THE POTENTIAL OF IMPROVED COOK STOVES IN FUEL WOOD SAVING AND CARBON DIOXIDE EMISSION REDUCTION: THE CASE OF SAYO WOREDA, OROMIA, WESTERN ETHIOPIA.

M.Sc. THESIS

HAWI ABERA TEKA

HAWASSA UNVERSITY, WONDO GENET, ETHIOPIA

MAY, 2019

POTENTIAL OF IMPROVED COOK STOVES IN FUEL WOOD SAVING AND CARBON-DIOXIDE EMISSION REDUCTION: THE CASE OF SAYO WOREDA, OROMIA, ETHIOPIA.

HAWI ABERA TEKA

ADVISOR: MOTUMA TOLERA (PhD)

THESIS SUBMITTED TO

DEPARTEMENT OF ENVIRONMENTAL SCIENCE

WANDO GENET COLLEGE OF FORESTERY AND NATURAL RESOURCES SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY

WONDO GENET, ETHIOPIA

IN THE PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE

DEGREE OF

MASTERS OF SCIENCE IN RENEWABLE ENERGY UTILIZATION AND MANAGEMENT

MAY, 2019

APPROVAL SHEET I

This is to certify that the thesis entitled “Potential of improved cook stove in fuel-wood saving and carbon-dioxide emission reduction in Sayo woreda, western Oromia, Ethiopia” submitted in partial fulfillment of the requirements for the degree of Master of Science in Renewable Energy Utilization and Management, the graduate program of Environmental Science and has been carried out by Hawi Abera Teka under my supervision. Therefore, I recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

Approved by:

Motuma Tolera Fayera (PhD)	________________	____________________
Name of Main Advisor	Signature	Date

APPROVAL SHEET II

We, undersigned members of the board examiners of the final open defense by Hawi Abera Teka have read and evaluated his thesis entitled “Potential of improved cook stove in fuel-wood saving and carbon-dioxide emission reduction in Sayo woreda, western Oromia, 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 Renewable Energy Utilization and Management.

Approved by:

1.________________________________ ________________ ______________

Name of external examiner Signature Date

2. ________________________________ ________________ ________________

Name of internal examiner Signature Date

3.________________________ ______________________ ________________

Name of chair person Signature Date

4.________________________ ______________________ ________________

Name of SGS Signature Date

ACKNOWLEGEMENT

The completion of this work has been possible through support and contribution of various individual and institutions. I sincerely wish to express my gratitude to Oromia Agriculture and Natural resource bureau and MRV (Measuring Reporting and Verification) project.

I have been great fortune to have had the support and professional guidance, comment and suggestion of my advisor Dr. Motuma Tolera.

Finally, I greatly appreciate my parents those help me in this work. Thank you for your everlasting love and support. You are the best

DECLARATION

I hereby declare and affirm that this thesis entitled “Potential of Improved Cook Stoves in Fuel-woo Saving and Carbon-dioxide Emission Reduction: The Case of Sayo woreda, Oromia, Ethiopia” is my own work any scholarly matter that is is included in the thesis has been given recognition through citation.

This thesis is submitted in partial fulfillment of the requirements for M.sc degree in Renewable Energy Utilization and Management at Hawassa University Wando Genet Collage of Forestry and Natural Resource. I solemnly declare that this thesis has not been submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

Hawi Abera Teka	________________	__________________
Name of student	Signature	Date

Table of contents

ACRONYMS AND ABBREVIATIONS

AEPRN	African Energy Policy Research Network
CCT	Control Cooking Test
CDM	Clean Development Mechanism
CO_2	Carbon-dioxide
CO_2e	Carbon-dioxide Equivalent
CRGE	Climate Resilient Green Economy
ECO	Energy Coordination Office
EPAE	Environmental Protection Authority of Ethiopia
ESAM	Energy Sector Management Assistance program
ETB	Ethiopia Birr
FAO	Food Association Organization
FDRE	Federal Democratic Republic of Ethiopia
FGD	Focus Group Discussion
GACC	Global Alliance of Clean Cook Stove
GHG	Green House Gas
Gt	Giga ton
GTZ	German Technical Cooperation
GVEP	Global Energy Partnership
IAP	Indoor Air Pollution
ICS	Improved Cook Stove
IEA	International Energy Agency
IEO	International Energy Outlook
KPT	Kitchen Performance Test
LPG	Liquefied Petroleum Gas

MFED	Ministry of Finance and Economic Development
NEMA	National Environment Management Authority
OECD	Organization for Economic cooperation and Development
OR	Odd Ratio
SAE	Standard Adult Equivalent
TCS	Traditional Cook Stove
UNDP	United Nations Development Program
UNEP	United Nations Environmental Program
UNFCCC	United Nations Climate Change Convention
VITA	Volunteer in Technical Assistance
WBISPP	Woody Biomass Inventory and Strategy Planning Project
WBT	Water Boiling Test

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

This study was examined to assess the potential of improved cook stove (ICS), (specifically Mirt stove which is designed for Ethiopia's staple food injera) in fuel-wood saving, carbon-dioxide emission reduction and assessed the determinants of household decision of its adoption in Sayo woreda, oromia regional state, western Ethiopia. Kitchen Performance Test (KPT) has been employed to determine potential of ICS in fuel-wood saving, and household survey were conducted to assess the determinants of household decision on adoption of ICS. Data for this study were collected from 191 household heads, selected using simple random sampling technique from two kebeles. For KPT, 30 ICS and 35 traditional cook stove (TCS) users were selected using stratified random sampling. To measure the efficiency of ICS and TCS, field test was conducted for eight days by using cross-sectional approach. Data gathered through questionnaire were analyzed using binary logistic regression and descriptive statistics; whereas data gathered from KPT were analyzed using independent t-test. The regression result revealed that, family size; higher education level and income level of household are positively and significantly influenced the decision of household adoption of ICS. The KPT result showed that an average of fuel-wood consumed for TCS per day for each standard adult equivalent (SAE) is 1.199 (standard deviation = 0.218) kg; while an average of 0.686 (standard deviation = 0.117) kg of fuel-wood is consumed per each SAE when ICS is used. Besides this, the result also demonstrated that using an ICS reduces annual emission of 0.86 tons of carbon-dioxide equivalent per ICS user. The findings of this study implied that improved cook stove has a major contribution in fuel-wood consumption saving as well as carbon-dioxide emission reduction. Hence it can be recommended that government and non-government should be focus on awareness of household and also long term payment modalities and reasonable subsidies should be available to lower income household.

Key words: *Adoption, kitchen Performance Test, Mirt stove, Traditional Cook Stove.*

1. INTRODUCTION

1.1 Back-ground

Globally, 2.8 billion people (Bailis, *et al.*, 2015), of which 90% live in developing countries (Urmee and Gyamfi 2014), depend on traditional biomass energy, such as firewood, charcoal, crop residues, and dung, for both cooking and heating (Raman *et al*., 2013). In Ethiopia, over 90 percent of the country's total energy for household cooking is derived from biomass fuels and fuel-wood is the major energy source which accounts 78%, while animal dung and crop residue account 12% and 8% respectively (WBISPP, EPAE, 2004). Such reliance on biomass energy is one of the major causes of environmental degradation and a contributor to the greenhouse gases emissions, such as Carbon-dioxide (Mano *et al*., 2017)

The consumption pattern of biomass has led to forest degradation and deforestation, atmospheric pollution from emissions of greenhouse gases (GHG) during the combustion of wood with its implications for climate change, and indoor air pollution leading to domestic health hazards particularly for women and children during cooking (WHO 2005). These emissions account for at least 2% of global greenhouse gas emissions contributing to global warming (Parker *et al*., 2015). All of these issues are more acutely felt in regions like sub-Saharan Africa, where more than 90% of the population rely on solid biomass to meet their energy needs (Parker *et al*., 2015).

Traditional stoves, while free and easy to construct, are highly inefficient and require between 20% - 50% more fuel-wood than alternative improved stoves (Bensch and Peters, 2015) and loose large percentage of the fuel energy due to incomplete combustion (Owsianowski *et al*., 2006). The thermal efficiency of traditional stoves is cited to be between 7% - 12% and therefore below ICSs (Wiskerke *et al*., 2010). Improved stoves can cut back indoor smoke levels considerably (WHO, 2006) and it is possible to reduce GHG emission by using improved cook stove, (Muller *et al*., 2011). Improved cooking stoves (ICS) that use less biomass have received significant attention as important intermediate technologies (Jeuland and Pattanayak, 2012), most of which use fuel-wood, which is the most important biomass fuel. Improved cook stove are designed to improve combustion efficiency of biomass, consume less fuel, save cooking time, increase convenience in cooking processes and create a smokeless environment in the kitchen or generally lead to a reduction in the volume of smoke produced during cooking (GACC, 2013).

FDRE (2011) and MoFED (2010) stated that in Ethiopia, in order to minimize the rate of deforestation, the document forwarded reduction of the demand for fuel-wood via the dissemination and usage of fuel-efficient stoves and/or alternative fuel cooking and baking techniques.

In Sayo woreda, energy consumption for domestic use could be modern and traditional. However, the traditional (fuel-wood, crop residue and charcoal) dominates the modern one (electricity and petroleum). Among petroleum products, diesel and kerosene are consumed both in rural and urban area. Even though the pressure on the forest resource has increased due to tendency to use of fuel-wood by the local community and traditional open fire cooking is predominant. Dissemination of ICS has recently introduced in 2006 E.C across kebeles of the woreda.

1.2 Statement of the problem

Forest degradation leads to carbon-dioxide emissions, which is primarily caused by fuel-wood consumption (46%) are expected to grow from 25 Mt of carbon-dioxide equivalent in 2010 to 45 Mt of carbon-dioxide in 2030 (CRGE, 2011).

In Ethiopia heavy reliance on Biomass resources play major role in the depletion of the country's forest resources (Shanko, 2001, Asres, 2002, Gebreegziabher, *et al*., 2010). In developing countries like Ethiopia, whose energy supply is heavily dependent on biomass fuels, technical advances in energy efficiency are critical. In order to reduce pressure on forests and the adverse impact of indoor air pollution, the government of Ethiopia is trying to increase the availability of fuel saving technologies such as improved cook stoves (cook *et al*, 2008). However stove dissemination could be sustainable only if new households adopt improved stove and if the changes in fuel use of a proposed new stove is understand.

Improved biomass energy technologies have been promoted but the adoption is low and disproportional (NEMA & GOK, 2009; ESPA & Practical Action East Africa, 2010). Limited adoption of improved technologies by households forms one of the focus areas of this research with the aim of determining the determinants of ICS adoption at household level.

From personal experience, it is very common to observe deforestation and health problem, dissemination of ICS was started recent time however their performance in saving fuel-wood and in real kitchen condition and their potential in emission reduction have never been conducted in Sayo woreda. Thus, this study is intended to quantify the amount of fuel-wood saved by ICS users and carbon-dioxide emission reduced by improved cook stove users as well as factor influencing adoption of improved cook stove at household and the community as a whole.

1.3 Objectives of the study

1.3.1 General objectives

The general objective of the study is to determine changes between improved cook stove and traditional cook stove in fuel-wood saving and to determine determinants adoption of improved cook stove.

1.3.2 Specific objective

The specific objectives of this study are:

1. To identify performance of improved cook stove (specifically Mirt stove) in reducing fuel-wood consumption under household kitchen condition.

2. To determine amount of carbon-dioxide emission reduced due to use of improved cook stove comparing to traditional cook stove

3. To identify factors affecting adoption of improved cook stove at household level.

1.4 Research question

What is the potential of improved cook stove in saving fuel-wood use?

What is the potential of improved cook stoves in reducing carbon-dioxide emission?

What are the factors influences the adoption of improved cook stove technologies at household level?

1.5 Significance of the study

Reduction in fuel-wood use is the most important reason for consumers to adopt an improved stove. Thus, whether based on government and donor programs or commercial marketing, there is a need to understand the changes in fuel use of a proposed new stove as well as the performance of existing in place stoves. In addition, such understanding is needed to evaluate the environmental benefits of stove introduction, particularly those related to pressure on deforestation from fuel-wood gathering and the global warming pressure from products of incomplete combustion.

