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Determinants of improved cookstove adoption and its benefits in Ethiopia.

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Abstract

Background

Biomass is the most dominant source of energy for both food cooking and lighting in rural parts of Ethiopia. Energy conversions are carried out in open fires using inefficient traditional stoves, results in poor quality of life due to smoking-related health outcomes, and consume a large quantity of wood. This resulted in increased costs of health and cutting trees which facilitates climate change. To change the situation, improved cooking stoves (ICS) have been introduced through youth cooperatives in the study area.

Objective

The study examined the major sources of energy for the rural households, evaluate the health and related benefits of using improved cook stove and assessing the determinants for its adoption.

Method

Data were collected from 344 households using a questionnaire in supplement with interview schedule. The collected data were analyzed using both descriptive and econometric models.

Results

The findings of the study showed that only 22.97% of the respondents adopted the ICS whereas the vast majority (67.03%) still rely on traditional stoves that are highly inefficient. The positive and significant variables in predicting the adoption of ICS were the educational level of household head (OR 1.23; CI at 95% 0.029-0.040), access to ICS (OR 5.88; CI at 95% 1.05-2.48), affordability (OR 2.31; CI at 95% 0.11-1.56) and demonstration about the stove (OR 6.74; CI at 95% 1.13-2.68). Family size (OR 0.74; CI at 95% -0.45-0.12) and Availability of firewood (OR 0.27; CI at 95% -2.00-.56) significantly and negatively affected the adoption of the ICS.

Conclusions

Low adoption levels of ICS were found in the study area. This has been triggered by socio-economic, institutional, financial, and resource endowments. Therefore, it is recommended that increasing access to improved stoves, diversifying income sources, creating awareness about ICS health benefits, climate changes, and providing reasonable prices will facilitate its adoption.

Keywords: adoption, health benefits, climate changes, energy conversion, improved cook stove

1. INTRODUCTION

Worldwide, almost 3 billion people in meeting their daily cooking and heating needs use traditional wood fuel. The majority of these people are living in developing countries including China and Sub-Saharan Africa [1]. This trend is expected to continue for several years due to the current world energy crises and poverty levels of the people living in developing countries [2]. The problem is triggered because the energy supply sector in these countries is characterized by irregular delivery of modern energy supplies joined with inefficient end-use energy conversion technologies which are resulted in indoor air pollution and serious health effects [3, 4, 5, 6]. Solid fuels burning using inefficient technologies represent unsustainable use of the wood resource. It results in aggravating deforestation in areas where wood resources are already scarce.

Renewable energy sources including sunlight, wind, rain, tides, and geothermal heat are available at a surplus level but with no technologies required to use them. Approximately 16% of global energy consumption comes from renewables: 10% is from traditional biomass, which is used mainly for heating, and 3.4% from hydroelectricity. Renewable energy sources such as small hydro, modern biomass, wind, solar, geothermal, and biofuels account for about 2.8% [7]. There has been a rapid growth in new renewables because of the increased uptake of the relevant technologies. The share of renewables in electricity is about 19%, and it is estimated that about 16% of global electricity comes from hydroelectricity and 3% from new renewable.

In Ethiopia, in the early 1970s, electric baking stoves, and wood-saving stoves have been introduced. The local named *Lakech*, *Mirt*, and *Tikikil* stoves have been introduced in the mid-1980s. Later in 2009, the national biogas program which has promoted to different parts of Ethiopia [8]. Even though these technologies have available at a different level, still the adoption rate is reported to be very low [9, 10]. In rural parts of Ethiopia, ICS adoption is around 6% in rural households as the findings evidenced [8, 11]. The national-level access to clean cooking technologies adoption is very low which resulted in the majority of households relying on using traditional cooking methods. From the total Ethiopian population, 94% remains without access to cooking services which is clean [12].

Improved cookstove programs are now seen as an integral part of reducing greenhouse gas emissions in the developing world [13] and get great attention from International

development agencies for its scaling up. Studies confirmed that end consumers give more importance to the cost aspect than environmental concerns [14]. Traditional cooking methods are harmful to human health as well as the environment, as people need to cut down trees or collect other biomass sources for fuel. However, clean stoves can solve both these environmental and health problems, as well as provide a sustainable method for cooking and heating in developing countries.

