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The Implication of Wood-Burning Stove Efficiency for Environment, Health and CO2 emissions in the Jogo-gudedo Watershed, Ethiopia

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Biomass energy is a major source of rural energy in Ethiopia. The heavy reliance on biomass energy has become a major cause of land resources degradation and a contributor to greenhouse gases (GHG) emissions. Fuel wood energy consumption can be reduced with efficient stoves. This research was conducted in the Jogo-gudedo Watershed, Ethiopia aiming to evaluate the performance of stoves and investigate the Households (HHs) biomass energy source and consumption. The HH fuel wood consumption and performances of the stoves was studied using experimental measurement, controlled cooking test (CCT), questioner survey and participatory demonstration and evaluation methods. Improved energy saving stoves (IESS) with traditional open fire furnace was tasted thrice for making identical size of Injera. The results showed that all respondents use fuel wood for cooking purpose. The remaining (99%), (95%), and (11%) of respondents were use animal dung, charcoal and crop residues respectively. Improved stove Gonziye was (51%) more efficient in fire wood consumption. The CCT results indicate that41.4gram wood per kilogram dough and 2.145 tons of CO_2 per stove per year was found to be saved by Gonziye in relation to traditional open fires furnace. This implies that the average savings of 149.4m^3fuel wood yearly for the total HHs of the watershed. Gonziye is a benevolent to reduce per capita energy consumption, time, indoor air pollution, carbon emission and have health, environmental and biodiversity conservation merits. It contributes for and inferred as best climate smart practice.

Key words: Improved Energy Saving Stove (IESS), Biomass energy, Fuel wood, Consumption, CO_2

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INTRODUCTION

Energy provides essential human services and has an implication on economic productivity and development of any country (Lofteness, 1978; Colombo, 1996; Karekezi, *et.al,* 1997).In developing countries biomass serves as exclusive energy source (Miller, 1986), and it accounts high proportion of gross national energy consumption at household sub-sector (Dunkerely, 1981). Globally biomass accounts for about 14 per cent of the world's energy supply (Habitat, 1993).In Africa, the potential of natural forest resource covers 22.2 per cent of the total land area and biomass resources are estimated at about 82 billion tones (Sokona, 1997). However, there are considerable differences in terms of spatial resource distribution that exist within the African countries. UNDP/ESMAP (1996) report stated that, in Ethiopia biomass energy accounts 101.3million toe or 42.4 percent of the total energy resource base. This infer fuel wood, crop residue, dung accounts 39.2, 7.6 and 3.2 percent of the national total energy resources respectively. According to FAO (2010), report indicates that there is acute biomass scarcity, where available supplies of fuel wood were insufficient to meet the minimum requirement. In Ethiopia more than 80 per cent of population in rural area have been dependent on woody biomass, crop residue and dung energy for centuries and there is strong cultural preference to use these energy sources. Biomass fuel demand has 2.5% average annual increment over the last two decades and the annual consumption of wood is much more than the yield in Ethiopia (Mekonnen, 2000). The annual per capita energy consumption is only 0.8 tonnes of biomass, 20 Kw of electricity and 20 liters of petroleum fuels (MoRD, 2002, (a)). Fuel wood estimated 78 per cent of the total final energy consumption in 1992/93 in the country (UNDP/ESMAP; 1996). In the developing countries like Ethiopia each year 10 million hectares of forest have removed due to fuel wood gathering. Due to this reason, fuel wood scarcity and increasing firewood cost become a common phenomenon and crop residue and animal dung are being substituted for fuel wood. This substitution reduces the availability of valuable soil nutrients and hence reduces soil fertility, contributing to slowdown in agricultural production (Bewket, 2003).Despite, traditional energy usage and cooking on open firefurnace are contributing to unnecessary high level of biomass resource extraction and consumption (Konemund, 2002; Dunkerely, 1981). Thus only 10 to 15 per cent of the gross input is received in form of useful energy (Dunkerely, 1981). Traditional open fire stove is an inefficient stove that commonly used in a large variety of domestic at the household level. Inefficient use of biomass has been linked to deforestation, indoor air pollution and decline in crop yield. Therefore, the improvements of energy use efficiency at the household level should receive major attention. Population growth, coupled with forest and woodland clearance for agriculture and the growing demand for fuel wood are the major concern for the last few decades in Ethiopia. The transformation of the energy use pattern from the traditional to modern energy saving is critical. Generation and selection of best fuel wood saving stove technologies would be basic for transformation of the energy use pattern in Ethiopia. The aim of this paper is to assess biomass energy source and consumption and evaluate energy saving stoves in the Jogo-gudedo watershed.