The study will benefit the stove manufacturers in creating awareness on the stove standards that they need to meet during manufacture. It will also create awareness on the factors affecting their production activities, so that they may best be able to deal with these factors, in order to optimize their production.

Introducing efficient stoves has two distinct effects on GHG emissions “it reduces forest degradation, with an impact of around 0.9 tons biomass/year per households; and woody biomass acts as carbon sink amounting to 2.1 tons per year per household” (FDRE, 2011).

This study will benefit the consumers by informing them on the importance of using improved cook stoves, and the information collected will ensure their needs are better understood, which will result in increased utilization of the cook stove

2. LITERATURE REVIEW

2.1 Energy source for cooking in developing country

In developing countries, about 1.26 billion people do not have access to electricity (IEA, 2013a), and 2.8 billion people (Bailis, *et al*., 2015) rely on traditional biomass (fuel-wood, charcoal, dung and agricultural residues) for cooking mainly in rural areas. According to IEA (2016) reported in 2040, 1.8 billion people will remain reliant on traditional biomass energy as a cooking fuel, with the overwhelming majority living in Sub-Saharan Africa. In Ethiopia, the household sector consumes 90% of total solid fuels (Getnet and Bekala, 2003) and cooking accounts 99.6% of the energy consumed in the sector (Guta, 2012).

2.2 Types of energy source for household consumption

Depending on typical level of energy development, type of fuels used for cooking in households can be categorized as traditional (animal dung, agricultural residues and fuel-wood), intermediate (charcoal, briquettes, lignite, coal and kerosene) and modern (solar, LPG, biogas, natural gas, electricity) (Malla, *et al*., 2014). Based on the way these cooking energy types are produced or extracted, they are sometimes termed as primary and secondary energy. Primary energy is directly obtained from natural resources such as fuel-wood, agricultural waste, animal dung, coal, solar and natural gas. Secondary energy types, which come from transformation of primary energy types, include petroleum products (kerosene, LPG) from crude oil, ethanol from sugar cane, charcoal and biogas produced from animal dung and agricultural waste, electricity produced from combustion of fossil-fuels and from renewable energy sources such as solar, hydro and wind (Smith *et al*., 2012).

Traditional biomass energy is a local energy source, which is readily available to meet the energy needs of significant proportion of the population, particularly the poor in rural areas of the developing world. Traditional biomass energy which is low cost and does not require processing before use is usually defined as fuel-wood and charcoal, agricultural residues, and animal dung (Hall & Mao, 1994).

In Eastern and Central Africa, traditional biomass (mainly charcoal, fuel-wood and dung) energy dominates the energy supply about 60 - 90% of the total energy supply in most countries (ADB FINESSE, 2006). Ethiopia is the third largest user in the world of traditional bio fuels for household energy use, next to Chad and Eritrea, with over 90% of the population dependent on biomass (e.g. fuel-wood and dung) to meet their energy needs (Jargstorf, 2004b).

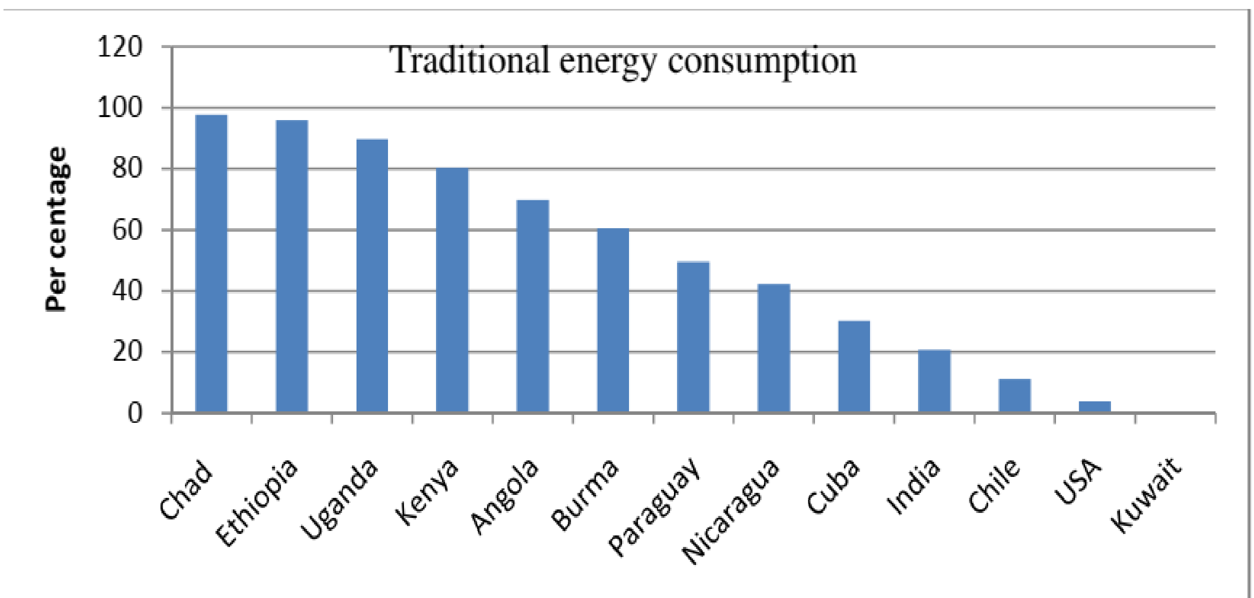

Figure 1: Shows traditional energy consumption trend

Source: NationMaster.com, 2010.

2.3 Impact of traditional biomass energy use on climate change

2.3.1. Impact on forest resource

Collection of traditional wood-fuel for cooking and heating is common throughout the tropics, and can lead to forest degradation where removals exceed re growth. Where annual harvest of wood-fuel exceeds the forest's incremental growth in biomass, it is considered to be unsustainable, and leads to a decline of woody biomass and to net carbon emissions (Bailis *et al*., 2015). Bailis *et al*., (2015) also estimated that 27–34% of wood-fuel harvest was unsustainable, particularly in East Africa and South Asia, and thus lead to significant forest degradation.

In a long-term outlook, deforestation in Ethiopia has been progressively increasing at alarming rates. According to FAO estimates the total area of natural forests in 1990 was 15.1 million hectare and was reduced within 20 years to 12.3 million hectare (FAO, 2002). Accordingly, Ethiopia has lost 140,000 hectare natural forest annually, and fuel-wood collection played an important role in the process (Feleke, 2002, Gebreegziabher, 2010).

2.3.2 Health impact

The main source of indoor air pollution on the worldwide is incomplete combustion of biomass (WHO, 2011) and in most developing countries it is burned in open that produces a lot of smoke (Akunne *et al*., 2006).

Study from Mondal *et al*., (2013), Dasgupta *et al*., (2006) show that, in rural household indoor air pollution is due to combustion of biomass fuels. However, in various developing countries wood stove emission is the main source of kitchen related indoor air pollution in many poor households.

Result from Huboyo *et al*. (2014), Arbex *et al*. (2007) also stated that, biomass is the only source which produces a lot of pollutants that are harmful for human health and also have effects on climate change.

In developing countries, women and children are exposed each day to pollution from indoor cooking smoke, in the form of small particulates, up to 20 times higher than the maximum recommended levels of the World Health Organization (WHO) and other environmental agencies around the world (WHO 2005). According to WHO and UNDP (2009), smoke from cooking fuels is estimated to account for nearly 2 million deaths, more than 99 percent of which occur in developing countries. This means that a significant percentage of the annual burden of disease is caused by cooking smoke. Because mothers and their young children are the main household members who regularly breathe such cooking smoke, they are disproportionately affected by the related health issues. Children are especially vulnerable; indeed, strong evidence supports the causal linkages between biomass combustion emissions and acute respiratory infection (ARI) among children, Smith (2000); Smith et al. Parikh et al. (2001); Kammen, Bailis, and Herzog (2002).

2.2.3 Impact on GHG emission

Until recently, cooking with biomass energy was seldom addressed by climate change practitioners since biomass was considered primarily a renewable energy source; but harvesting unsustainable levels of biomass can lead to pressure on biomass resources, with implications for the local and global environment (World Bank, 2009a).

About 730 million tons of biomass is burned every year in developing countries, (WHO 2007), amounting to more than 1 billion tons of carbon-dioxide emitted into the atmosphere.

Houghton (2012) estimated that, the average annual net emissions from harvesting of timber and wood-fuel (with the exclusion of the re-clearing of forest fallow within the shifting cultivation cycle) just 10% of the summed emissions from deforestation and degradation, with degradation emissions dominated by timber harvest with marginal emissions from wood-fuel.

At a global level, about 2 % of carbon-dioxide emission is attributed to fuel-wood combustion (Ahuja, 1990). In addition to carbon-dioxide emissions, combustion of fuel-wood and agro-residues leads to emission of products of incomplete combustion. Combustion of fuel-wood and other biomass fuels leads to carbon-dioxide emissions, as nearly 50% of wood is carbon (Pearson, et al. 2005).

2.3 Major types of cook stove in Ethiopia

Over the past one hundred years, middle and upper-income families have adopted different type of stoves, especially when access to petroleum-based fuels was a problem (Kammen 1995).

Ethiopia is a country where people practice different cooking habits, requirements and preferences. Hilawe Lakew, (1999) cited in Teshome, (2014), reviewed types of stoves in the household sub sector are categorized as Traditional, Modern and improved stoves, as follows:

2.3.1 Traditional cook stove

Traditional stoves (three stone open fires) are those that are developed and produced locally by the users themselves or local artisans (Urmee and Gyamfi 2014).

These stoves are mostly made of the local cheap materials available in the surrounding areas and are subject to modification at different times by the users themselves, as different conditions appeared with regard to their uses. For example, there are open-fire stove, enclosed stoves and traditional charcoal stoves. The open-fire Injera baking stove is the most Popular in our country due to its flexibility in construction and space utilization.

As the name indicates, three stones are used to raise the “mitad” to a height of about 12 cm from the ground (Hilawe Lakew, 1999).

2.3.2 Modern stove

Modern stoves are those developed for the utilization of modern fuels (Kerosene, Liquefied Petroleum gas and Electricity (Teshome, 2014).

2.3.3 Improved Cook Stove (ICS)

In 1970s, after the huge rise in oil prices the recent spate of improved stove programs began focusing on energy efficiency (Barnes et al. 1994). In addition to minimize reliance on biomass fuels, a desire to prevent or mitigate deforestation contributed to the growth of stove programs. With higher oil prices, increasing deforestation, and talk of an impending "fuel-wood crisis," governments, donors, and nongovernmental organizations (NGOs) started to finance and develop stove programs (Barnes et al. 1994).

Improved stoves are those that are developed through an improved stove programs taking the energy scarcity of the country into account that comes from unsustainable use of resources by the household sub sector (Teshome, 2014).

Around the globe, the task of cooking is an essential part of life for people yet in East Africa it is a task that can consume many hours of the day and have far reaching consequences on health and the environment as well as social and economic impacts (GVEP International, 2012). During the 1990s, Indoor Air Pollution (IAP) began to link smoky stoves with health issues. At that time, it was accepted that to remove smoke from the house, chimney was desirable. Thus, energy conservation and smoke removal became a popular mandate (WHO and UNDP 2009)

In Ethiopia, types of injera baking stoves are; Mirt stove, Addis (Aprovecho stove), Yekum, Gonzye, and Electrical stove, (htt://energypedia.info/wiki/list of stove in Ethiopia)

2.4. The role of improved cook stove in reducing fuel-wood consumption and its environmental benefit

The efficiency of improved cook stoves results in environmental benefit and reduces fuel-wood consumption. Existing case studies have shown that improved cook stove can reduce fuel-wood consumption by over 50% (Haider, M.N 2002)

Improved cook stove are cooking stoves that use biomass (charcoal, wood, paper or vegetable matter) and are designed to maximize thermal and fuel efficiency, operate safely and minimize emissions harmful to human health (UNEP, 2010). The global technical potential for GHG emission reductions from improved cook stove projects has been estimated as 1 Giga ton of carbon-dioxide (1 Gt CO_2) per year (Muller et al. 2011).

Improved cook stove (ICS) dissemination programs were initiated in the 1970s, encouraged by a perceived link between deforestation and household energy (Arnold et al., 2003).

