaw Y., 2005. The role of communities in closed area management in Ethiopia. Mountain Res. Dev. 25(1): pp.44-50.

Ministry of Mines and Energy (MME), 2013. Energy Resources Potential of Ethiopia Energy Development, Follow up and Expansion Department Addis.

MOE, 2005. Educational Statistics Annual Abstract, Addis Ababa: MOE, EMIS. P 5. Addis Ababa, Ethiopia.

Mugo, F., and Gathui, T. 2010. Biomass energy use in Kenya. A background paper prepared for the International Institute for Environment and Development (IIED) for an international ESPA workshop on biomass energy, pp,19-21, Parliament House Hotel, Edinburgh. Practical Action, Nairobi, Kenya.

Müller, N., Michaelowa, A. and Eschman, M., 2011. Proposal for a new standardized baseline for charcoal projects in the Clean Development Mechanism. Zurich. pp, 86.

Muys, B. Kideya Gabrielinos and Bruneel, S., 2000. The Ecology and Silvicultre of Dryland Forest rehabilitation in Ethiopia. Journal of the Drylands 1(1): pp. 1-2.

Nagothu US., 2001. Fuelwood and fodder extraction and deforestation: mainstream views in India discussed on the basis of data from the semi-arid region of Rajasthan. Geoforum 32(3): pp. 319-332.

National Clean Cook Stoves Program Ethiopia (NCCSPE, 2011). Road map

Njenga, M., 2013. Evaluating Fuel Briquette Technologies and their Implications on Greenhouse Gases and Livelihoods in Kenya. Ph.D. Thesis Submitted to the Faculty of Agriculture, University of Nairobi.

Njenga, M., Yonemitsu, A., Karanjaa, N., Iiyama, M., Kithinji, J., Dubbeling, M., ...and Jamnadass, R. R., 2013. Implications of Charcoal Briquette Produced by Local

Communities on Livelihoods and Environment in Nairobi Kenya. International Journal of Renewable Energy Development, 2(1), pp. 19.

Nijeb Muhamad, 2008. Impact of 'Katikala' Production on the Degradation of Woodland Vegetation and Emission of CO PM during Distillation in Arsi Negele District, central Rift valley of Ethiopia.

Oduori, S.M., Rembold, F., Abdulle, O.H. and Vargas, R., 2011. Assessment of charcoal driven deforestation rates in a fragile rangeland environment in North Eastern Somalia using very high-resolution imagery. Journal of Arid Environments, 75(11), pp.1173-1181.

Pachauri S., Mueller, A., Kemmler, A. and D. Spreng., 2006, 'On measuring energy poverty in Indian households', World Development 32(12): pp. 2083-2104

Pawar, K. V., and Rothkar, R. V. (2015). Forest Conservation and Environmental Awareness. Procedia Earth and Planetary Science 11 (2015) pp. 212 – 215.

Pearson, T., Walker, S. and Brown, S., 2005. Sourcebook for land-use, land-use change and forestry projects. Winrock International and the Bio-carbon fund of the World Bank. Arlington, USA, Pp. 19-35.

Pennise, D. M., Smith, K. R., Kithinji, J. P., Rezende, M. E., Raad, T. J., Zhang, J., and Fan, C. 2001. Emissions of greenhouse gases and other airborne pollutants from charcoal making in Kenya and Brazil. Journal of Geophysical Research: Atmospheres (1984–2012), 106(D20), pp.24143-24155.

Robecca Toole, 2015. The Energy Ladder: A Valid Model for Household Fuel Transitions in Sub-Saharan Africa.

SEI, 2002. Charcoal Potential in Southern Africa, CHAPOSA: Final Report. inco-dev, Stockholm Environment Institute, Stockholm.

Seidel, A., 2008. Charcoal in Africa importance, problems and possible solution strategies. gtz, Eschborn.

Simie, H., 2007. The quest for conservation in the midst of deforestation, resource degradation and unsustainable livelihood practices in and around Mt. Zukala.

Smith, K.R, Samet J.M, Romieu l., Bruce N, 2004. Indoor Air pollution in Developing Countries and Acute Lower Respiratory Infections in children.

Songsore, J., 2003. The urban housing crisis in Ghana capital: The state versus the people. Ghana Social Science Journal, 2(1), pp.1-31.

Sylvie, D. emurger, Martin Fournier ,2011. Poverty and Fuel wood consumption: A case study of rural Households in Northern China. China Economic Review, Elsevier, 2011, 22 (4), pp. 512-523.

Townson, I.M. 1995. Patterns of non-timber forest products enterprise activity in the forest zone of southern Ghana: main report. Report to the ODA Forestry Research Programme, Oxford.

Van Beukering, p., kahyarara, G., Massey, E., di prima, s., Hess, s., Makundi, v., and vander leeuw, k. 2007. optimization of the charcoal Hain in Tanzania. Poverty reduction and environmental Management (PREM) program. Institute for environmental studies. Amsterdam, the Netherland.

Wezel, A., Bender, S., 2004. Degradation of agro-pastoral village land in semi-arid southeastern Cuba. J. Arid. Environ. 59, 299

World Bank, 2010. Enabling Reforms: a stakeholder-based analysis of the political economy of Tanzania's charcoal sector and the poverty and social impacts of proposed reforms. Washington DC.

Yamane, Taro, (1967). Statistics, An Introductory Analysis, 2nd ed., New York: Harper and Row.

Yigardu, M., 2003. Growth, Morphology and Biomass of Arundinoid alpine (Highland Bamboo) (Poaceae) as Affected by Landrace, Environment and Silvicultural Management in the Choke Mountain, Northwestern Ethiopia (Doctoral dissertation, Addis Ababa University).