MATERIALS AND METHODS

Description of study area

Jogo-gudedo watershed is found in the central rift valley of Ethiopia at 8^0 33' 25'' N latitude and 39^0 12' 29'' E longitudes. It has an altitude ranging from 1644 - 2054 m.a.s.l. It is found East Shoa zone between Mojo and Nazareth town approximately 80 km away from the capital, Addis Ababa (Figure 1). The watershed has an area of 1824 ha.

The rainfall follows a bimodal pattern with short rainy season (March to April) and main rainy season (July to September). The average annual rainfall of the study watershed is around 798 mm. The watershed has 28.5C^0 and 14C^0 maximum and min annual mean temperature respectively. It has inadequate amount, poor in distribution (erratic) and intensive mainly during July and August rainfall characteristics. Runoff and soil loss are severe in the upper reach of the watershed whereas in the middle of the watershed, owing to the flatness of the area, water logging problem is occurred. The dominant soil type in the watershed is mollic Andosols followed by mollic Fluvisol with a parent material of volcanic ash and loam texture (Abera and Fitih, 2015).

Description of tasted stoves

Framers in Jogo-gudedo watershed used different type of stoves for cooking purpose. Traditional open fire furnace was the most widely used stove type. Baking *Injera* is unique home activity and traditional food for most Ethiopian. The IESS's distributed by NGOs were namely Mirt and Gonziye. IESS and the traditional open fire furnace have their own difference and made from different materials. The crop that commonly used to make *Injera* is Tef (*Eragrostistef (Zucc)* Trotter) and was used for evaluation.

Traditional open fire furnace

In most home of Ethiopian HHs the traditional open fire furnace which is fires surrounded by three-stone called "*Gulicha*" is widely and commonly used. The three stone or "*Gulicha*" used for traditional open fire furnace were built by the users and made from clay in many regions of Ethiopia (Figure 2(c)). "*Gulicha*" is affordable by any HHs, relatively it is simple to make locally and require low cost to purchase.

Gonziye and Mirte stove

GIZ and BoA developed an efficient wood burning stove called the Gonziye which called by women name and

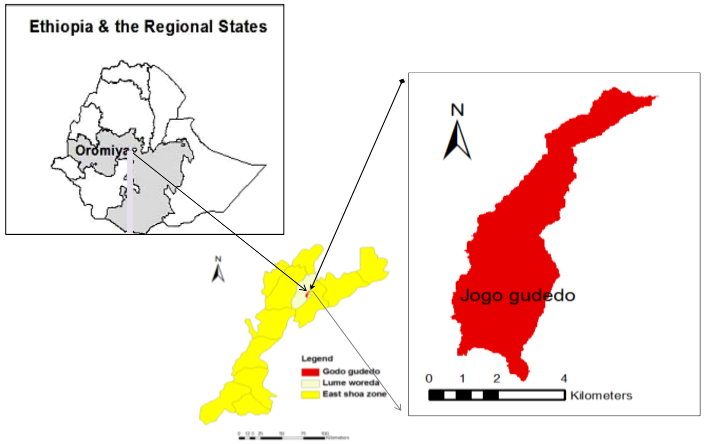

Figure 1: Location of the study watershed.

