Original Research Article

Factors Affecting Adoption of Harari Fuel-Efficient Stoves among Rural Households in Dire Dawa Administration, Ethiopia

ABSTRACT

Developing countries attempt different programs and projects to promote and disseminate improved cookstoves with health, economic, and environmental benefits. It is also important to understand factors affecting people's decisions to adopt fuel-efficient cookstoves. This study aimed to investigate factors affecting the adoption of Harari fuel-efficient stoves among rural households in Dire Dawa Administration Ethiopia. The study used a mixed approach of both quantitative and qualitative research methods to achieve objectives. The data were collected from 152 sample households randomly selected from the study area (55=adopters and 97=non-adopters) from four rural kebeles (villages). The collected data through household surveys was analyzed by descriptive statistics, independent sample t-test, one sample t-test, and binary logistic regression using Stata 16SE software. One sample t-test result revealed that residents do have a positive attitude toward the benefits of fuel-efficient stoves with statistical significance at P< 0.001 probability. The logistic regression results revealed that access to extension, awareness of fuel-efficient stoves, kitchen service, and education households were found to be significant in determining the probability of fuel-efficient stove adoption positively at P< 0.05 level of significance. The main barrier to the adoption of the Harari fuel-efficient cookstove was found to be a lack of awareness about the benefits of the stove and the size of the household kitchen. In the study area, there was a low adoption rate of the Harari fuel-efficient cookstove. This is due to a variety of factors, including culture, socioeconomic, institutional, financial, and resource endowments. Thus, policymakers should prioritize the variables indicated above to encourage the adoption of Harari fuel-efficient stoves.

Keywords: Adoption, Harari Fuel-efficient stove, binary logistic regression

1. INTRODUCTION

The primary energy source in rural areas of developing countries is fuelwood, as it is well known, and other materials are charcoal, and crop residues and animal dung are also regularly utilized as well with traditional and inefficient stove technologies (Klasen *et al*., 2013).The most common way to cook food, and boil water is by traditional open fire constructed of three stones (World Bank, 2011). Additionally, biomass is the primary fuel in sub-Saharan Africa's impoverished rural areas, where cooking is typically done over a three-stone fire.

Countries in Sub-Saharan Africa usually depend on fuelwood as one of their primary energy sources which is harvested from nearby forests and used for domestic energy (UNVVD/NAP, 2004). Since the beginning of human history, the ancient cocking method has been adopted for food preparation. These methods are still used up to now and are the most

popular type of stove in developing countries (Mamuye *et al.,* 2017). Traditional cookstoves create a lot of smoke, which has a bad influence on human health and increases deforestation exacerbating the effects of climate change, which result in floods and droughts, in turn affecting production of the crops and livestock (Puzzolo *et al.*, 2013). If actions are not taken to decrease the heavy reliance on fuel wood, it is predicted that by 2030, 652 million people will be dependent on biomass for energy (IEA, 2010).

In Ethiopia, clean stove initiatives are one of the climate change resilience are in place (EPACC, 2011). Around 95% of Ethiopia's energy sources in both rural and urban locations depend on traditional solid fuels (Zenahbezu, 2017). The rapid destruction of the forest's natural resources results in a wood shortage in the area. The original 65% of the total forest coverage of the country was reduced to 2.2% in 2000 with the current deforestation rate of 80,000 to 200,000 hectares per annul Tsegaye (2019). The major reasons for deforestation are the clearing of forests and woodlands for cultivating crops and livestock production, and the cutting of trees and shrubs for various purposes, notably for fuel wood, charcoal, construction materials, *etc*. However, in Ethiopia, more than 140,000 hectares of forests are lost per year mainly for firewood (FAO, 2010).

Currently, traditional cook stove methods with wood fuel are used very inefficiently in rural areas of developing countries. More fuel is lost compared to improved cooking stoves, and these activities are the main sources of interior and outdoor pollution (Zenebe, 2007)**.** Numerous attempts have been made to create and implement more fuel-efficient cookstoves in developing nations due to low cooking efficiency and an increasing fuelwood scarcityin households (Puzzolo *et al*., 2013). The Ethiopian government has taken several steps to promote and disseminate the adoption of environmentally friendly technologies for household energy requirements, including better *injera* baking stoves for rural areas. However, this technology at the required level has not been widely adopted in Ethiopia's rural areas, due to the various factors influencing improved cook stove adoption decisions at the household level (Damte & Koch, 2011).