APPENDICES

Appendix 1. Questioner for charcoal producer

Kebele _____

Impact of wood fuel production and consumption on zukala forest in Liben Zukala district, Oromia state, Ethiopia

(1) HOUSEHOLD INFORMATION

1, what are your household status and main source

Household members	gender	Age	Educational level	occupation	Source of income	Monthly income	Other source of income

2, Are you involved in charcoal production? Yes No

3. If yes, how long have you been in charcoal production and how much Agricultural land size?

a, Below 5 years b, 6-10 years c, 11-15 years d, 16 years and above

b, _____

II, Source of material for charcoal production

6,Which specious of tree/wood favorable for charcoal burning? _____

7, Where do you get the materials for charcoal production from? Tick (√) where appropriate

a, forest b, farm plot C, Others specify

8, What methods do you use for charcoal processing? Tick (√) appropriately

A, Traditional earth or saw dust mound procedure ( )

B, mobile metal kiln method ( )

C, pit kiln method

D, Others

9, How many bags/Quantities of charcoal do you usually harvest from a single production?

10, Can you approximate how many bags of charcoal do you need per month?

A, less than one bag

B, 1-3 bags

C,4-7 bags

D, other _____

11, How much do you usually sell bag of charcoal?

_____

12, How much income do you get per production?

_____

13, How often do you engage in charcoal production in a month?

_____

14, Where do you often burn/produce the charcoal?

a, Around the house b, in the forest c, farm plots

ii, could you give some reason for the choice charcoal production location?

15, Where do you usually sell the charcoal?

a, With in the district b, outside the district c, Booth

16, What makes you to produce charcoal?

_____

17, Do you think charcoal production reduce forest cover? Yes No

18, Which do you think is the most sever cause of deforestation in your area?

a, wood fuel c, settlement d, agricultural expansion

f, Others specify

THANK YOU

Appendix 2. Questionnaire directed to consumers of charcoal and firewood

kebele_____

Gender_____

Age _____

Education _____

Occupation _____

Income _____

Agricultural land size _____

1.How big is your family

_____

2.Do you use charcoal/fire wood to cook?

a, Yes b, No

3. How often do you cook using charcoal/fire wood

_____

4. From where do you get it?

a, market b, forest c, producer

5. How much do you buy it

_____

6.How much charcoal/fire wood consume per day?

_____

7, Do you have any preference of species on the types of charcoal/fire wood?

a, Yes b, No c, Other _____

8, If yes, which types of species do you prefer for charcoal/fire wood?

_____

Do you think fuel wood consumption reduce forest cover? Yes No

if yes, how? _____

Appendix 3, Questionnaires directed to Fire wood seller

I, General information

Household members	**gender**	**Age**	**Educational level**	**occupation**	**Source of income**	**Monthly income**	**Other source of income**

2, How long have you been in fuel wood /charcoal marketing?

a, below 5 years b,6-10 years c, 11-15 years d,16 years and above

3, Where do you get fuelwood/ charcoal?

A, from forest b, agricultural land c, from market c, Others

4, What kind of transport do you use?

_____

5, How often do you transport charcoal/fire wood?

a, Daily b, weekly c, monthly d, yearly

6, i, Where Do you sell?

a, inside the district b, outside the district c, Both

7, How many bags sell per day?

_____

7, How much do you earn from fuel wood business per month?

_____

8, When do you get most returns/profit from fuel wood/charcoal marketing?

A, dry season b, rainy season c, all season

9, Do you think fuel wood/charcoal consumption affect forest resource? Yes No

10, i, are you aware of wood fuel consumption affect forest resource? Yes No

ii, if yes, mention some of the impacts you know

_____

Appendix 4. Institutional Questionnaire for Liben Zukala District Environmental protection and Forestry office

1, Do you have incidence of fuel wood consumption and charcoal production in your district? yes ( ) No ( )

2.If yes, as a natural resource-based establishment, do you have district program mitigating the effects of commercial charcoal production on the forest resource?

3 i,,do you have any challenges in the implementation of regulation? Yes No

ii, if yes, could you describe them?

4, What measures are in place to address the challenge?

5, Do you have charcoal related training programs for communities or out reach of any kind? Yes No

6, Are there structures for stake holder participation in your organization? yes ( ) No ( )

A, If yes, outline the structures in place for stakeholder participation

Observation Guide

kebele _____ Date _____

Location(I) Governmental forest (II) private owned land (III) Land use (I) Dense forest (II) Wood land (III) Grass land (4) Cultivated land (5) Other land specify

Dominant Specious

Kiln site _____

Number

Size_____

Market

Supply of charcoal

_____

Supply of fuel wood

_____

Appendix 5. cheek list for key informant discussion

1. Have you noted any change in the forest cover in your area?
   A) yes B) No

2. If your answer to question number 2 is yes, what changes did you observed?

Increase/decrease in:

A) Agricultural land

B) Forest cover

c) Settlement and infrastructure

Do you think fuel wood consumption and charcoal production influences forest?

What are the driving forces to implement fuel wood production and marketing?

What is your role to reduce fire wood consumption and charcoal activity?

Appendix 6, Cheek list for group discussion

- What is the attitude of you towards the forest degradation? (what did people think/say?)
- What do you think about the aim of having the sustainable use resource is one thing must not forget during fire wood collection and charcoal production? (explore biodiversity conservation, climate change, wild life conservation and soil erosion)
- Do you think the sustainable use of resources likely to improve the quality and quantity of the resource? if not, Why