Figure 2: Types of tasted stoves are a) Mirte b) Gonziye c) traditional open fire furnace

Mirte which in the Amharic language means ‘‘the one that best’’ referring to the fact that the device ‘‘keeps’ (takes care of) users’ health, environment, and economy. Mirte and Gonziye stoves are an improved design of the *Injera* baking stoves as shown (Fig 2(a,b)). The Gonziye and Mirte stoves are built using clay and cement with sand respectively. Clay stoves are usually easy to build with simple training, and material is available locally. The external dimensions of the Gonziye and Mirte stoves were circle120cm wide diameter, with a height of 60cm and120cm wide diameter with a height of 75cm respectively. However, Mirte stove has additional function compared to Gonziye and traditional open fire furnace. This additional function of Mirte stove has extra smaller chamber with 40cm diameter designed to hold pots and traditional Kettle “*Jebena”*; used to cook “*Wot*” and boiling Coffee respectively.

METHOD OF DATA COLLECTION AND ANALYSIS

Survey

HHs head survey was carried out to collect the qualitative and quantitative information reading HH fuel-wood consumption and source. A simple random sampling technique was used to select the sample households from the watershed. The sample population were 5% of the total households of the watershed. Out of 1020 total household heads, samples of household heads were taken. The survey questionnaire included both open and close ended questions which werepre–tested by administering it to selected 10 respondents and from the pre-test, necessary modifications was made on the questionnaire and survey was implemented. The interview was also conducted by technical assistances of Melkassa Agricultural Research Centre (MARC). The survey questionnaire covered a wide range of information including household characteristics, farming system and asset endowment, landholding systems, fuel-wood consumption, demand and stove characteristics and usage.

Experimental stove performance test

The approaches were developed based on the standards to *Injera* baking test which measure the fuel wood needed and time taken to baking *Injera* under controlled conditions. RCBD was carried out with three replication and three treatments. Mirte, Gonziye and traditional open fire furnace were the treatments. Evaluation test were conducted three times and considered as a replication. Wood consumption, time to cook 10 *Injera* and rate of wood consumption of the three tested stoves was evaluated. The fuel-wood that was used for test was taken from the same species and similar moisture content and weighted in kg. Both IES stoves Gonziye and Mirte compared with traditional open fire furnace by the same person at the same time and place used dry *Eucalyptus globules* species as a fuel-wood. *Injera* baking test has three components: a test at initial time from cold start to warm start condition that is conducted to measure fuel-wood consumption and time taken to make *Injera*. The second time was the warm condition and *Injera* backing time. The third time is the thermal efficiency of the cooking stove to make *Injera* after stopping injecting the fuel-wood in to stoves. Fuel-wood and dough weight were then measured. The time from the start of ignition to removal of each *Injera* was recorded. After finishing the *Injera* baking, the remaining wood was weighed. Analysis of variance (ANOVA) was made using SAS software to test statistically significance differences ($p < 0.05$) between the treatments.

Controlled Cooking Test (CCT) evaluation

A controlled cooking test (CCT) for specific fuel consumption (SC) test was conducted three times using fuel-wood type**.** *Eucalyptusglobulus* was used as a fire-wood. The amount of dough was measured

$$SC = \frac{fd}{Wf} \times 1000 \ldots\ldots\ldots\ldots\ldots\ldots \text{Bailis, (2004)}$$

Where: SC, specific fuel consumption; W_f, the amount of dough consumed; f_d, the equivalent dry wood consumed and expressed as grams of fuel-wood used to bake 1kg of dough.

Carbon balance estimation

The performance of stoves was evaluated for total carbon saving using IPCC procedure. The calculation was based on IPCC default net calorific values, emission factors and carbon storage in forests, according to the formula

$$E = \text{fuelwood saved} \times \text{fNRB} \times \text{NCV} \times \text{EF} \ldots\ldots\ldots\ldots \text{IPCC (2006 (a))}$$

where: E, emissions; fNRB, fraction of non-renewable biomass; NCV, net calorific value; EF, default emission factor (per unit of energy).

Participatory demonstration and evaluation

To evaluate the convenience of the IESS in relation to traditional open fire stove, ten women's were selected for stove performance test in the farmer's kitchen at local condition. Participatory demonstration and evaluation was carried out to evaluate the nature, behavior, safety and suitability of the stoves. After the demonstration was accomplished discussion and interview with DAs and all women's was held. Information on stove performance, benefits, short comings of improved stove and their preferences were collected.