According to Foundation, (2008); Kammen, (1995) improved cook stoves are a promising measure for sustainable and efficient use of fuel-wood. The use of improved cook stoves significantly reduces high levels of harmful indoor air pollution in countries dependent on fuel-wood for household energy (Rehfuess, *et al*., 2006). Reduced indoor air pollution is a major benefit of improved cook stove use and therefore deserves mention.

2.5 Development of Improved cook stove in Ethiopia

In Ethiopia, improved cook stove improved cook stoves are disseminated in 1980 by various initiatives (such as the Gaia project (Gaia Project, 2012) and a CDM project implemented by World Vision (World vision, 2013). Estimates from GIZ state that, 455,000 ICS were commercially distributed in Ethiopia until 2011to enhance efficient use of biomass resources (GIZ-ECO 2011). Moreover, the overall goal of the project is to contribute to environmental protection and sustainable environmental development.

The Ethiopian government is actively promoting the use of ICS and has announced its intention to distribute 9.4 million improved cook stoves by mid-decade. Most of these are Mirt stoves which are used primarily to bake injera, which is the main staple bread in Ethiopia (UNFCCC, 2013). The injera is traditionally prepared on a clay plate, called a mitad, with a radius of about 60 cm and a thickness up to 4 cm (Dresen et al. 2014).

2.5.1 Description of Mirt stove

Mirt stove was first developed by the Ethiopian Rural Energy Development and Promotion Centre in the early 1990s in Ethiopia (Assefa, 2007; Dawit, 2008).

Mirt stove is produced mainly from red ash (or in its absence, pumice or river sand) mixed with cement (Gashie, 2005; GTZ, 2007). It is mainly used for baking injera, a staple food for the majority of Ethiopians, which consumes large amount of firewood in the baking process (Gashie, 2005).

In Ethiopia dissemination projects state that, “Mirt” stoves have shown good acceptance for injera baking, with dissemination projects often being extended due to higher demand (Gaia project and UNFCCC, 2013). As shown on figure below (2), on top of baking injera, the chimney side of the stove can be used for cooking and boiling (e.g. wot, coffee) activities (Dresen, *et al*., 2014).

Figure 2: Shows design of Mirt stove

Source: http://www.researchgate.net

2.6 Determinant of adoption of improved cook stove

Three models, namely innovation diffusion, adoption perception and the economic constraints, are widely applied to explain the determinants and behavior of individuals when adopting a new technology/new idea (Wossink *et al*., 1997; Sarkar 1998). Innovation diffusion is access to information about an innovation to adoption decision (Wejnert 2002). According to adoption perception model, the first step is the perception of the need to adopt. Such perception is dependent on individual characteristics such as education, experience and the human values of the potential adopter (Sarker *et al*., 2008). The economic constraints model argues factors of production such as access to credit, land, labor and other critical inputs conditioned technology adoption decisions and is driven by utility maximization (Kebede *et al*., 1990; Makokha *et al*., 1999)

Barnes et al. (1994), Soini and Coe, (2014) stated that, multiple cook stove programs have failed because the stoves were not designed to be compatible with traditional cooking methods, they were too costly to purchase and maintain, and the stoves did not offer any additional benefits besides reduced fuel-wood consumption.

Adoption and dissemination of new technologies depend to a larger extent on demographic characteristics, environmental characteristics, institutional support services, nature of the technology and its benefits as perceived by the clientele, Baidu, *et al*., (1999), Nhembo, (2003), Simon (2006). Such characteristics of improved biomass technologies for cooking make adoption responses unique as they are related to the individual, some to the situation in which the individual is and some to the nature of the practice (Lionbergen & Gwin1991).

According to Duflo and Greenstone, (2008) shows, households at lower levels of income and development tend to be at the bottom of the energy ladder, using fuel that is cheap and locally available but not very clean nor efficient.

As stressed by Manyo Plange (2011) and Jan (2012), Economic determinants of fuel choice is by large the most widely covered driver of fuel choice. There are several components to economic factors which include household income; cost of equipment and fuel, and noneconomic costs such as time and access to fuels Barnes et al. (1994) and he revealed that the price of stoves can be a significant barrier to their adoption.

Ergeneman (2003) also emphasized that the incidence of rural poverty is an important determinant for the adoption of improved cook stoves. He added that it is hard to imagine a rural household which is barely meeting its subsistence needs being able to afford the whole cost of an improved cook stove.

Women's choices of fuel efficient stoves also depend upon existing environmental factors and culture and (Manyo Plange 2011). The cultural factor has particular significance because it can form the basis through which individual decisions are made. It comprises not only the local traditions specific to tribes, but also of woman's beliefs and understanding like age and education. Cultural factors play an important role in cooking fuel decision making and should not be overlooked Sri Lanka by (Wijayatunga and Attalage, 2003) as cited in (Manyo Plange 2011).

Gender can influence adoption of a technology positively or negatively depending on gender responsibilities and ownership of resources (Simon, 2006). Different gender responsibilities can be reflected in different tasks among men and women regarding energy supply and management systems or in differences in resource ownership such as livestock, houses and land. Gender had a significant influence in the adoption of stall-feeding technology in semi-arid areas of Tanzania (Kaliba et al 1997). Nhembo (2003) argues that if a technology to be adopted is expected to reduce women workload, then women may prefer to adopt it.

Karlsson (2003) suggest that because women are the primary users of energy, it is therefore important that they are involved in decision making on energy issues specifically, in designing and implementing projects to meet their needs. He identifies lack of education and technical training as an important constraint on women's participation in energy decision-making processes and in activities involving energy use. According to Karlsson, (2003) women already have valuable knowledge about local conditions and resources, additional education about energy technologies and solutions would increase their ability to contribute to energy solutions and to adopt new cleaner fuels and equipment. Women, who have learned new skills and obtained improved access to energy for households and income generating activities, can create new resources for investing in better conditions for themselves, their families and their communities.

Study from Rehfuess *et al*., (2014) identified that, high wood prices or scarce supplies of wood are also factors which increase the likelihood of stove adoption.

The other common reason for failed improved cook stove projects is lack of education and training on stove purpose and use (Jagadish, 2004).

To maximize chances of ICS being adopted, the improved cook stove should be as simple, straight forward, and convenient to use as the traditional cook stove and support local cooking and fuel use practices (Soini and Coe 2014).

2.6.1Explanatory variables and their justifications

Age: household head’s age was indicated to be significant negative factor that determines the adoption of improved cook stoves across studies reviewed Lewis and Pattanayak (2012). In contrary, results from Gebreegziabher *et al*., (2010) show that household head’s age to be positive and statistically significant determinant factor of cook stove adoption and utilization decision.

Therefore, based on the previous empirical works and with the assumption that older people may tend to be conservative in accepting new cooking technologies, in this study it was expected that age have negative significant on adoption of improved cook stove .

Sex: Adrianzén, (2009); Damte & Koch, (2011) reported that, women headed households are more likely to adopt fuel efficient new technologies as compared to male headed households.

This study also was reveal that the probability of female headed households adopting ICS has significantly higher than that of their male headed.

Education level: As result from Chambwera and Folmer, (2007) shows, education can be used as a long-term policy to shift household fuel use from traditional biomass to ICS. This study also argued that higher education level implies the larger the probability of using clean fuel sources.

Family size: Report from (Gebreegziabher *et al*., 2010; Pine *et al*., 2012) revealed that an increase in family size has a positive and significant influence on the adoption of ICS. This study also improve that large family have positive significant on adoption of ICS.

Level of income: Households at lower levels of income to be at the bottom of the energy ladder, using fuel that is cheap and locally available but not very clean nor efficient (Duflo and Greenstone, 2008). Also this study improve that income have positive significant on adoption of ICS.

Having separate kitchen: Having enough space and capacity to construct separate kitchen plays an important role in adoption of ICS (Adrianzén, 2009; Damte & Koch, 2011; Axén, 2012; Puzzolo *et al*., 2013). However, since the majority of rural households may get advantage mainly for fuel storage, to decide on free space and others in their living compound, as a result the existence of separate kitchen may provide weak support for adoption decision in rural households (Wubishet, 2009). This study improve that having separate kitchen has no impact on adoption of improved cook stove in the study area.

3. MATERIALS AND METHOD

3.1 General description of the study area

This study was conducted in Sayo woreda which is located in Kellem Wollega zone, Oromia Regional state, Western Ethiopia. Dembi-Dollo is a capital (town) of Kellem Wollega zone and situated about 652 km West of Addis Ababa. Sayo woreda is found on latitude 8°32'N and longitude 34°48'E with an elevation between 1701 and 1827 meters above sea level. The woreda has tropical climate and remains mostly hot and humid throughout the year. The average annual rainfall of the area is 700 to 1100 mm. The area is bordered by West Wollega zone to the north, Gambella regional state to the regional state to the west. The total human population of this area is 35,065 Sayo District, Bureau of Agricultural Survey Annual report, (2001).

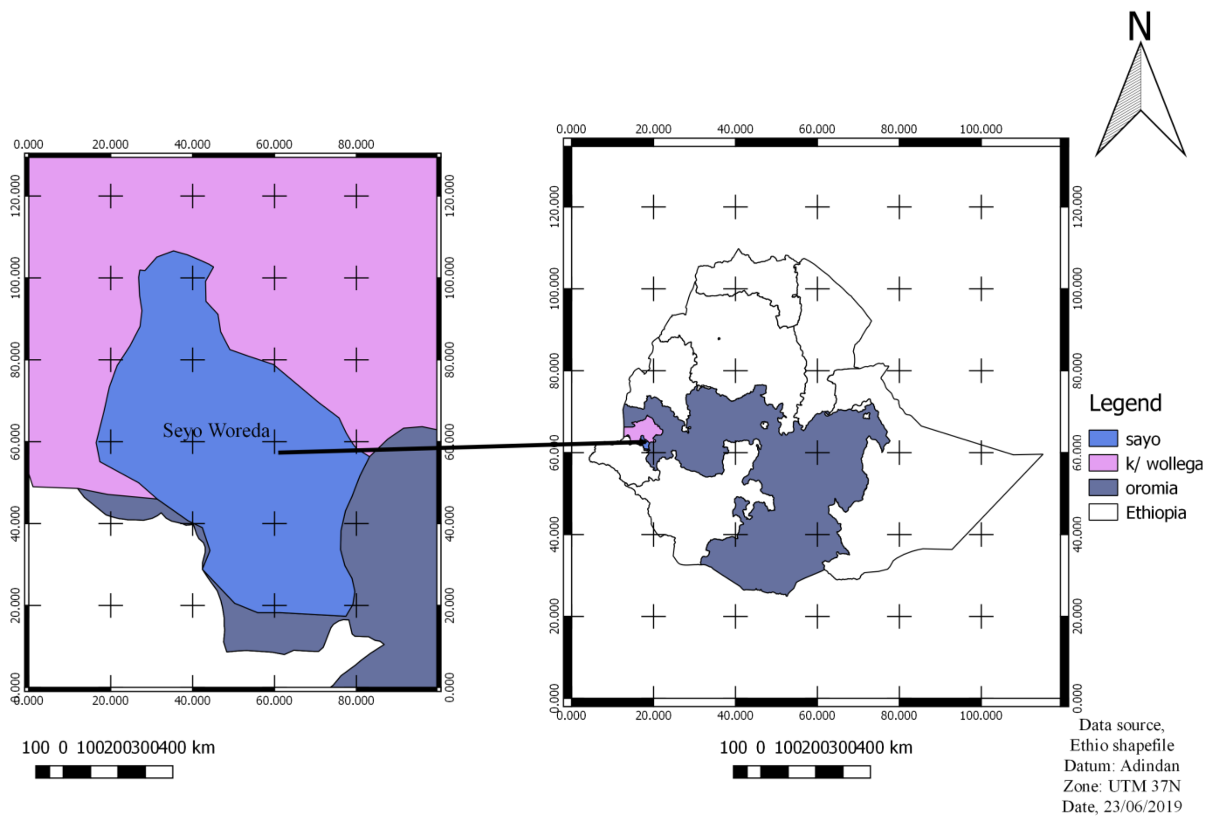

Figure 3: Shows location of Sayo woreda

3.2 Data Sources

Data for factor affecting household adoption of improved cook stove were used from primary and secondary data and household field survey were used to determine amount of fuel-wood consumed on improved cook stove and traditional cook stove, using Kitchen Performance Test (KPT) based on the Volunteer in Technical Assistance (VITA) protocol (Lillywhite, 1984; VITA, 1985)

3.3. Sample size selection and sampling procedure

Sayo woreda was selected purposively and two kebeles namely, Abba Jara and Tabor were randomly selected from five kebeles among which 298 of ICS was disseminated by non-government organization working on sustainable land management program.