Ethiopia is a developing nation in a sub-Saharan region that suffers from vast environmental degradation, and this clean stove, technology could play a significant role in promoting sustainable change and development. However, to encourage stove adoption, it is important to determine what factors make the new technology attractive to households.

Heavy reliance on wood-based biomass and the use of inefficient wood energy conversion technologies are reported to be among the leading causes of deforestation and poor indoor air quality. In Ethiopia, most of the Rural Population uses Kerosene for lighting and firewood for cooking. These have caused many health problems because of the smoke emitted and also due to burns caused by the open flames [15].

According to the [16], over four million people die each year from indoor air pollution. Inefficient stoves also require people to cut down a lot of trees to fuelwood, which leads to deforestation, forest degradation, and, ultimately, global warming.

In Ethiopia, clean stove initiatives as one of the climate change resilience are in place. About 94% of the country's energy demand is fulfilled by wood, branches, charcoal, dung, and agricultural residues, which all produce smoke and harmful emissions when they are burned. Also, sub-Saharan Africa has the highest rates of deforestation in the world, and Ethiopia's rapidly-growing population is adding to the strain on the increasingly scarce supply of firewood [17].

Developing clear policy initiates and organizational internal donors, these problems from unclean cooking and heating, however, are preventable. Replacing traditional stoves with clean, affordable, and fuel-efficient ones would save lives and protect natural resources in developing nations, and also contribute to growing environmental protection and economic development efforts around the world. To productively promote these stoves among people in developing nations, however, the demand on the side of users should be identified and facilitate to achieve the desired outcomes.

For this, there are numerous energy options available, but not yet identified properly by focusing on how much the community are ready and willing to use such energy-saving technologies. This study, therefore, sought to find out the factors influencing the adoption of wood-saving stoves in Ethiopia. Therefore, the results obtained from this result could serve as a base for availing energy-saving technologies to reduce the dependency of households on biomass energy. Therefore, this study was done with the following specific objectives;

- Examine the major sources of energy for the rural households
- Evaluate the health and related benefits of using improved cookstove and
- Assess the determinants for the adoption of improved cook stoves

2. METHODS

Multistage sampling procedures were implemented to select the appropriate sample for the study. The study sites were selected based on the introduction of an improved cookstove through youths who are organized to produce and sell for households in the district. To have a representative sample for the study, [18] formula was used at 5% level of error.

$$n = \frac{N}{1 + N(e)^2} = \frac{2459}{1 + 2459(0.05)^2} = 344 \text{ households were randomly selected using simple}$$

random sampling techniques.

Where n is the sample size, N is the population under the study, e is the margin of error

After deciding the sampling size, the required data were collected through using both structured and unstructured questionnaires. To get a clear picture of the subject under the study, a pilot survey was carried out with the collaboration of development agents. Then, the main survey to get collect primary data was undertaken from September to November 2020.

Secondary data which is important to know the level of wood saving stoves availability, its price, and biomass consumption were obtained from district energy office reports and publications. Moreover, the focus group discussion with community members and key

informants interviews were undertaken to cross-check information obtained from different sources of data collection.

To analyze and present data collected, descriptive, and inferential and econometrics models were implemented. The STATA software version 14.2 was used to enter and process the data. Descriptive statistics including frequency distributions, percentage, standard deviation and mean analysis were used to compare attributes in the sample.

The t-test and chi-square analysis were used to compare the improved cookstove adopters and non-adopters. The logistic regression model was used to evaluate the determinants for the adoption of improved wood-saving stoves. The model outputs were assessed against its prediction power and explanation of determinants for the wood saving stove adoption decision.