RESULT AND DISCUSSION

The total households living in the study watershed is 1020. Among the interviewed respondents 86% of them were women's while the remaining14%weremale households. Majority of the watershed community are illiterate 49%, read and write 44% and the remaining 7% are primary and secondary school level graduates, respectively. From the interviewed household heads, the minimum and maximum ages of the respondents were 21 and 83 respectively and the average was 43 years. The minimum and maximum household sizes were 2 and 9, with the average being 3.5, respectively. The average land holding at Jogo-gudedo watershed was 1.75ha.

Household energy source and consumption

All respondents were use fuel wood, 11% of use crop residue and 99% animal dung for food cooking while all are use Kerosene for lighting. Out of the total respondents 95% were use charcoal for coffee, tea and water boiling and cooking "*Wot*". This shows that woody biomass and non-woody biomass fuel resource is highly used for cooking purpose. Meanwhile, kerosene is the only major source of light in the area. The majority of the respondents use mixed (both woody and non-woody fuel biomass resources) for cooking. It is in line with Bewket, (2003) in Chemoga watershed and Ministry of Rural Development MoRD, (2002, b) report, in Ethiopia people are use animal dung and crop residue to substitute fuel wood. As a result of this, soil fertility declined and 1 to 1.5 million tons of grain production is lost per year in some part of Ethiopia (Shibru, 1996).From the total respondents45% of them were acquired fuel wood by collecting from their local area the remaining purchase from the market. This shows that farmers use the surround plantation forest and cut backyard trees in order to get woody biomass fuel resource. This in turn is believed to have an adverse effect on the forest cover of the area leading to land degradation and deforestation. Besides expensive or unavailable alternative fuel sources, such as kerosene or electricity, some additional biomass fuel alternatives are commonly used in the study watershed.

As indicated in table 1, the total domestic consumption of wood biomass in Jogo-gudedo watershed is 697680kg/yr and average per capita HH fuel-wood consumption was 684kg/ca/yr (equivalent to 38MJ/kg).Estimation made for 2009 show that energy consumption per capita by fuel type was 748kg or fuel wood, 7kg for charcoal, 111kg for dung, 78 kg for agricultural residues.This indicates that our finding result has no significant difference or slight deviation with the national energy consumption estimation. The total annual expense for biomass energy is 7, 140ETB. Respondents commonly indicated that trees from home gardens agro forestry systems were used as a fire wood source. The fact that governmental forests are only mentioned after home gardens may be due to a bias, since fuel collection from governmental forests is mostly illegal.

Woody and non woody fuel energy trend in the watershed

The demand for biomass fuel seems also to have been increasing with the growing demands of energy for household cooking. From the total respondents 82% of them reported that, fuel wood demand was increased in the past five years. The survey result showed us, fuel wood demand rate stands at 125kg/ca/yr in the past five years. Among sample HHs in the watershed 82% of them perceived that of that there is shortage of woody biomass fuel resource while 18% of the respondents believe that remain the same. This shows that majority of the localities believe that there is shortage of both woody and non-woody fuel biomass resources in the Jogo-gudedo watershed area.

Stoves performances

All measurements were carried out in a certain time interval with equal *Injera* baking activities. The wind condition during evaluation was moderate wind condition and equal wood size and weight distribution. The experiment was carried out with three identical "*Mitad*" which media on *Injera* is baking on that have near same weight for minimizing the error. During *Injera* baking test the result shows us Gonziye stove performed very well comparing with traditional open fire and Mirt stove had relatively consistent in the three test phases. As indicated in Table 2, the improved energy saving stoves Gonziye and Mirt stove have 51% and 27% more efficiency in fuel wood consumption than the traditional open furnaces respectively. Deginet, *et.al,* (2015) similarly reported that Gonziye and Merit stove can save more than 20% and 33% of wood biomass respectively in relation to traditional open stove.