Based on the general formula developed by Yamane (1967), number of household included in survey was determined.

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

Where:

n=Sample size required

N= Total population size

e = Error level

Kumar (2014) indicates that a sample size of 10% of the target population is large enough so long as it allows for reliable data analysis and allows testing for significance difference between estimates. There are 2889 households. Therefore, placing information the above formula at 93% confidence level and error limit of 7% sample size were determined in:

$$n = \frac{2889}{1+2889(0.7)2} = 191$$

Accordingly, 191 respondents were therefore were deemed to be the lowest acceptable number of responses to maintain a 93% confidence level and 7% precision of the population. Since household selected was from the similar socio-economic (based on local criteria like wealth) 7% of precision level of the population used has no effect on the accuracy of representative sample size in the study area. Therefore by using simple random sample technique 191 household heads was selected. Sample size in each kebele was determined in proportion to the number of households head in each kebele.

Household size for KPT was selected, by following Gold Standard Foundation, (2011).

Table 1: Shows sample selection for KPT

Group size of household	Sample size recommended
Less than 300	30 sample
300 up to 1000	10%
Above 1000	At least 100

Source: Golden Standard Foundation (2011)

Accordingly, by using stratified random sampling, the study was conducted with 30 households from ICS users and 35 households from TCS users.

3.4 Data collection method

Both quantitative and qualitative types of primary data collection were used. Secondary data was gathered from published and unpublished sources including books, journal articles, office reports and records, magazines, and internet which were relevant to the topic under discussion. In this study household survey, focus group discussions were also used as discussed below.

3.4.1 Household survey data collection.

From the kebeles where the ICS was disseminated, 191 house-holds were selected randomly to gather data on determinants that determine adoptions of ICS by means of a household survey.

VITA, (1985) developed three method for stove performance test; the Kitchen Performance Test (KPT), the Water Boiling Test (WBT), and the Controlled Cooking Test (CCT).

Kitchen Performance Test is done in the field, and can thus better represent stove users' actual cooking behavior where the WBT is laboratory results on stove performance which do not necessarily translate to cooking actual meals in households, and thus the accuracy of this method is frequently called into question. Meanwhile, CCT demonstrates what is possible under ideal conditions, but not necessarily what occurs under daily use (Bailis, 2004, Bailis, Smith, *et al*., 2007).

The Kitchen Performance Test (KPT) is the principal field based procedure to measure household fuel consumption. The primary objective of the KPT is to quantify fuel consumption under typical household and stove usage conditions (Bailis *et al*., 2018).

In this study KPT method was used to estimate the actual daily household cooking result and to identify problem with stove in real household condition followed (VITA, 1985).

3.4.2 Focus Group Discussion

In this study, focus group discussion which has eight members were conducted by following Bloor et al., (2001) and Finch and Lewis, (2003) whose reported that, optimum size for a focus group discussion ranges from six to eight members.

During focus group discussion information about problems and consequences of fuel-wood scarcity; barriers to adoption of improved cook stove technology, opportunities available for further dissemination of the improved cook stove technology, and also disadvantage of using improved cook stove as compared to traditional cook stove was discussed.

3.4.3 Procedure for fuel-wood consumption measurement

For implementation of KPT, Bailis *et al*., (2018) stated that, the KPT can be done by comparing fuel consumption in two or more groups of families for a period of 3–7 days, with one group using the traditional stove and the other groups using the improved stoves. This is a cross-sectional study, in which two groups of households, one using the old stove and one using the new stove, are compared at the same time.

In this study, for KPT data collection, cross-sectional approach which used to collect data of fuel-wood consumption from two separate groups of families using ICS and TCS was conducted. For each improved cook stove and traditional cook stove user group, average per capita fuel-wood consumption was compared for eight days from SAE.

Moisture content is generally in the range of 20% - 25% for dense hard woods and 15% - 20% for soft woods and low density hard woods (Richard 2007). Since stove was tested in real household condition the wood used in this test was air dried which is dried by exposure to the air out door and moisture content is 15% -20%.

To minimizing the variation in influencing factors the same fuel-wood (*Maesa lanceolata)* for both ICS and TCS was used.

Each participant household was asked to prepare enough fuel-wood which was selected for testing purpose.

On the first day of the study, the initial weight of fuel-wood for each household was weighted and they reminded to use only weighted wood, as they use weighed fuel-wood for only injera baking on mirt stove and TCS according to their selection, also they are requested as they store in dry area. Number of people that eat their meals, gender and age of each person since the last day was recorded to calculate standard adult equivalent (SAE). On days two up to eight, the remaining fuel-wood's was weighted, and if the remaining fuel-wood was not sufficient for the next day, extra fuel-wood was measured and added to the remaining fuel-wood also number of people that eat the meal was recorded for all day. All data were recorded on KPT daily data forms during the study period.

During field test, both ICS and TCS were evaluated quantitatively and qualitatively. Qualitative assessment was based interview related to factors affecting adoption of ICS and problem related with using ICS.

The results from KPT were expressed in terms of standard adult equivalent (SAE) in terms of, sex and age as the following (Table 2).

Table 2: Shows Standard adult equivalent (SAE) factors in terms of sex and age

Gender and age	Fraction of standard adult equivalent
Child:0-14 years	0.5
Female: over 14 years	0.8
Male: 15-59 years	1

Source: FAO, 2003

The amount of fuel-wood consumed per day for both ICS and traditional stove was measured by improved Balance.

3.5 Method of data analysis

The data obtained from KPT was summarized by using Microsoft office excel spreadsheet and Statistical Package for Social Studies (SPSS) version 20.

Data gathered through questionnaire was analyzed using binary logistic regression and descriptive statics

3.5.1 Estimating fuel-wood saved due to using ICS

The approach using the KPT is simply subtracts the quantity of woody biomass used by improved cook stove users from the amount of biomass used by traditional cook stove users. To determine significant different in mean per capita consumption of fuel-wood households used TCS and ICS, independent t-test were used.

The quantification of emission reductions relies on the factor fuel saved representing the quantity of woody biomass that is saved or reduced by the project activities (UNFCCC, 2012).

3.5.2 Estimating reduction of carbon-dioxide emissions from ICS

The contribution of using ICS in reducing carbon-dioxide emission was estimated based on efficiency of fuel-wood saving per standard adult equivalent of households using ICS.

Lee et al. (2013) suggested that, the use of a weighted average value of 81.6ton of carbon-dioxide per tera joule, representing emission factor of fuel-wood.

The contribution of fuel-wood conservation to reduced forest degradation and therefore fewer carbon emissions depends on the nature of fuel-wood harvest (Johnson et al. 2009; Lee et al. 2013). A key parameter is therefore the fraction of woody biomass used that can be established as non-renewable biomass (UNFCCC 2012).

The calculation was done based on clean development mechanism and United Nation's frame work of Convention on Climate Change (CDM and UNFCCC, 2013), using formula:

$$ER_y = B_y * f_{NRB,\,y} * NCV_{biomass} * EF_{fuel\text{-}wood} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where**:** ER_y = Emissions reductions during year y in ton of carbon-dioxide equivalent

B_y, = Annual fuel-wood saved per ICS in tons

$f_{NRB,y}$ = Fraction of woody biomass saved by the ICS in year y that can be established as non-renewable biomass

NCV = Net calorific value of non-renewable biomass.

$EF_{fuel\text{-}wood}$ = Emission factor for substitution of other fuel by similar users.

Table 3: Shows Default values of parameters used for calculating reduction of carbon-dioxide emission by using ICS

Parameter	Value	Source
Net caloric value of fuel-wood	0.015TJ/ton	IPCC, 2006
Emission factor of fuel-wood	81.6 tCO_2/TJ	UNFCCC, 2013
Fraction of non renewable biomass	88%	UNFCCC, 2012

3.6 Analysis of determinants of adoption of improved cook stove

Adoption in this study is dependant variable defined as willingness to accept and use of improved cook stove technology.

The qualitative dependant variable is adoption which takes 1 if household adopt improved cook stove and 0 if household not adopt improved cook stove technology.

According to Cramer, (2003), Leech *et al*., (2005), logistic regression is a probability estimation model applied when the dependent variable is binary (dummy variable) and the independent variable is in any form of measurement scale.

The binary logistic prediction equation is:

$$P_i = \frac{1}{1+e^{-z_i}} \quad \ldots\ldots\ldots\ldots \quad (3)$$

Where Pi is the probability of improved cook stove being "adopt" and Zi is odd ratio which is the probability of improved cook stove adopt or not and e is base of natural logarithm

The probability that household being adopt improved cook stove was interpreted from the odds ratio, which can be written as:

$$e^{z_i} = \frac{P_i}{1-P_i} = \frac{1+e^{z_i}}{1+e^{-z_i}} \text{ -- (4)}$$

Linear function of explanatory variable (Xi) and expressed as:

$$Zi = \beta o + \sum \beta iXi + \mu i \text{ -- (5)}$$

Where, β0 = intercept, which is the estimation of probability of adoption of improved cook stove, when X=0, βi = coefficient associated with explanatory variable, xi is independent variables, μi = error term. In this case, X1= Age, X2= Sex, X3= Education level, X4= Family size, X5= level of income, X6= separate kitchen, μi error term.

Table 4: Shows description of explanatory variables for ICS technology adoption model

Variable	Type	Description
AGE	Continuous	Age of household head in years
SEX	Binary	Sex of household head (1= male, 2= female)
LEVLEDU	Continuous	Household head's educational level in year of schooling (0=illiterate, 1=primary, 2= secondary, 3= collage and above)
FAMILY SIZE	Continuous	Total number of people in the household
LEVLINCOME	Continuous	Income of household per year in birr.
HVINGSEPKITC	Binary	Presence or absence of separate kitchen(1= presence, 0= absence)

4. RESULTS

4.1 Socio-economic characteristics of the households

Table 5: Shows Socio-economic characteristics of the respondents

Socio-economic characteristics of the respondents		Frequency	Percent	Mean	Standard deviation
Sex	Male	163	85.3		
	Female	28	14.7	1.14	0.35
Education level	Illiterate	80	41.9		
	Primary school	52	27.2		
	Secondary school	22	11.5	1.088	1.14
	Above 12 grade	37	19.4		

Source: survey data (2019)

4.2 Types and sources of energy

The most common type of energy used by households for various purposes in the study area is fuel-wood (85 %) and 15 % use both (mixing) of crop residue and fuel-wood (standard deviation = 0.358.)

The primary source of fuel-wood in the study area is forest (85 %), (12%) from their own plantation either home garden or wood lot and 3% from crop residue.

The following table shows types of fuel-wood species used in the study area

Table 6: Shows type of species fuel-wood used in the studied area

Species type	Number of household used	Percent
Vernoia amygdalina	63	33
Vernonia auriulifera	50	26.2
Maesa lanceolata	36	81.8
Eucalyptus	23	12
Croton macrostachyus	19	10
Standard deviation = 1.354		

Source: survey data (2019)

4.3 Types of stoves used in the study area

Improved cook stoves were not common in the study area prior to facilitation by the association of NGOs working on sustainable land management program (SLMP) in the study area.

Table 7: Shows types and end use of stoves

End use	Type of stove	Number of users	Percent
Baking injera	ICS	53	27.7
	Traditional enclosed	5	2.6
	TCS	133	69.6
Baking bread	TCS	186	97.4
	Traditional enclosed	5	2.6
Coffee and Tea	TCS	184	96.3
	Metal stove charcoal	7	3.7

Source: own data, (2019)

Table 8: Shows daily fuel-wood consumption of traditional and improved cook stove per capita day and annually

Stove type	Daily average per capita fuel-wood consumed	Annual average per capita fuel-wood consumed
Using the TCS	1.199 kg	437.6 kg
Using the ICS	0.686 kg	250.39 kg
Saving of per capita using ICS	0.513 kg	187.21 kg

Source: field test data (2019)

4.4 Emission reduced due to use of ICS

The result shows that improved cook stove has the potential to reduce carbon-dioxide compared to traditional open fire. Accordingly, from 0.18721 ton of fuel-wood saved, 0.86 ton carbon dioxide equivalent per capita per year was saved

4.3 Factor influencing household adoption of ICS

The result shows that, from explanatory variables taken (sex, age, family size, education level, having separate kitchen, income level and education level) three variables namely family size, education level and income level of the household were significantly influence the adoption of improved cook stove in the study area.