As developed by [19], in using the logistic regression model, the dependent variable should be dichotomous. The dependent variable is the decision of improved wood saving stove adoption, the value of 1 is assigned for adopters and 0 for non-adopters. The mathematical model is expressed as;

$$Pi = \frac{e^{zi}}{1 + e^{zi}} \dots\dots\dots 1$$

1-Pi stands for the probability that the household adopts wood saving stoves and can be written as;

$$1 - pi = \frac{1}{1 + e^{zi}} \dots\dots\dots (2)$$

Dividing equation 1 by equation 2 and simplified forms gives

$$\frac{pi}{1 - pi} = \frac{1 + e^{zi}}{1 + e^{-zi}} = e^{zi} \dots\dots\dots (3)$$

The third equation shows the odds ratio in favor of being an adopter. It is the ratio that shows the probability that the farmers being an adopter of an improved cookstove to the probability of non-adopter.

The logistic regression model is obtained by taking the logarithm of equation (3) as presented here;

$$\ln\left(\frac{pi}{1-pi}\right) = \ln(e^{\beta_0} + \sum_{j=1}^n \beta_j X_j) = \ln(e^{z_i}) \dots \dots \dots (4)$$

Where Ln is the logarithm of the odds ratio, which is linear in both X and in the parameter. As a result, when the stochastic disturbance term u_i is included,

$$Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots \dots \dots + \beta_n X_n + u_i \dots \dots \dots (5)$$

3. RESULTS AND DISCUSSIONS

3.1. Summary for a socio-demographic profile of the respondents

Adoptions status of improved wood saving stoves

The prevalence of using ICS in the study area was found to be 22.97%. The vast majority of 77.13 did not adopt yet (Table 1). The average age of the sample households was 41.76 with a standard deviation of 0.64. The mean ages for adopters and non-adopters households were 41.72 and 41.88 years respectively. The average family size of the respondent's households was 5.72 and 6.94 respectively with statistical differences at 1% level of significance.

Table 1: Summary statistics for continuous variables of the respondents (n=344)

Variables	Total mean	sample	Std.dev	Adoption category		t-test value
				Adopters Mean	Non-adopters Mean	
Age household head	41.76		0.64	41.72	41.88	0.10
Family size	6.66		0.15	5.72	6.94	3.48***
Educational level	1.99		0.10	3.15	1.64	6.58***
Annual income	9104.46		486.4	10725.8	8621.10	1.82**
Land size	1.42		0.45	1.50	1.39	1.01
Frequency of training	1.08		0.05	1.24	1.03	1.52*

***, **, * significant at 1%, 5% and 10% respectively

The mean educational enrollment in schooling years for the adopter respondents was 3.15 and 1.64 for non-adopters. The land size owned by the adopter households was 1.5 hectares and 1.39 for non-adopters respectively. The participation of households in training related to the use of ICS shows 1.24 days for adopters and 1.03 days for non-adopters.

From the total sample households interviewed, 35% were female-headed and the remaining 65% were male-headed. The statically significant differences were found between ICS adopters and non-adopters in their access to firewood at 1% level of significance. In the same manner participation in off-farm income activity, access to ICS, and awareness campaign about its importance were found to be significant influences over the adoption of the improved wood saving stove.

Table 2: Summary statistics for dummy variables of the respondents

Variables	Category	Total sample	Adopters	Non-adopters	Chi2 test
Adoption of ICS		344	79	265	
Sex of the household	Male	224	61	163	6.6**
	Female	120	18	102	
Access to firewood	yes	207	23	184	41.28***
Off-farm income	yes	167	49	118	7.45***
Access to ICS	yes	114	59	55	79.88***
Demonstration	yes	157	65	92	55.48***
Affordability	yes	122	48	74	28.66***

***, **, * significant at 1%, 5% and 10% respectively

3.2. Sources of energy to cook by the households

Figure 2 presents the major energy sources for respondent households. The survey result shows that vast majority of 76.1% of the respondents gets their energy requirements for cooking purpose from firewood. Only 3.9% access energy from clean energy sources of electricity.

Figure 1: Major sources of energy for respondent's household for cooking

The remaining 18.3% and 1.7% full filled their energy requirement from crop residue and charcoal respectively.