More thorough research can thus help us know and better understand which factors are most important in assuring adoption and continuing use (Puzzolo *et al*., 2013). It is related to the factors influencing the introduction of improved cook stoves. Furthermore, most adoption of previous studies in Ethiopia focuses on a particular '*Mriti*' fuel-efficient stove type. However, this researcher recommends further study to be conducted to investigate factors affecting "*Harari*" fuel-efficient stove adoption using important variables.

Adoption of any technology in the household of rural areas as a general and improved fuel efficiency stove technology, in particular, depends on various factors and varies from place to place. Numerous studies have shown that using fuel-efficient stoves lowers smoke emissions and improves human health conditions in the study area (Sarkar *et al*., 2006; GIZ ECO, 2014). In the assessment of the fuel-efficient stove in DFAP (Development Food Assistance Program) implementation areas in the rural Dire Dawa Administrationand East Hararghe, the household interviewee assured that a fuel-efficient stove is better than a three-stone open-fire stove in reducing the amount of smoke and reducing risk burring and saving fuel consumption (CRS, 2016). On the other hand, it is clear that the adoption rate is not in line with expectations and is gradually declining throughout the years in this area.

The fact that the adoption of fuel-efficient stoves is low, regardless of the benefits they offer, implies the need to study how people in the area perceive fuel-efficient stoves and the factors affecting the adoption of fuel-efficient stoves. Therefore, this study investigated factors affecting the adoption of Harari fuel-efficient stoves in rural households of the Dire Dawa Administration.

To this end, this study may contribute to filling this gap by identifying factors influencing the adoption of improved cook stoves in rural households in the study area.

2. MATERIAL AND METHODS

2.1 Selection and Description of the Study Area

The study was carried out in Dire Dawa Administration (DDA) which is geographically located between 10° 0`0'' N and 42°10'0'' E longitude and found in the eastern part of Ethiopia 515 km away from the capital Addis Ababa.The topography of the administration varies from very high steep mountains to flat plains where altitude ranges from 950-2260 masl. Agriculture (both crop and livestock production) is the mainstay of the economy in the study area. Subsistence mixed farming constitutes 93% of the total farm households in the study area.