5. DISCUSSIONS

5.1 Fuel-wood saved due to ICS

The KPT results reported in this study showed that per capita the consumption of fuel-wood with TCS was 1.199 kg (SD = 0.218) per day per standard adult equivalent while using ICS consumed 0.686 kg (SD = 0.117) of firewood per day per standard adult equivalent for baking injera. The amount of fuel-wood saved per capita per day from using of ICS is 0.513kg per standard adult equivalent. Annually improved cook stove consume 250.39 kg and traditional improved cook stove consume 437.6 kg per standard adult equivalent per stove. This shows ICS has potential of fuel-wood saving compared to TCS. The use of ICS resulted in fuel-wood saving of 42.7% as compared to TCS for baking injera. This was equivalent to annual per capita fuel-wood saving of 187.2 kg per stove. According to, MacCarty *et al*., (2010), Hoffmann *et al*., (2015) the results of improved cook stove performance with regard to fuel-wood consumption depend on the type of stove constructed. Generally, stoves optimizing fuel efficiency are cited to use between 29% and 61% less fuel-wood than TCS (Jetter and Kariher 2009, Garland *et al*., 2015). Never the less findings of this study can be compared to test results from another studies. The result observed in this study was consistency with the result of a controlled cooking test (9 tests for ICS and 5 tests for TCS) conducted in southern Ethiopia by Dresen *et al*., (2014) where firewood savings of 40% had been reported. Also this result is line with Thakuri (2009) who estimated based on observational data, ICS use 42% less wood than traditional stoves.

The result reported in this study is also consistent with MacCarty *et al*., (2010) who conducted a WBT with a two pot rocket stove and showed that compared to TCS, the two pot rocket stove consumed approximately 45% less firewood. Also this result is comparable with Fikadu, *et al*., (2019) who reported using mirt stove save 48% in southern Ethiopia.

Also Hoffmann et al (2016) reported that using improved cook stove reduces fuel-wood by 40%. However, the result observed in this study was higher than the result of controlled cooking experiments conducted by World Food Program WFP (2013) in which reported that energy saving stoves saved between 30% - 40% of the fuel-wood. Similarly Gizachew and Tolera (2018) reported saving of 33% from KPT in Bale Eco-region of the south east Ethiopia. Such difference between controlled tests and performances under real household condition is expected (Bailis *et al*. 2007, Berrueta, *et al*. 2008). The difference can attributed to the fact that, our study conducted at different agro-ecology and type of fuel-wood used in our test was different. The different agro-ecologies have different climate and different vegetation type and consume different amount of fuel-wood (Khuman *et al*. 2011, Bunafsha *et al*. 2014). Also Johnson *et al*. (2009), Lee and Chandler (2013) sate that, different stove designs and different site conditions result in different performance figures for ICSs.

5.2 Emissions reduction in carbon-dioxide equivalent (CO_2e)

This study revealed that, using ICS has contribution in reducing carbon-dioxide compared to TCS. The average fuel-wood saving of 187.2 kg per capita per year reported in this study corresponds to 0.2 tons of carbon-dioxide equivalent per each ICS per capita per year. With the average household size (measured in SAEs) of 4.27, this could lead to an annual emission reduction of 0.86 tons of carbon-dioxide equivalent per ICS user.

In the studied area according to focus group discussion report and field observation, there is technical problem related to construction of chimney part mirt stove. Accordingly since riser part of chimney was break down all respondents reported that they did not using chimney of mirt stove. However according to Dresen et al. (2014), an additional fuel-wood saving of about 9% can be achieved from the boiling and cooking activities that can be done simultaneously with baking injera or bread.

5.3 Factors affecting adoption of improved cook stove

In this study as the binary logistic regression model revealed, having a larger family size, education level of household head and income level positively and significantly affect adoption of ICS $P < 0.05$ (Table 5).

With regard to model fitness, the variation in the adoption of improved cook stove by household or variation independent variable is explained 58.2% (R^2) by independent variables used in the model.

Probability of adoption of ICS increase with family sizes, educational level and income level of households (OR= 1.543 and 11.214, 1.002) respectively (Table 5).

This study revealed that, having larger family size is positively associated with adoption of improved cook stove, which implies the important role that could be played by the availability of family labor (number of adults in the household). This finding is line with (Balew et al. 2014), who report that, larger family might divert part of its labor into economic activities to generate additional income.

The result show that, educational level of household heads improved cook stove users are class of; 2 (1%) are from illiterate, 2 (1%) are from primary school, 14 (7.3%) are from secondary school and 35 (18.3%) are from any collage and above. In terms of non users; 78 (40.8%) are illiterate, 50 (26.2%) are primary school, 8 (4.2%) are secondary school, 2 (1%) are collage and above. This shows that, those high level of education are more adopters of ICS.

The binary logistic also showed that (Table 9), education of household heads level is significantly associated with households' decision to adopt ICS $P < 0.05$ which implies that, as level of education increase having information about new technology also increase. Hence, in this study having higher education level of households has a higher probability of using improved stoves. This is related to access to full package of information about the technologies (Beyene and Koch, 2013; Inayatullah, 2011)

In this study, household income level were found to be positively significant in determining the probability of improved cook stove adoption at $p<0.05$ (Table 9). Which means that higher income household can afford advance payment for ICS. Lewis et al (2011) suggests that high use of ICS cannot be assumed even when stoves are highly subsidized or given free of charge.

Table 9: Shows binary logistic model result (determinants of fuel efficient stove adoption)

Variables	B	S.E.	Wald	Df	Sig.	Exp(B)
Age	-.078	.041	3.541	1	.060	.925
Sex	-.066	1.443	.002	1	.964	.937
Family size	.434	.220	3.909	1	.048	1.543
Education level	2.417	.511	22.375	1	.000	11.214
Having separate kitchen	-17.56	9279.18	.000	1	.998	.000
Income level	.002	.001	14.810	1	.000	1.002
Constant	10.27	9279.186	.000	1	.999	29107
n=191 R^2= 0.582		*Log likelihood= 59.182*		*sig. 0.000*		

Source: statistical result from survey data (2019)

5.4 Limitation and opportunities to use improved cook stove

Report from focal group discussion revealed that, compared to TCS, ICS has some problem like; stoves can't be used for space heating; the stove is too heavy to carry if it needs to be transported for repair and the stoves don’t allow enough workspace for the cook and stove takes space where fuel-wood will be stored

Gill, (1985) also state that other improved cook stoves are mobile, but ICS can only be moved with assistance creating a disadvantage for users. With three-stones, women can easily move their cooking location to reduce smoke and utilize the wind for the fire.

6. CONCLUSION

This study presented results on the fuel-wood and emission reduction potential of ICS (specifically called mirt stove), and determinants of its adoption.

The prominent source of fuel in the study area is wood and the sources of fuel-wood are from forest and household own plantation either home garden or wood lots.

The findings from this study show that there is differential emission and fuel use saving performance among cook stoves. The average firewood saving of 187.2 kg per capita reported in this study corresponds to 0.2 tons of carbon-dioxide equivalent per each ICS per capita per year. With the average household size (measured in standard adult equivalent) of 4.27, this could lead to an annual emission reduction of 0.86 tons of carbon-dioxide equivalent per ICS user.

Generally, the use of ICS was found to lead to fuel-wood savings of 42.7% for injera baking in the study area.

The result of this study show that; income, education level of house-hold and family size positively and significantly influence house-holds' decision to adopt ICS.

7. RECOMMENDATION

Based on the major findings of the study, the following plausible recommendations have been forwarded:

- ✓ In order to effectively utilize the ICS in the study area, there is need to look at family size, level of income and education level of household as they determine the adoption of the ICS the area.
- ✓ The awareness campaign should be enhanced to raising the population on the benefit of ICS through existing channels of communication and capacity building and active attendance of government could extend the ICS.
- ✓ The use of ICS can be integrated in clean development strategies mainly in the studied area where biomass play major role as an energy role; hence, to increase dissemination of ICS governments and organizations which support stove projects may offer subsidies to make stoves more affordable.

8. REFERENCE

ADB FINESSE/UNDP/IEA. 2006. Sustainable Production and Consumption of Biomass for Energy in Africa. Sub-Regional Synthesis Report Easter and Central Africa

Ahuja D. R. 1990. Research needs for improving bio fuel burning cook stove technologies. Natural Resources Forum 14, 125–34

Akunne, A.F., Louis, V.R., Sanon, M., Sauerborn, R., 2006. Biomass solid fuel and acute respiratory infections: The ventilation factor. Int. J. Hyg. Environ. Health 209, 445–450.

Arbex, M.A., Martins, L.C., De Oliveire, R.C., Pereira, L.A.M., Arbex, F.F., Cancado, J.E.D., et al., 2007. Air pollution from biomass burning and asthma hospital admission in a sugarcane plantation area in Brazil. J. Epidemiol. Commun. Health 61, 395–400.

Arnold, M., Kohlin, G., Persson, R., Shepherd, G., 2003. Fuel-wood revisited: what has changed in the last decade? CIFOR Occasional Paper, 39. Bogor, Indonesia

Asres, W. G. 2002. Overview of energy status and trends in Ethiopia: Paper presented on Energy Conference.

Assefa, Y. 2007. Assessing environmental benefits of Mirt stoves with particular reference to indoor air pollution (carbon monoxide and suspended particulate matter) and energy conservation. (Msc thesis) Addis Ababa, Ethiopia: Addis Ababa University.

Axen GJ. 2012. Fuel Efficient and Efficient Aid: An Analysis of Factors Affecting the Spread of Fuel Efficient Cooking Stoves in Northern Tanzania [Bachelor's Thesis]. Stockholm (Sweden): S€odert€orn Univ.; .

Baidu-Forson, 1999. Adoption of soil and water conservation practices in the Sudan-Sahelian zone. Constrains and incentives. Agricultural Economics, 3(21), pp. 231-239.

Bailis, R. 2004. Controlled Cooking Test (CCT). CCT Version 2.0 August 2004. http://www.pciaonline.org/files/CCT_Version_2.0_0.pdf.

Bailis, R., Smith, K. R. and Edwards, R. 2007. Kitchen Performance Test (KPT). KPT Version 3.0 January 2007. http://pciaonline.org/files/KPT_Version_3.0_0.pdf

Bailis R, Drigo R, Ghilardi A and Masera O. 2015. The carbon footprint of traditional wood-fuels Nat. Clim. Change 5 266–72

Bailis, Rob et al. 2018. Kitchen performance test (KPT). ; 1-16.

Balew, S., Agwata, J., & Anyango, S. (2014). Determinants of adoption choices of climate change adapta- tion strategies in crop production by small scale farmers in some regions of Central Ethiopia. Journal of Natural Sciences Research, 4(4), 78–93.

Barnes DF., Open shaw K, Smith KR, and Plas R. 1994. What makes people cook with improved biomass stoves? A comparative international review of stove programs: World Bank technical paper No 242 energy series.

Bartz, Peter, K. & Janseen, W., 1999. Influence of Technology Characteristics on the Rate and Speed of Adoption. Agricultural Economics, 2(21), pp. 121-130

Bensch, G. & Peters, J. 2013. Alleviating Deforestation Pressures? Impacts of Improved Stove Dissemination on Charcoal Consumption in Urban Senegal. Land Economics 89, 676–698

Bensch, G. & Peters, J. 2015. The intensive margin of technology adoption, Experimental evidence on improved cooking stoves in rural Senegal. Journal of Health Economics 42, 44–63 .

Berrueta, V. M., Edwards, R. D., & Masera, O. R. 2008. Energy performance of wood- burning cook stoves in Michoacán, Mexico. Renewable Energy, 33(5), 859–870

Beyne .A, Bluffstone .R, Gebreegzbiaher .Z, Martinsson .P, Mekonnen .A, Vieider .F. 2015. Do Improved Biomass Cook stoves Reduce Fuel-wood Consumption and Carbon Emissions ?