3.3. Importance of adopting ICS

The adoption of ICS has multiple importance (Figure 3). The use of ICS reduces the consumption of firewood. A traditional wood stove is inefficient and consumes a lot of firewood. The household survey result shows that the use of ICS reduces firewood consumption by about half. The focused group discussion also confirms the reduced use of firewood. In the study area, women are responsible members of the household who are expected to cook food. The adoption of ICS reduces the workload and improves the quality of life. The traditional cooking stoves produce a lot of smoke which results in respiratory diseases [20]. The households also reported that the adoption of improved cook stoves improved their lifestyles, and reduces health costs. The key informants interview and focused group discussion results confirmed that, previously the community uses open fire system. The use of traditional cooking stoves produces high level smokes which results in respiratory track diseases and eye diseases. Due to the adoption of ICS brought a significant improvements over the health situation of women.

The study has also shown that after the adoption of ICS, men have also started to participate in cooking activities which were initially the only responsibility of women. This could result in gender equality and women have leisure time to take part in social activities. Those households who reside in semi-urban areas are also in shortage of firewood [21]. Hence,

households are expected to purchase firewood from the market. The adoption of ICS has reduced the use of firewood and its cost of acquisition.

Figure 2: Importance of adopting ICS

3.4. Determinants for the adoption of improved wood saving stoves

To examine the determinants for the adoption of improved wood cooking-saving stoves, a logistic regression model was used. Before running the data into the model, its fitness was checked. The Likelihood ratio value of 164.73 shows that the model is well fitted to the data at 1% level of significance. The prevalence of adoption of improved wood-saving stoves was found 22.97% which is very low. The positive and significant variables in predicting the adoption of ICS were the educational level of household head (OR 1.23; CI at 95% 0.029-0.040), access to the improved stove (OR 5.88; CI at 95% 1.05-2.48), affordability (OR 2.31; CI at 95% 0.11-1.56) and demonstration about the stove (OR 6.74; CI at 95% 1.13-2.68). Family size (OR 0.74; CI at 95% -0.45-0.12) and Availability of firewood (OR 0.27; CI at 95% -2.00-.56) significantly and negatively affected the adoption of the ICS.

Table 3: Determinants of adoption of improved wood saving stoves (n=344)

Adoption of cooking stove	Coef.	Odds ratio	Z	P>z	CI at 95%
Constant	-3.53	0.029	-3.76	0.000	[-5.382-1.69]
Age household head	0.02	1.023	1.56	0.118	[-0.005-0.052]

Family size	-0.28***	0.748	-3.48	0.000	[-0.4521-0.126]
Educational level	0.21**	1.239	2.27	0.023	[.029-.0400]
Sex of household head	0.68	1.976	1.60	0.109	[-0.151-1.514]
Annual income	0.02	1.00	0.97	0.333	[-0.021-0.064]
Land size	0.03	1.036	0.17	0.861	[-0.368-0.440]
Availability of firewood	-1.28***	0.276	-3.48	0.001	[-2.00--0.561]
Training frequency	0.15	1.166	0.99	0.323	[-0.151-0.459]
Off farm activity	0.04	1.049	0.13	0.900	[-0.701-0.796]
Access to stove	1.77***	5.88	4.86	0.000	[1.057-2.487]
Affordability of wood saving stove	0.84**	2.316	2.26	0.024	[0.113-1.56]
Demonstration	1.90***	6.749	4.81	0.000	[1.131-2.687]
Number of observations = 344 LR chi2(12)= 164.73 P-value= 0.000***					

***, ** significant at 1% and 5% respectively

Discussion

The study evaluated the magnitude and determinants for the adoption of an improved cookstove among randomly selected 344 respondents from Ethiopia. The prevalence of using ICS stove was 22.97%. Findings of the study have a direct relationship between the wastage energy which results due to the use of traditional cooking stoves with lower efficiency. It is also lower as compared with studies conducted in 2015 in Ethiopia with a prevalence rate of 75% [22]. But found higher as compared with study finding of [23]. These differences in the adoption of ICS among different parts of Ethiopia might be due to geographic disparity, income sources, and availability of energy at a cheap price. It is believed that the use of improved stoves can help to create a healthy community and reduce wastage of energy [24].