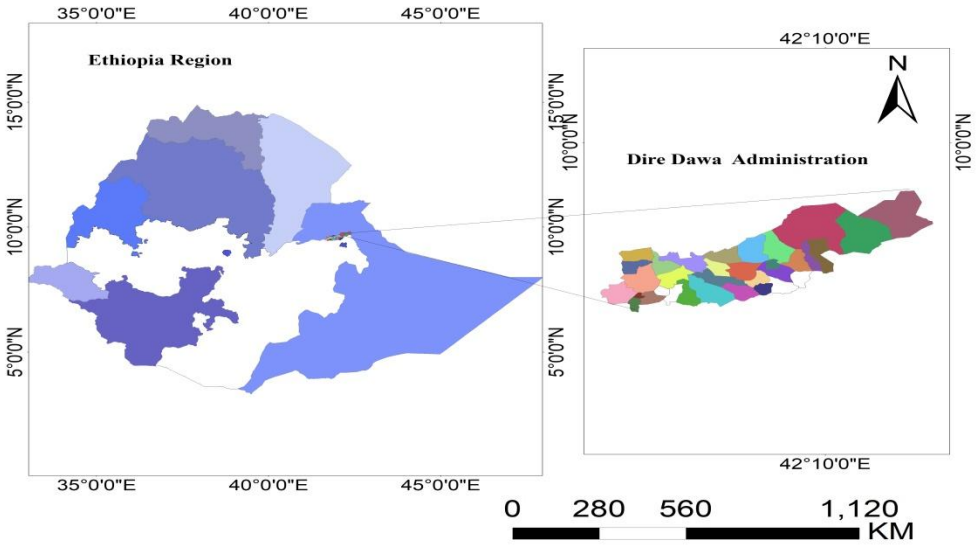

Fig. 1 Study area Map

The total population of Dire Dawa was estimated to be 342,827 out of which 253,692 live in urban while the rest 89,135 live in rural areas (FDREPCC, 2008).
About 13.47% of the total area of the administration is cultivable land; whereas 2.22% and 84.31% of the total area is urban land and non-cultivated land, respectively. The administration is characterized by relatively the annual temperature and rainfall ranging between 24.8°c and 31.4°c, and 500-850 mm, respectively. The natural forest has been cleared to satisfy the demands of the ever-increasing population. The remaining high forests cover less than 1% while the majority of the landmass is covered with shrub lands.

2.2 Description of Stove in the Study Area

2.2.1 Harari stove

Similar to other fuel-efficient stoves, *Harari* stoves are produced from sand and cement mixture using mortar. It is designed to accommodate ate *injera* backing plate and cooking or boiling pot. However, the size of the stove is small compared to *Classic* and *Mirt* stoves. The *Harari-type* stove has dimensions of 40cm in diameter, 21cm in height, and 2cm in thickness. Fuel and air inlet and smoke outlet also constitute parts of the *Harari* stove
Harari stove is promoted in ECC-SDCOH (Ethiopian Catholic Church Social and Development Coordinating Office of Hararghe) implementation areas. The main gradient used for the production of *injera* in the Hararghe area is sorghum flour which makes storage of *injera* difficult for more than two days. Therefore, households bake *injera* every day to feed their family fresh *injera*.

Fig. 2*Harari* stove

2.3 Research Design

In this study, an exploratory research design was used to investigate and identify the problems that affect the adoption of*Harari* fuel-efficient stoves in rural households. Data were collected through the survey method of data collection using appropriate instruments such as structured questionnaires based on interview techniques. Both qualitative and

quantitative data were collected to provide a thorough study of the research problem. More focus should be placed on one sort of data in a concurrent mixed study design (Creswell. JW. 2012). Employed the cross-sectional technique to gather data, analyze it, and draw conclusions about the entire population based on information obtained from a small sample of respondents. Because only a small portion of the population was sampled at a time during the study's conduct. The research aimed at assessing factors influencing adoption practices of "*Harari*" fuel efficiency stoves in rural households kebele in Dire Dawa Administration.

2.4 Data Type and Sources

In this study, both quantitative and qualitative types of data collection were included. Concerning the data sources, the researcher used both primary and secondary sources. The primary data sources of this study were collected from sample households and key respondents through a structured questionnaire and key oral interview.Secondary sources of information used for this study were collected from the Cluster Agricultural Office, kebele extension agents, health extension workers and Non-governmental CRS (specifically rural energy experts) and Cluster waterand energy office, project reports and documents, and additional research papers, demographic and socioeconomic profiles, published materials such as books, journals.

2.5 Sampling Design and Procedures

The sample size for this study was established by taking into account several variables, including the cost of the research, the amount of time required the availability of human resources, and accessibility. These considerations led to the fixation of covering four rural Kebeles from the total of 38 rural kebeles in the Dire Dawa Administration. This study selected four kebeles *Awelle, Halo-busa,Dajuma*, and *Belewa* by using a purposive sampling technique. In this rural kebele, *Harari* fuel efficiencies stove has been introduced and distributed before the research was conducted.

The appropriate level of precision for social research is 5% but it is impossible to collect data from a total population due to time and financial limitations, The researcher used a 7% level of precision. The selected four kebeles are *Awele, Halo-busa,Dajuma*, and *Belewa* The number of households for 425, 389, 463, and 405 respectively which is a total of 1682 households.

According to Israel (1992), the sample size of the population is less than 10,000, the sample size can be derived by computing the minimum sample size required for accuracy.So, to estimate the proportions via considering the standard normal deviation set at 93% confidence level (z=1.81) and the percentage of choice of the target population or response (50% =0.5, where q=1-p, 0%=0.5) and the confidence interval (0.07 = ±7).