Evidence from Rural Ethiopia Using a Randomized Treatment Trial with Electronic Monitoring. (June).

Bloor, M., Frankland, J., Thomas, M., & Robson, K. 2001. Focus groups in social research. London: SAGE Publications.

Bunafsha, M., Hable, R. Fezakov, M., Samimi, C., Abdulnazarov, A., and Koellner, T. 2014. Factors Influencing household fuel-wood consumption in the western pamirs, Takijistan. Mountain research and development 34 (2): 147-156

Chambwera, M., and H. Folmer. 2007. “Fuel Switching in Harare: An Almost Ideal Demand System Approach.” Energy Policy 35: 2538–2548.

Cooke P, K€ohlin G, Hyde WF. 2008. Fuel-wood, forests and community management e evidence from household studies. Environ Dev Econ ;13:103e35

CRGE . 2011. Ethiopia's climate-resilient green economy: Green economy strategy. Addis Ababa, Ethiopia: Federal Democratic Republic of Ethiopia.

Cramer, J. S. 2003. Logit models from economics and other fields. Cambridge: Cambridge University Press

Damte, A., & Koch, S. 2011. Clean fuel-saving technology adoption in urban Ethiopia. World renewable energy (pp. 1046–1053) (Working paper)

Dasgupta, S., Huq, M., Khaliquzzaman, M., Pandey, K., Wheeler, D., 2006. Indoor air quality for poor families: new evidence from Bangladesh. Indoor Air 16, 426–444.

Dawit, W. 2008. Fuel efficient technology adoption in Ethiopia: Evidence from im- proved “Mirt” stove technology: A case in selected kebeles from “Adea” woreda. Ethiopian Journal ofEconomics, 17(2), 77–107

Dresen, E., DeVries, B., Herold, M., Verchot, L., & Müller, R. 2014. Fuel-wood savings and carbon emission reductions by the use of improved cooking stoves in an Afromontane Forest, Ethiopia. Landarzt, 3, 1137–1157. https://doi.org/10.3390/land3031137.

Duflo E. 2008. Greenstone M. and Hanna R. Indoor air pollution, health and economic well-being, Surveys and Perspectives Integrating Environment and Society (SAPIENS). Vol. no.1,.

Egeru, A.S. 2014. Rural households‟ fuel-wood demand determinants in dry land areas of eastern Uganda. Energy sources, part B: economics, planning and policy9: 39-45.

EPAE. 2004. Third National report on the implementation of the UNCCD/NAP in Ethiopia. Environmental Protection Authority of Ethiopia (EPAE); Addis Ababa: Ethiopia.

ESPA & Practical Action East Africa. 2010. Biomass Energy use in Kenya, Nairobi: Ecosystem Services for poverty Alleviation. European

Euland, M. A. and S. Pattanayak. 2012. “Benefits and Costs of Improved Cook stoves: Assessing the Implications of Variability in Health, Forest and Climate Impacts.” PloS one, 7, e30338.

FAO 1983. Fuel-wood surveys. UN Food and Agriculture Organization.

Federal Democratic Republic of Ethiopia. 2011. Growth and transformation plan (GTP) 2010/11-2014/15. Addis Ababa: Ministry of Finance and Economic Development

Feleke, S. Forest resource utilization in Ethiopia. 2002. In Proceedings of a National Conference on Forest Resources of Ethiopia: Status, Challenges and Opportunities, Addis Ababa, Ethiopia, 27–29 November .

Fikadu,M.,Bekele, T., and Feleke, S.2019. PT US CR. Scientific African, e00064. https://doi.org/10.1016/j.sciaf.2019.e00064

Finch, H., & Lewis, J. 2003. Focus Groups. In J. Ritchie, & J. Lewis (eds.), Qualitative research practice: A guide for social science students and researchers (pp.170-198). London: SAGE Publication

Food and Agriculture Organization. 2010. Global Forest Resources Assessment 2010 Main Report

Foundation, U. N. 2008. Blueprint for Action: The West African Economic Monetary Union, Biomass Energy Regional Program. The Hub for Rural Development in West and Central Africa.

Gaia Project. Available online: http://www.gaia.fi/news/gaia news. 2012. Gaias improved cook stove project generates results in ethiopia.1261.news (accessed on 12 January 2013).

Garland Jagoe , Wasirwa , Nguyen , Roth C, Patel A, Shah N, Derby E, Mitchell J and Pennise D 2015. Impacts of household energy programs on fuel consumption in Benin, Uganda, and India Energy Sustain. Dev. 27 168–73

Gashie, W. 2005. Factors controlling households energy use: Implication for the conservation of the environment. Addis Ababa, Ethiopia: Addis Ababa University

Gebreegziabher, Mekonnen, Kassie, & Köhlin, G. 2010. Urban energy transition and technology adoption: The case ofTigray, Northern Ethiopia. Discussion paper EfD 10 (22). Washington, DC: Environment for Development (EfD) Initiative, and Resources for the Future (RFF).

Gebreegziabher, van Kooten, van Soest, D.P. 2011. Stove Adoption and Implications for Deforestation and Land Degradation: The Case of Ethiopia, Proceedings of the Ninth International Conference on the Ethiopian Economy, Addis Ababa, Ethiopia, 21–23 July

Getnet, T. and Bekala, I. 2003. Application of Model for the Analysis and Projection of Energy Demand (MAED). Technical Committee-IAE technical cooperation project RAF0016. 1-25.

Gizachew, B., & Tolera, M. 2018. Energy for Sustainable Development Adoption and kitchen performance test of improved cook stove in the. *Energy for Sustainable Development*, *45*, 186–189 https://doi.org/10.1016/j.esd.2018.07.002

Global Alliance for Clean Cook stoves. 2000. CLEAN COOKSTOVES AND FUELS: A Catalog of Carbon Offset Projects and Advisory Service Providers. (2014).

GTZ-HENRP. 2000. Project Brief, First Phase, Jan 1998-Dec2000

Guta, DD. 2012. Assessment of Biomass Fuel Resource Potential and Utilization in Ethiopia: Sourcing Strategies for Renewable Energies. International Journal of Renewable Energy Research 2 (1): 131-139.

GVEP International, 2012. The Improved Cook stove Sector in East Africa, United Kingdom: GVEP International

Haider, M. N. 2002. Success without Subsidy A Case Study of the Fuel-Efficient Smokeless Stoves Project. Changa Manga, Pakistan: United Nations Development Program.

Hall, D.O. and Mao, Y.S., 1994. Biomass and Coal in Africa. Zed Books Ltd, London.

Hilawi, Lakew 1999. A report on assessment of households cooking technologies in Ethiopia (unpublished).

Hoffmann , Uckert , Reif, M¨uller and Sieber. 2015. Traditional biomass energy consumption and the potential introduction of firewood efficient stoves: insights from western Tanzania Reg. Environ. Change 15 1191–201

Hoffmann, Harry, Tropentag. 2016. Harming own interests? Lessons learned from villagers' change of perceptions regarding innovative improved cooking stoves

Houghton RA. 2012. Carbon emissions and the drivers of deforestation and forest degradation in the tropics. Curr Opin Environ Sustain.

Huboyo, H.S., Tohno, S., Lestari, P., et al., 2014. Characteristics of indoor air pollution in rural mountainous and rural coastal communities in Indonesia. Atmos. Environ. 82, 343–350

IEA 2016 World Energy Outlook 2016 Executive Summary (Paris: IEA)

IEA, World Energy Outlook (2013) International Energy Agency, Paris http://www.worldenergyoutlook.org

Inayatullah, J. 2011. What makes people adopt improved cook stoves? Empirical evidence from rural Northwest Pakistan. The governance of clean development. Working paper series 012 – January 2011.

Intergovernmental Panel on Climate Change (IPCC). 2006. IPCC guidelines for national greenhouse ipcc-nggip.iges.o

Jan, I. What makes people adopt improved cook stove?; 2012, Empirical evidence from rural northwest Pakistan

Jargstorf, B., 2004b. Renewable Energy & Development, Deutsche Gesellschaft Technische Zusammenarbeit & Ethiopian Rural Energy Development and Promotion Centre, Addis Ababa, Ethiopia.

Jetter JJ, Kariher P. 2009. Solid-fuel household cook stoves: characterization ofperformance and emissions. Biomass Bioenergy

JohnsonM, Edwards R, Berrueta V and Masera O 2009 . New approaches to performance testing of improved cook stoves Environ. Sci. Technol. 44 368–74

Kaliba, A., Feather stone, A. & Normare, D., 1997. A stall feeding Management for improved cattle in semi arid central Tanzania. International Association of Agricultural Economics, 23(17), pp. 133-146.

Kammen, Daniel M. 1995. Cook stoves for the Developing World. Scientific American 273(1): 72–75.

Kammen, Daniel M., Robert Bailis, and Antonia V. Herzog. 2002. Clean Energy for Development and Economic Growth: Biomass and Other Renewable Energy Options To Meet Energy and Development Needs in Poor Nations. New York: United Nations Development Programme and Government of Morocco

Karlsson, G., 2003. Technical Training for women regarding energy technologies. UNDP briefing paper. Online Available at: http://www.sustainable-solutions.com/docs Accessed 29 September 2014.

Khuman Y.S., Pandey, R., Rao, K.S. 2011. Fuel-wood consumption patterns in Fakot watershed, Garhwal Himalaya, uttarakhand. Energy 36 (8): 4769-4776

Kumar, R. 2014. Importance of training in organization development. International research journal of management science and technology 5(1): 286-293

Lee, C. M. et al. (2013) 'Assessing the Climate Impacts of Cook stove Projects : Issues in Emissions

Leech, N. L., Barrett, K. C., &Morgan, G. A. 2005. SPSS for intermediate statistics: Use and interpretation (2nd ed.). Mahwah, NJ: Lawrence Erlbaum Associates, Inc

Lewis JJ, Pattanayak SK 2011. Determinants of stove adoption and fuel switching: A systematic review. Durham, NC, USA: Duke University.

Lewis, J. J., and Pattanayak, S. K. 2012. Who adopts improved fuels and cook stoves? A systematic review. Environmental health perspectives,120(5), 637-645.

Lillywhite, M. 1984. Improved Cook stoves: A Training Manual, Domestic Technology International, Inc. under subcontract to: Denver Research Institute for the US Peace Corps: http://mngunix1.marasconewton.com/peacecorps/Documents/T0040/t0040e/t0040e00.htm#Contents.

Lionbergen, H. F. & Gwin, P. H., 1991. Technology Transfer , Columbia: University of Missouri Press.

MacCarty N, Still D and Ogle D 2010. Fuel use and emissions performance of fifty cooking stoves in the laboratory and related benchmarks of performance Energy Sust. Dev. 14 161–71

Malla, Sunil, TimilsinaR, Govinda. 2014. Malla, Sunil, TimilsinaR, Govinda. 2014. Household Cooking Fuel Choice and Adoption of Improved Cookstoves in Developing Countries A Review.

Manao, David Owino, Tim Oloo and Simon Kassaina.2017. The efficiency of energy saving stove in Amboseli Ecosystem - Analysis of Time, Energy and carbon emissions saving. : 87–96.

Manyo-Plange, N.C. 2011. The changing climate of household energy: Determinants of cooking fuel choice in domestic settings in Axim, Ghana,. Accessed 24/2/2014 from www.ssrn.com/abstract=1999345.

McConnell, B. (2008). Peace Corps Volunteer, Tanzania 2003-05; The Gambia 2006 (households that depend on smoke for beneficial uses ed.).

Miftah, F., Tsegaye, B. and Sisay, F. 2017. Impact of energy consumption on indoor pollution in rural wooden house of southern Ethiopia in times of climate change. Global journal of current research 4(3): 14-26

Ministry of Water and Energy. 2013a. Energy Sector Mapping and Database Development (ESMAD).

Modi, V, McDade, S, Lallement, D, and Saghir, J. Energy and the Millennium Development Goals. Energy sector management assistance program, United Nations Development program. World Bank: New York, 2006.