The low level of ICS adoption urges development partners to take into account how to improve and facilitate its adoption. This is because the use of ICS improves the health of the community and reducing the cutting of trees for firewood which in turn implies climate change.

The educational level of household heads: In most adoption studies, education was found to be the main tool in facilitating the technology uptakes. The odds in favor of adopting an improved wood-saving stove increased by a factor of 1.46 units as the educational status (OR 1.29; CI at 95% 0.21-0.55) of household heads increased by 1 schooling years. As it is expected that educated household heads are more informed about the new technologies and

are more likely able to process information. In addition, educated households are more likely to evaluate the effects of using traditional cooking stoves in deteriorating health. The finding is in line with [23].

Family size: The result of the study shows that family size negatively and significantly influences the adoption of ICS. This could be due to that as a family size increases, there is adequate labor to collect firewood. In the study, the link between accesses to firewood has a negative influence on the adoption of ICS. Therefore, the existence of family labor in surplus resulted in not adopting ICS. The odds in favor of adopting ICS decreases by the factor of 0.74 units as family size increases by one person.

Availability of firewood: Based on the findings of the study, easy and adequate availability of firewood reduces the adoption of ICS in the study area. The households responded that as there is adequate firewood in the surrounding, purchasing the improved is not necessarily. They further noted that, in a situation, purchasing an improved stove is considered a wastage of money. The odds in favor of adopting ICS reduces by the factor of 0.27 as there is adequate firewood. The result forced the stakeholders involved in the system to create awareness that using ICS has multiple benefits.

Access to ICS: Availability of technologies at right time and place could facilitate its uptake. The results of the study show that access to ICS positively and significantly affects its adoption. The odds in favor of adopting improved wood-saving stoves increased by 5.88 units as they are accessible at the right place and time. The possible reason for this is that households can have better information about the importance of the technology and can easily get it.

Affordability of improved saving stove: The actual and perceived price of the technology could have remarkable influences on its use. In the study area, there is a shortage of cash and households are highly sensitive to the price of technologies. The odds in favor of adopting the ICS increased by a factor of 2.31 as if the price is perceived affordable (OR 2.31; CI at 95% 0.11-1.56). The previous study also supports that the perceived price as affordable of the technologies facilitates the adoption [24, 25].

Demonstration about improved stove: Demonstration about the method of use and importance of technology creates possible facilitative roles in initiating and its uptake. In the

study area, those youths who are organized to produce and supply ICS in the vicinity promote their product through the direct display to users. The findings of the study confirmed that the odds in favor of adopting ICS increase by the factor of 6.74 as the awareness about the technology is created at a 1% level of significance. This could be due that the demonstration helps the households to get firsthand information. The previous findings that have been carried out in Southern Ethiopia by [24] also confirmed that promotion to potential users facilitates the adoption of an improved cooking stove.

Conclusions

The adoption of improved wood-saving stoves in the study area was found to be very low. For these several demographic, economic, institutional, technology-related, and resource endowments. To facilitate the adoption of improved cookstoves, the extension offices, energy supply planners, development partners, and policymakers need to devise possible mechanisms to facilitate the adoption of ICS to improve health at the household and community level. Moreover, creating awareness about the use of ICS in protecting the environment through reducing cutting trees which in turn enable to protect a climate change is a prominent action.

Abbreviations

ICS: Improved cooking stove; OR odds ratio

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Authors' contributions

ZG developed the research proposal, prepared tools for data collection, reviewed the documents, and analyzed and prepared the report. SK supervised the data collected, entered and cleaned the data, comments on the final outputs. AA analyzed the data and corrected the draft article prepared by ZG. MM worked on literature review and proposing a methodologies used in the manuscript.

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Availability of data and materials

The data that support the findings of this study are available from the corresponding author on reasonable request and with permission of the “Integrated Landscape Management to Enhance Food Security and Ecosystem Resilience project” in Ethiopia

Approval and consent to participate

Not applicable

Competing interests

The authors declare that they have no competing interests.

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