The formula:$n_i = \frac{(Z^2(P)(1-P))}{d^2}$ 1

Where: ni= initial numbers of sample size

z = standard normal variable at the required confidence level (read from a table)

p = percentage of target population choice or response

q= where 1-p

d = margin of error at the required level of statistical significance or tolerance of the desired level of confidence is 0.07.

Therefore$n_i = \frac{(1.81^2(0.5)0.5)}{0.07^2} = \frac{0.819025}{0.0049}$ n_i=167

Finite population correction factor: - When the sample size for the study denotes a significant (e.g. over 5%) percentage of the residents, a finite. population correction factor could be applied (Kothari, 2004). During conducting this study, the researchers applied this formula to reduce the sample size.

$n_a = \frac{n_i}{1+\frac{(n_i-1)}{N}} = \frac{167}{1+\frac{(167-1)}{1682}} = \frac{167}{1682+166} = \frac{167}{1848}$ = 151.998=152 2

The sample size selected by the researcher was 152 from rural households head participants of the total population (N= 1682). These 152 households were selected from four Kebeles' rural areas by using the proportionality formula (Kothari, 2004).

Samples from each kebeles were selected based on proportional sampling and the sample selected from each selected kebeles was proportional to the population in each kebeles and was determined using the Bowley (1925) formula:

$\mathbf{n_i} = \frac{(\boldsymbol{N_i})(\boldsymbol{n})}{\sum \boldsymbol{Ni}}$ 3

Where, ni - the sample to be selected from ith kebeles (villages), Ni- the total population living in ith kebeles. $\sum \boldsymbol{Ni}$ - The summation of the population living in selected four kebeles, n-total sample size for the district. Finally, 152 sample households were selected using a simple random sampling method based on probability proportional to the size sampling technique. A systematic random sampling technique was employed to select the households for the structured questionnaire, with each Kebele being selected from the households' frame.

This sampling technique is advantageous due to its simplicity, expediency, and cost-effectiveness (Zou, 2006). In selecting the respondents, the household head was chosen.

Table 1 Distribution of sample size to each Kebele

Sampled kebeles	Total population(N)	Sampled household(n)	Percentage share
Dajuma	463	42	27.52
Awale	425	38	25.26
Halo-busa	389	35	23.13
Belewa	405	37	24.07
Total	1682	152	100

Source; Constructed by Author, 2023

2.6 Questionnaires

The primary data on rural household characteristics of the respondents, people's attitudes towards fuel-efficient stoves, and determinant factors influencing fuel-efficient stove adoption were collected through structured questionnaires.The questionnaire covered various aspects of fuel-efficient stove adoption, including demographic, institutional, and social factors that have direct or indirect factors on fuel-efficient stove usage, as well as barriers to the adoption of *Harari* stoves.

2.7 Data Analysis and Interpretation

Quantitative data is analyzed by using descriptive statistics such as mean difference, averages, standard error, minimum, maximum, cross-tabulation, percentage, and frequency distribution to summarize, present, and interpret survey results such as demographic, socioeconomic, and institutional factors. Inferential statistics such as the t-test one sample t-test was used to analyze the perception of people towards the benefit of the fuel-efficient stove. Independent sample t-test was used to analyze the mean of adopters and non-adopters based on continuous variables and applied to check the statistical significance while chi-square was used to identify the associations between categorical variables. The binary logistic regression model was used to examine factors influencing the adoption of the *Harari* fuel-efficient stove in the study area using STATA Version 16 software.