Mondal, N.K., Bhaumik, R., Das, C.R., et al., 2013. Assessment of indoor pollutants generated from bio and synthetic fuels in selected villages of Burdwan, West Bengal. J. Environ. Biol. 34, 963–966

Müller, N., Spalding-Fecher, R., Bryan, S., Battye, W., Kollmuss, A., et al. 2011. Piloting Greater Use of Standardized Approaches in the Clean Development Mechanism – Phase I: Identification of Countries and Project Types Amenable to Standardized Approaches. Commissioned by the UK Department for International Development. Zurich. http://www.perspectives.cc/typo3home/groups/15/DFID/Piloting_greater_use_of_standardised_appr oaches_in_the_CDM_Phase_1_report.pdf

NEMA & GOK, 2009, Kitui District Environment Action Plan (2009-2013), Nairobi: Nema.

Nhembo, 2003. Assessment of the adoption rate of rain water harvesting technologies for crop production in Dodoma, Tanzania. A Dissertation for the award of MA (Rural Development), Morogoro: Sokoine University of Agriculture. Nyariki,

Owsianowski, J. and Philippe, B (ND). Improved cooking stoves for developing countries. www.paracod.org on 2/12/11.

Parikh J., K. Balakrishnan, V. Laxmi, and H. Biswas. 2001. "Exposure from Cooking with Biofuels: Pollution Monitoring and Analysis for Rural Tamil Nadu, India." Energy 26: 949–62

Parker, C., Keenlyside, P., Galt, H., Haupt, F. & Varns, T. 2015. Linkages between cook stoves and REDD +. 1–50

Pearson,T., S., and Brown, S.2005 source book for land use, land use change and forestry project. Win-rock international and bio carbon fund of the World bank.57pp.

Pine, K., Edwards, R., Masera, O., Schilmann, A., Marrón-Mares, A., & Riojas-Rodríguez, H. (2012). Adoption and use ofimproved biomass stoves in Rural Mexico. Energy Sustain Dev, 15,176–183

Puzzolo, E., Stanistreet, D., Pope, D., Bruce, N., & Rehfuess, E. (2013). Factors influencing the large-scale uptake by households of cleaner and more efficient household energy technologies: Systematic review Reports/WV_Fuel-efficient Cooking Stoves Report.pdf

Raman P, Murali J, Sakthivadivel D and Vigneswaran V S 2013 Performance evaluation of three types of forced draft cook stoves using fuel-wood and coconut shell Biomass Bio energy 49 333–40

Rehfuess, E., Mehta, S., & Pruss-Ustun, A. 2006. Assessing household solid fuel use: multiple implications for the Millennium Development Goals. Environmental Health Perspectives, 114(3), 373-378.

Richard Bergman, 2007. Drying and control of moisture content and dimensional changes. 1-20.

Sagar & Kartha, 2007. Bio energy and sustainable development? Ann Rev Environ Resour. ,

SDBOA. 2011. Sayo District, Bureau of Agricultural very Survey. Annual report, pp: 121-123.

Shanko, M. 2001. Ethiopia's experience. Poverty Reduction Aspects of Successful Improved Household Stoves Programs Project 7368. Final Summary Report, 62

Simon, 2006. Adoption of Rotational Woodlot Technology in Semi-arid areas of Tanzania, Morogoro. Tanzania: Sokoina University of Agriculture

Smith, K. R., J. M. Samet, I. Romieu, and N. Bruce. 2000a. "Indoor Air Pollution in Developing Countries and Acute Lower Respiratory Infections in Children." Thorax 55: 518–32.

Smith, K.R., K. Balakrishnan, C. Butler, Z. Chafe, I. Fairlie, P. Kinney, T. Kjellstrom, D. L. Mauzerall, T. McKone, A. McMichael, and M. Schneider. 2012. "Chapter 4 - Energy and Health." In Global Energy Assessment - Toward a Sustainable Future, 255-324. Cambridge

University Press, Cambridge, UK and New York, NY, USA and the International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.

Soini, E. & Coe, R. 2014. Principles for design of projects introducing improved wood-burning cooking stoves. Development in Practice. 24, 908–920 .

Thakuri, M. B. M. 2009. "Revising the Need of Improved Stoves: Estimating Health, Time and Carbon Benefits," SANDEE Working Paper No. 44-09. Kathmandu. Thomas,

Teshome, Wakene. 2014 the impact of fuel-wood saving mirt stove ; in addis ababa , ethiopia . school of social sciences the impact of fuel-wood saving mirt stove ; in the case of giz-eco : energy project in addis ababa , ethiopia ' Pr." thesis.

The Gold Standard Foundation 2011. Technologies and Practices to Displace Decentralized Thermal Energy Consumption. Geneva, The Gold Standard Foundation: 66.

UNEP, 2010. Investing in improved stoves in Haiti: Discussion paper, July 2010. United Nations Environment Program, 2010.

UNFCCC 2012b. Default Values of Fraction of Non-Renewable Biomass for Least Developed Countries and Small Island Developing States. 67th Meeting Report, Annex 22. United Nations Framework Convention on Climate Change, Executive Board of the Clean Development Mechanism, Bonn. http://cdm.unfccc.int/DNA/fNRB/index.html.

UNFCCC. 2013. http://cdm.unfccc.int/Reference/Documents (Accessed January, 2016).

Urmee T and Gyamfi S 2014 A review of improved cooks tove technologies and programs Renew. Sust. Energy Rev. 33 625–35

Urmee T and Gyamfi S 2014 A review of improved cook stove technologies and programs Renew. Sust. Energy Rev. 33 625–35

Volunteers in Technical Assistance, Inc. (VITA) 1985. Testing the efficiency of wood burning cook stoves. Arlington, Virginia: International Standards, Volunteers in Technical Assistance, Inc.

WB. World development indicators. Washington DC: World Bank; 2015.

WFP (2013) WFP Safe Project in Kenya. Controlled Cooking Test Report. World Food Programme

WHO (World Health Organization) and UNDP (United Nations Development Program). 2009. The Energy Access Situation in Developing Countries. New York: United Nations Development Program.

WHO (World Health Organization). 2005. WHO Air Quality Guidelines Global Update 2005. Copenhagen: World Health Organization.

WHO, 2006. Fuel For life: Household Energy and Health. Geneva: WHO.

WHO, 2011. Indoor Air Pollution and Health; Fact sheet 292. Wolde-Ghiorgis, W. 2002. Renewable energy for rural development in Ethiopia: The case for new energy policies and institutional reform. Energy Policy, 30, 1095–1105.

Woody Biomass Inventory and Strategic Planning Project (WBISPP). (2004), Forest Resources of Ethiopia, Addis Ababa, Ethiopia.

Wijaytunga, P. D. C., & Attalage, R. A. 2003. Analysis of household cooking energy demand and its environmental impact in Sri Lanka. Energy Conversion and Management, 43(16), 2213–2223

Wiskerke WT,DornburgV,Rubanza CD,MalimbwiR E and Faaij A P 2010. Cost/benefit analysis of biomass energy supply options for rural smallholders in the semi-arid eastern part of Shinyanga Region in Tanzania Renew. Sust. Energy Rev. 14 148–65

World Bank, 2009. World Development Indicators (WDI). WDI Online Databases. Available at http://web.worldbank.org/.

Wubishet, D 2009. FUEL EFFICIENT TECHNOLOGY ADOPTION IN ETHIOPIA : EVIDENCE FROM IMPROVED ‘ MIRT ’ STOVE TECHNOLOGY : A CASE IN SELECTED.” article (March 2009): 77–107.

Yamane, T. (1967). Statistics, an introductory analysis (2nd ed.). New York: Harper and Row

9. APPENDIX

Appendices1: Household survey questionnaire

Woreda …………………………interviewer's Name ……………………..

Kebele ……………………………Date of interview ……………………..

Code of sampled household …………interview starting time………… End time…….

Dear Respondents,

I am from Hawassa University Wando genet collage of forestry and natural resource, I am researcher and I went to ask some question regarding my finding. The main purpose of this interview questionnaire is to acquire information relevant for a research entitled "Potential of ICS in reducing fuel-wood consumption and carbon-dioxide emission". The research outcome is expected to be helpful for the identification of household traditional cook stove user consumption per day as compared to ICS and environment related interventions. Therefore, your genuine answer to the interview questionnaire is a necessary condition for the reliability of this research outputs. The information is meant only for academic purpose. The responses you give will not have a negative impact on anybody. I honestly assure you that your personal information will be kept confidentially. Hence, just feel free to provide the correct answer. Thank for your responsible cooperation in advance!!!

1. What is your position?

1. Household head ( ) 2. Spouse ( ). 3. Son ( )

4. Daughter ( ) 5. Parent ( )

2) Gender of the respondent 1. Male ( ) 2. Female ( )

3). what is your age in years? ________________

4). Marital status 1. Married ( ) 2. Single ( ) 3. Widow ( )

5).What is highest level education of household?

1. Illiterate ( ) 2. Primary ( )

3. Secondary ( ) 4. College ( ) 5. University ( )

6) What is main occupation? 1. Farming-crops ( ) 2. Livestock keeping ( )

3. Business ( ) 4. Salaried ( ) 5 Casual work ( )

6. Others (specify)…………………………………………………..

Household characteristics and Demographics

7) What is the type of this household headship?

1. Male headed ( ) 2. Female headed ( )

3. Child headed ( ) 4. Separated/Divorced ( )

8) How many members are there in this household?

9) What is the source of the household income?

Income source

1. Farming-crops ( ) 2. Livestock keeping ( )

3. Business ( ) 4. Salaried employment ( )

5. Pension ( ) 6. Other specify______________________________________

No	Income source	Monthly Income range
1		
2		
3		
4		
5		
6		
7		

10. What is Source of fuel-wood?

1. Forest ( ) 2. Crop residue ( ). 3. Others Specify______________________

No	Type of fuel	Source

12. Do you ever face fuel shortages? 1) Yes ( ) 2). No ( )

13) If yes, for which fuel types?

1. 2.

15. Have you ever heard about improved cook stove?

1) Yes ( ) 2) No ( )

16. If yes why do you have improved cook stove? 1. yes 2 no ( )

Why do you like using ICS?

1. Readily available ( ) 2. Affordable ( )

(3) Easy to use ( ) 4. No other alternative ( )

5. Others (specify)………………………………………………………………………………..

18 have you separate kitchen 1. Yes ( ) 2 no ( )

19 if yes is it have enough space for ICS 1. Yes ( ) 2. No ( )

17. Why don't you invest on improved cook stove?

1) Have no enough money

2) I don't want to invest this much money

3) I have enough fuel-wood my surrounding

4) I don’t have enough information about improved cook stove

5) Other, specify…………………………………………………………....................

…………………………………………………………………………………………..

18. Are you interested to build the ICS if you get the money in credit from credit associations?

1. Yes ( ) 2) No ( )

19. Why do you like using the traditional cook stove?

1. Readily available ( ) 2. Cheap ( )

3. Easy to use ( ) 4. No other alternative ( )

5) Others (specify) ………………………………………………..

20. Do you know of other biomass fuels? 1. Yes ( ) 2. No ( )

21. If yes, which ones?

…………………………………………………………………………………………

………………………………………………………………………………………….

22. Why don’t you currently use them?

……………………………………………………………………………………..

…………………………………………………………………………………….