As indicated Table-2, treatments have statistically significant difference on wood consumption. This result is not in line with Deginet, *et.al,* (2015)the absence of statistical difference (F=2.28, p= 0.1829) on the weight of wood consumed both by the three stoves. The burning rate of fuel wood under Gonziye and Mirt stove was 4.9kg/hr and 7.2kg/hr. However, Fuel-wood and energy consumption of traditional open fire was 9.9kg/hr. Traditional open fire stoves showed a considerably higher fuel-wood and energy consumption compared to Gonziye and Mirte stoves. Although, there was large variability on initial time clod warm. Three more *Injera* were baked using the remaining thermal energy of Gonziye than traditional open fire furnace. Moreover, it seems that using clay plates able to have more thermal energy and can be used very efficiently.

Specific fuel consumption (SC)

Specific fuel consumption of stoves statistically significant at 95% confidence interval (*P*=0.0001) with 30.5gm.wood/kg. dough grand mean and (SE=1.5; CV=8.54). The study is in line with Elisabeth *et.al*, (2014), CCT on specific fuel consumption of stoves statistically significant(*p*=0.042). As indicated Figure 4, the result showed that, Gonziye was performed by saving 41.4gm.wood/kg. dough than traditional open fire furnace. In this study CCT result indicate that fuel wood saving of 60% were found and it is in line with Elisabeth *et.al,* (2014) finding that fuel wood savings of 48.8% but with 11% deviation. Together, indicated that Mirt stove was better than Gonziye and it is not in line with this study, this might be due to the difference of clay material the stove made from, and variation of wall thickness and "*Mitad*" which media on *Injera* is baking on. These sources of variation need further experimental research.

Carbon balance estimation

IPCC procedure was used to calculate CO_2 emission and

Table 1: Fuel wood source and HH consumption for different activities in Jogo-gudedo watershed

Energy source	Unit	Average Weekly consumption in (2012-2015) years	Annual expenses per HH in ETB	Lists of cooking and others activities that needs different energy source
Wood biomass	Kg	57	5,700	*Injera* and Bread baking, wet cooking, water boiling, coffee and tea boiling, local alcohol ("*Areke and Tela*") preparation, heating, water boiling, coffee and tea boiling, lightening
Crop residue	(in bundle)	1	240	
Animal dung	(50kg Sack)	0.53	720	
Charcoal	(50kg Sack)	0.25	480	
Kerosene	Liter	0.25	149	
			7,289	

Table 2: Energy saving stoves performance

Performance Indicators		Stoves type Mirit	Gonziye	Traditional Open fire furnace	Statistics	
	units	Mean	Mean	Mean	(P=o.o5)	CV
Wood consumed	kg	3.43	2.2	8.6	0.0001	8.54
Time taken to bake 10 *Injera*/Baking time/	min	28	27	34	0.0702	15.25
Burning rate of fuel wood	kg/hr	7.2	4.9	9.9		
Stoves made from		Cement	Clay	Clay		
Cost incur per stove	ETB	150	60	10		
Calorific value (MJ/kg) of *Eucalyptus camaldulensis*= 29.500MJ/kg (FAO (1993))						

judge stoves performance. It is known that CO_2 emission factors varied according to the type of vegetation and burning conditions. There is also an assumption on a net calorific value of *Eucalyptus globulus*29.500MJ/kg (FAO (1993)and an emission factor of 112g of CO_2 per MJ of fuel-wood (IPCC, 2006 (b)).The results from experiment indicated that savings of 2.298tonCO_2per stove were found.

Implications of Improved Energy Saving Stoves (IESS)

Fuel-wood, vegetation diversity and environment conservation benefits

IESS could positively contribute to forest conservation. Fuel-wood biomass most of the times are mature trees, these mature trees have took several decades to reach at mature stage and host several micro and macro flora and faunas over their stems, barks, leaves and branches. Therefore, if once removed these mature trees for energy or other purposes there will be a loss of diversities hosted over them and dependent or symbiotic associated organisms. During discussion women farmers confirmed that, most often, crop residues and animal dung were not used by households independently of the presence of IESS rather users have been using wood chips, leafs and small branches. Therefore, using IESS in rural community will have positive implication on soil fertility improvement, biodiversity conservation and environmental rehabilitation.

Economic Benefits

Wood fuel consumption is particularly high in rural areas, where alternative sources of fuel are either unavailable or unaffordable for the majority of consumers. In our study, it was found that 65% of fuel-wood is purchased from the local market or from resellers for an average of 7,289 ETB per year(equivalent to approximately 339 USD) was spent. Annual expense of the HHs for woody and non woody biomass is the highest next to expense for food

Figure 3: Participants of selected women HHs during participatory evaluation and demonstration

Control Cooking Test (CCT) was performed to test specific fuel consumption stoves efficiency with nine observations.

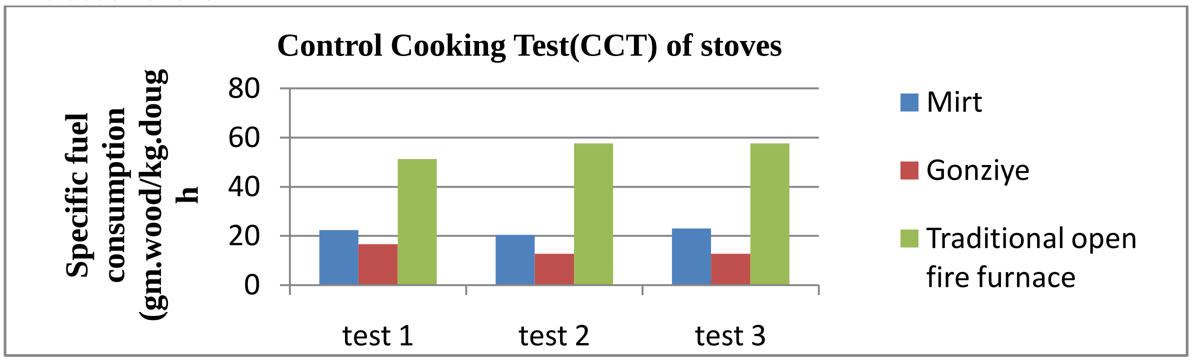

Figure 4: Control Cooking Test (CCT) specific fuel consumption stoves efficiency

(10,216 ETB) in the watershed. This shows that, monthly expenditure for fuel wood is significant and the highest share from both total and biomass fuel. Similarly, Mekonnen, (2000) reported that, households in the lower expenditure group spend higher proportion of their budget on fuels (9 to 19 per cent). The benefits of IES stove would be significant in poor rural community. IES stove users could save 3717 ETB per households over the year and just by installing energy saving stoves. In Ethiopia, the prices of a kg of fuel wood and that of charcoal increased from time to time at alarming rate (Getachew, 2002). Therefore, we suggest that local government should consider subsidizing the capital costs of these improved stoves for poor households to enable vast dissemination of IES stoves the Jogo-gudedo watershed. Out of ETB 7,289 spent for fuel biomass per month by the sample households, ETB5,700 (78.2%) was spent on fire wood. Fire wood is the dominant fuel source for *Injera* baking and identified IES stove is pertinent for this particular home activity. Similar report indicates that, In Addis Ababa has increased from US$9 to US$ 90 per tone between 1973 and 1983 and claimed up to 20% of household income (Susanne, *et al*., 2013).

Health and suitability benefits

Inefficient open fires used to cook household meal exacerbate health problems associated with indoor air pollution (Bruce *et.al,* 2000).Demonstration and evaluations of stove varieties (Mirt, Gonziye and traditional open furnace) were conducted by women's members, enabling end-users to discuss the relative advantages and disadvantages of stoves Figure-3. Selection of the best IESS was completed accordingly, Gonziye was selected over Mirt. The users often mentioned that the design of Mirt stoves is not appropriate for the separately bought clay *Mitad*. During participatory demonstration and evaluation, women participant evaluators agreed on the nature of IESS that have less smoke, minimized risk of burning, better taste of the food and reduced expenditures for fuel-wood. Therefore, the IESS avoided health effects (incidence of blindness and prevalence of respiratory symptoms and illnesses) associated with each smoke and over heat. In line with this study result, the study of Dawit, (2012) confirmed that improved cooking stoves reduced indoor air pollution and health effects. Therefore, IESS could reduce the probability of health problems encounters on women's. The potential advantages of IESS regarding reduction in indoor air pollution, decreased per capita energy consumption and various other societal welfare benefits need to popularize in the community.