23. Which types of stove you use for the following purpose?

No	Type of stove	Baking injera	Baking bread	Boiling coffee	For others (if any)
1					
2					
3					
4					

27. How do you look the price of stove?

1) Low 2) middle 3) high 4) very high

Focused Group Questions

1. What do you think about advantage & disadvantage of cooking with ICS and TCS??

2. Do you think ICS has disadvantage as compared to traditional cook stove

3. Do you think ICS have impact on traditional food preparation?

4. Do you think reduction of indoor smoke due to ICS have impact? (Like, house heating during cold condition and other)

5. Do you think sitting constant place of ICS have impact?

6. What do you think about size of ICS on enjera baking does have impact?

7. Are you looking for an alternative for the current fuel you are using?

8. What is the biggest barrier for buying an improved cook stove?

(1) High investment cost of stove

(2) Scarcity of budget

9. Why do you think people would use improved cook stoves if money weren’t an issue?

10. Why are you using more than one fuel at the same time? Why don’t you fully switch?

11. Are there any cultural reasons behind that? What foods do you always cook using charcoal, firewood?

12. Are there any enjera that cannot be baked using ICS?

13. Are people willing to switch to other biomass fuels? Reasons for No and Yes

14. Are people able to switch to other biomass fuels? Reasons for No and Yes

15. Are people willing to switch to improved stoves using same biomass fuel? Reasons for No and Yes

16. Are people able to switch to improved stoves using same biomass fuel? Reasons for No and Yes

17. Why would you be interested in ICS?

18. Which ICS are being promoted in this area? By who

19. If an alternative would arise (ICS) would we have to target women or men? Who makes the financial decisions?

20. Do you have any other comments, questions, ideas you want to add before we finish the interview?

Appendices 2: Daily KPT result

HH size of ICS users

No of Adult equivalent

No of HH	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Avg. Per capita
1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
2	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
3	5.3	5.3	4.3	3.3	3.3	3.3	3.3	2.3	3.8
4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
6	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
7	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
8	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
9	4.6	3.6	3.6	4.6	4.6	4.6	4.6	4.6	4.35
10	4.8	4.8	3.8	3.8	3.8	3.8	4.8	4.8	4 .3
11	5.6	5.6	5.6	5.6	5.6	4.6	5.6	3.6	5.25
12	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
13	5.9	5.9	3.9	3.9	3.9	3.9	5.9	5.9	4.9
14	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6
15	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
16	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
17	7.2	7.2	5.2	5.2	5.2	5.2	7.2	7.2	6.2
18	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
19	6.2	6.2	6.2	5.2	5.2	5.2	5.2	6.2	5.7
20	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1
21	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
22	4.9	4.9	3.3	3.3	3.3	3.3	4.9	4.9	4.1
23	5.9	5.9	5.9	4.3	4.3	4.3	5.9	5.9	5.3
24	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
25	5.4	5.4	3.4	3.4	3.4	3.4	3.4	3.4	3.9
26	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
27	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
28	4.8	3.8	4.8	3.8	3.8	3.8	4.8	4.8	4.3
29	4.6	4.6	4.6	4.6	2.8	2.8	4.6	4.6	4.15
30	6.9	4.9	5.9	5.9	4.9	4.9	6.9	6.9	5.9
									4.2775

Per Capita wood consumed (Kg), ICS user								**Average per capita wood consumed per SAE**
day 1	day 2	day 3	day 4	day5	day6	day 7	day 8	
0.3921569	0.5882353	0.5882353	0.3921569	0.5882353	0.5882353	0.3921569	0.5882353	0.5147059
0.4878049	0.7317073	0.4878049	0.2439024	0.4878049	0.7317073	0.4878049	0.7317073	0.5487805
0.5660377	0.3773585	0.6976744	0.9090909	0.9090909	0.6060606	0.3030303	0.8695652	0.6547386
0.3030303	0.6060606	0.3030303	0.6060606	0.6060606	0.6060606	0.6060606	0.3030303	0.4924242
0.8	0.8	1.2	0.4	0.8	0.8	1.2	0.4	0.8
0.3571429	0.7142857	0.7142857	0.3571429	0.3571429	0.7142857	0.7142857	0.3571429	0.5357143
1.0714286	0.7142857	0.7142857	0.7142857	1.0714286	0.7142857	0.7142857	0.3571429	0.7589286
0.8333333	0.5555556	0.5555556	0.8333333	0.8333333	0.5555556	0.5555556	0.5555556	0.6597222
0.8695652	1.1111111	0.8333333	0.6521739	0.8695652	0.6521739	0.4347826	0.6521739	0.7593599
0.8333333	1.0416667	0.7894737	0.7894737	0.7894737	1.0526316	0.8333333	0.8333333	0.8703399
0.7142857	0.8928571	0.8928571	0.7142857	0.7142857	0.6521739	0.8928571	0.8333333	0.788367
0.7317073	0.9756098	0.9756098	0.7317073	0.7317073	0.9756098	0.9756098	0.7317073	0.8536585
0.6779661	0.6779661	0.7692308	0.7692308	0.7692308	0.7692308	0.6779661	0.6779661	0.7235984
0.8695652	1.0869565	0.8695652	0.6521739	0.6521739	0.6521739	0.8695652	0.8695652	0.8152174
0.9615385	0.9615385	0.7692308	0.7692308	0.9615385	0.9615385	0.9615385	0.7692308	0.8894231
0.7317073	0.4878049	0.4878049	0.4878049	0.4878049	0.7317073	0.4878049	0.7317073	0.5792683
0.8333333	0.8333333	0.9615385	0.9615385	0.7692308	0.9615385	0.9722222	0.9722222	0.9081197
0.7692308	0.5128205	0.5128205	0.7692308	0.7692308	0.5128205	0.5128205	0.7692308	0.6410256
0.8064516	0.6451613	0.6451613	0.7692308	0.7692308	0.7692308	0.9615385	0.8064516	0.7715571
0.6557377	0.6557377	0.8196721	0.6557377	0.6557377	0.8196721	0.6557377	0.6557377	0.6967213
0.5263158	0.5263158	0.5263158	0.7894737	0.7894737	0.5263158	0.5263158	0.7894737	0.625
0.6122449	0.8163265	0.6060606	0.6060606	0.6060606	0.6060606	0.6122449	0.6122449	0.634663
0.6779661	0.6779661	0.8474576	0.6976744	0.6976744	0.9302326	0.5084746	0.6779661	0.7144265
0.6060606	0.3030303	0.6060606	0.6060606	0.6060606	0.3030303	0.6060606	0.6060606	0.530303
0.7407407	0.7407407	0.5882353	0.5882353	0.5882353	0.5882353	0.5882353	0.5882353	0.6263617
0.9090909	0.3030303	0.9090909	0.3030303	0.6060606	0.6060606	0.6060606	0.6060606	0.6060606
0.5555556	0.5555556	0.8333333	0.8333333	0.5555556	0.5555556	0.8333333	0.5555556	0.6597222
0.625	0.7894737	0.625	0.2631579	0.5263158	0.5263158	0.4166667	0.625	0.5496162
0.6521739	0.6521739	0.4347826	0.6521739	0.7142857	0.7142857	0.6521739	0.6521739	0.640528
0.7246377	0.6122449	1.0169492	0.6779661	0.6122449	0.8163265	0.5797101	0.7246377	0.7205896
0.6965048	0.6982303	0.7193485	0.6398319	0.6964758	0.6999704	0.6712744	0.6634149	**0.6856314**

				No. of Adult Equivalent of TCS users					
HH No	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Avg. No of SAE
1	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
2	4.1	4.1	3.1	3.1	3.1	3.1	3.1	3.1	3.35
3	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
4	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
5	5.4	5.4	2.8	2.8	2.8	2.8	2.8	5.4	3.75
6	4.6	4.6	4.6	4.6	3.6	3.6	3.6	4.6	4.25
7	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
8	3.8	3.8	3.8	3.8	3.8	2.8	2.8	2.8	3.425
9	5.6	5.6	5.6	5.6	4.6	4.6	4.6	5.6	5.25
10	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
11	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
12	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
13	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
14	5.9	5.9	5.9	3.9	3.9	3.9	3.9	5.9	4.9
15	6.4	6.4	5.4	5.4	5.4	5.4	5.4	6.4	5.775
16	5.6	5.6	5.6	3.6	3.6	3.6	3.6	5.6	4.6
17	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
18	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
19	5.4	5.4	2.8	2.8	2.8	2.8	2.8	5.4	3.775
20	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
21	4.6	3.6	4.6	4.6	3.6	3.6	4.6	4.6	4.225
22	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
23	5.4	5.4	2.8	2.8	2.8	2.8	5.4	5.4	4.1
24	5.4	5.4	5.4	4.4	5.4	4.4	4.4	5.4	5.025
25	7.1	5.1	7.1	7.1	7.1	5.1	4.1	4.1	5.85
26	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6
27	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
28	4.4	5.4	4.4	4.4	5.4	5.4	5.4	5.4	5.025
29	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
30	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
31	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
32	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4

33	3.8	4.8	4.8	2.8	4.8	4.8	4.8	4.8	4.425
34	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
35	4.9	4.9	3.3	3.3	3.3	3.3	3.3	4.9	3.9
Average	4.43429	4.40571	4.13714	3.93714	3.96571	3.85143	3.92571	4.34857	**4.12571**

Per capita fuel-wood consumed (Kg) of TCS user

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	**Avg. per capita per (SAE)**
1.11111	1.11111	1.11111	1.11111	1.11111	1.11111	1.11111	1.11111	1.11111
0.97561	0.97561	0.96774	0.96774	0.64516	1.29032	0.64516	0.96774	0.92939
1.53846	1.53846	2.30769	1.53846	1.92308	1.15385	1.53846	1.53846	1.63462
1.07143	1.07143	1.42857	1.78571	1.07143	1.07143	1.42857	1.42857	1.29464
1.2963	1.11111	1.42857	1.78571	1.42857	1.42857	1.78571	1.2963	1.44511
1.52174	0.86957	0.86957	0.86957	0.83333	0.83333	1.11111	1.52174	1.05374
1.15385	1.15385	0.96154	0.96154	1.15385	1.15385	1.15385	0.76923	1.05769
1.31579	1.31579	1.05263	1.05263	1.31579	1.07143	1.07143	1.42857	1.20301
1.42857	0.89286	1.25	1.25	1.30435	1.52174	1.52174	1.42857	1.32473
1.13636	1.36364	1.13636	1.36364	1.36364	1.13636	1.13636	1.36364	1.25
1.39535	1.16279	1.16279	1.16279	1.39535	1.16279	1.16279	1.39535	1.25
1.21212	1.51515	0.90909	1.21212	1.21212	1.51515	0.90909	1.21212	1.21212
1.21951	0.97561	0.97561	1.21951	0.97561	0.97561	0.97561	0.97561	1.03659
1.18644	1.18644	1.35593	1.28205	1.02564	1.28205	1.02564	1.18644	1.19133
1.25	1.09375	0.92593	1.11111	1.11111	1.2963	1.11111	1.25	1.14366
1.25	1.42857	1.07143	1.11111	1.11111	1.11111	1.11111	1.25	1.18056
1.35593	1.35593	1.18644	1.18644	1.35593	1.01695	1.35593	1.18644	1.25
1.42857	1.07143	1.07143	1.42857	1.42857	1.78571	0.71429	1.07143	1.25
1.48148	1.11111	1.78571	1.07143	1.42857	1.42857	1.07143	1.11111	1.31118
1.19048	0.95238	0.95238	0.95238	1.19048	0.95238	1.19048	1.19048	1.07143
1.30435	1.38889	0.86957	0.86957	1.38889	0.83333	1.08696	1.08696	1.10356
1.42857	1.42857	1.07143	1.07143	1.78571	1.07143	1.07143	1.07143	1.25
1.2963	1.11111	1.07143	1.07143	1.42857	1.07143	0.74074	0.92593	1.08962
1.2963	1.38889	1.11111	1.81818	0.92593	1.81818	0.90909	1.11111	1.29735
1.26761	1.56863	1.12676	1.26761	0.98592	1.37255	1.70732	1.70732	1.37546
1.08696	1.08696	1.30435	1.19565	1.30435	1.30435	1.30435	1.08696	1.20924
1.21951	0.73171	1.46341	1.21951	1.21951	1.21951	1.21951	0.97561	1.15854
1.59091	0.92593	1.36364	1.13636	1.2963	1.11111	0.92593	0.92593	1.15951
1.17647	1.56863	0.78431	1.37255	0.98039	1.17647	1.17647	1.17647	1.17647
1.51515	0.90909	1.21212	1.21212	1.51515	0.90909	1.21212	1.21212	1.21212
1.25	0.9375	1.40625	0.625	1.25	1.40625	0.9375	1.25	1.13281
1.59091	0.68182	1.13636	1.13636	1.59091	0.68182	1.13636	1.13636	1.13636
1.05263	1.04167	1.25	1.07143	1.35417	1.04167	1.25	1.25	1.16395
1.51515	0.90909	1.21212	1.21212	1.21212	0.90909	0.90909	1.51515	1.17424

1.42857	1.02041	0.90909	1.21212	1.21212	1.06061	1.21212	0.81633	1.10892
1.3011	1.14158	1.17721	1.19757	1.25242	1.17959	1.14086	1.19802	**1.19854**