Climate Greenhouse gas emission control benefits

The result showed that, IESS benefits was beyond adaptation to changing climatic circumstances, it also contribute towards mitigation or more traditional development goals such as health and food security. In Ethiopia,748kgin average of fuel-wood would be required per capita consumption and 10ha forest removed for fuel wood purpose Despite, we found that 684kg fuel wood consumption per capita at Jogo-gudedo watershed and IESS potential to reduce fuel wood consumption 40-60%. Therefore,1010 IESS dissemination to all HH families of Jogo-gudedo watershed could save approximately418,608 kg fuel wood and 2121 tons of CO_2 per year. The National Metrological Agencies (NAMSA) report showed that, the total greenhouse gas emissions is estimated to have increased to nearly $100MtCO_2$ in 2010, twice that of 1994. Per capita emission was $0.9tCO_2$ in 1994 and it stands at $1.2tCO_2$ in 2010 (NAMSA, 2007). The CO_2 trend that has been experienced so far is clear. Therefore, IES stoves dissemination to all HH families could tackle the most important driver of forest degradation in the study area and therefore constitutes a possible strategy to mitigate forest degradation for Ethiopia. IESS have an effective and efficient contribution to conserve and securing carbon storage forests.

Possible factors that affecting dissemination of IESS

Widespread use of IESS could be deterred in the rural poor community by various socio-economic, culture and policy factors. Affordability of IESS to poor farmers, lack of infrastructure, market remote villages, lack of know-how of utilization and Lack of technologies with information gap could be the possible factors that affect adoption. During demonstration and evaluation women's participant perceive that smoke preserves rafter and seeds from insect attack this could be the possible challenges on dissemination of IESS.IESS confine the fire flame not to go outside and reduced the heat that could be reaching the surrounding room area. They reflect that the fire place is a social focal point for household the place which they sit and talk. It is, therefore, the fireplace and ash also have both ritual and practical value. However, participant women's respond that the positive side effects can still increase the acceptance of IESS in their community. This implies that, stove dissemination activity was found to have a positive impact on fuel-wood savings and carbon emission reductions, accompanied by a very high stove user acceptance.

CONCLUSION AND RECOMMENDATION

Stove performance test has shown the possibility of saving energy by selecting efficient stoves for conservation of wood biomass and minimize heat losses. Fuel wood saving stoves could be produced at low cost and provide a cost-effective solution, environmental protection and improved livelihoods. Households can benefit from IESS through savings in fuel-wood expenditure and time for collecting. The Improved Gonziye stove offers clear benefits with respect to traditional open fire furnace, with an average reduction in energy consumption of 51% in households exclusively using fuel-wood. Gonziye is cost effective stove compared to Mirt and traditional open fire furnace or three stone *Injera* baking system. Alternative purposes of open fire were negligible in relation to IESS merits. Only by also considering the fuel-wood consumption efficiency, the economic advantage, health benefits and conservation advantages Gonziye stove proved most beneficial for households firewood demand. Encouraging the use of more appropriate (or energy efficient) stoves and other sources of energy that can reduce the use of dung as fuel are important options because they can improve energy efficiency and agricultural productivity, as well as improved health from reduced indoor air pollution. This study confirms that efficient cooking stoves, if they are well adapted to the local cooking habits, constitute a cost-effective and practical solution for simultaneously mitigating climate change, and conserving forests. Emphasis should be on effective mechanisms for wider dissemination and utilization of IESS as part of rural socio-economic development processes in Ethiopia. Strategies for dissemination and popularization of IESS should encompass holistic socio-cultural, economic and incentive mechanism for poor rural community. Hence, assuring sustainability of biomass fuel utilization and concurrently increasing supply of biomass resources through measures like afforestation should encompass biomass energy saving activities. Reaching rural community with IESS and other renewable energy investments (like solar, wind and mini-hydropower) are paramount essential. For this purpose, promoting and disseminating efficient improved stove technologies and awareness rising is critical. Enhancing private-government cooperation on promoting dissemination of IESS technologies and modern renewable energies would be important policy measures.

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