2.8 Model Specification

To assess the major factor affecting the adaptation of *the Harari* fuel-efficient stove, a binary logistic regression model was applied. The logitmodel was used to identify determining factors influencing fuel-efficient stove adoption at the household level. This model was appropriate because the dependent variable is dichotomous (adopters and non-adopters of the *Harari* fuel-efficient stove) and the independent variables are in continuous, categorical, and nominal scales.
Pi probability of adopters with the value is 1, otherwise a value of 0, i.e. non-adopters of the *Harari* fuel-efficient stove with the probability of 1- Pi and xi's are independent variables affecting the adoption of fuel-efficient stoves. Therefore the parameter β_0 gives the log odds of the household not using fuel-efficient stoves (when xi =0) and β1 shows how these odds differ for users (when xi =1). We can write the model in terms of odds (Tabachnick and Fidell; 2013:447) as:

$$\boldsymbol{P_i} = \frac{e^{Z_i}}{1+e^{Z_i}} \quad (4)$$

Where: Pi is 1is the probability of being an adopter*Harari*fuel-efficient stove
The probability that the household belongs to the non-adopters (1-Pi) is

$$\mathbf{1} - \boldsymbol{P_i} = \frac{1}{1+e^{Z_i}} \quad (5)$$

The odds ratio in favor of adopters*of Harari* fuel-efficient stove that is, the ratio of the probability of adopters*Harari*fuel-efficient stove to that of the probability of non-adopters.

$$\frac{Pi}{1-Pi} = \frac{\frac{e^{Z_i}}{1+e^{Z_i}}}{\frac{1}{1+e^{Z_i}}}$$

$$\frac{Pi}{1-Pi} = e^{Z_i} \quad (6)$$

When the natural logarithm of both sides of the equation is written is obtained

$$\ln\left[\frac{Pi}{1-Pi}\right] = \beta_0 + \beta_1 X_1 + \ldots + \beta_{ni} X_{ni} = Zi$$

$$Zi = \beta_0 + \beta_1 X_1 + \ldots + \beta_{ni} X_{ni} + Ui \quad (7)$$

2.8 Operational Definition and Description of Variables

2.8.1 Dependent variable

The dependent variable is the adoption of the fuel-efficient stove. The value of '1' is given to households that have adopted fuel-efficient stoves and the value of '0' is given to households that do not adopt fuel-efficient stoves

2.8.2 Independent variable

Independent variables are variables that determine whether a household adopts or non-adopts a fuel-efficient stove.

Table 2 Description of variables

Variable	Description of variable	Measurement	Expected sign
HFES	Harari fuel efficiency stove adoption	Dummy = 1 if adopt Harari stove, 0= non adopt Harari stove	
	Explanatory variable		
AGEHH	Age of the women	Continuous	+/-
Totalhh	Total family size	Continuous	+/-
EDhusb	Education level of household head	Dummy = 1 if educated, 0= non formal education	+/-
MARTS	Marital status	Dummy =1 if married, 0=for single	+/-
RMTIC	Remittance income	Dummy =1 if yes, 0=no	+/-
TLIVEST	total number of livestock owned by the HH	Continuous	+/-
Ccesstoext	Access to extension services	Dummy =1 if yes , 0 = no otherwise	+/-
AWARF	Awareness of FES	Dummy =1 if yes, 0= no	
SEPKITC	Kitchen services	Dummy =1 if separate kitchen, 0= inside the living house	+/-

Source: Own survey, 2023

3. RESULTS AND DISCUSSION

3.1 Status of Harari Stove Adoption

To identify the current status of *Harari* fuel-efficient stove adoption by rural households in the Dire Dawa Administration, household respondents were asked whether they Harari" fuel efficiency stoves or not in the form of a 'Yes' or 'No' response question. Similar studies, for instance, (Inayat, 2011; Dawit, 2008) used such type of objective response and direct measure of binary dependent variable in determining the practice of *Harari* Stove. For this reason, we included both households who adopted and those who did not adopt in our analysis to look at common explanatory variables and factors that affect households' decision to adopt a *Harari* stove. The result found by this study is shown in Table following. As it is observed in Table.3 Out of the total of 152 respondents, 55 were adopters (36.18%) of *Harari* stove, while the other 97 were not adopters (63.82%).

Table. 3 Status of *Harari* Stove Adoption

Adoption	Number of households	Percent (%)
Adopters	55	36.18
Non-adopters	97	63.82
Total	152	100

Source: Own survey data; 2023

This indicates that the majority of the households surveyed were found to be non-adopters. According to the findings, fewer than half of the sample (36.18%) in the study area were adopted. The majority of previous investigations that used the *Mirt* stove as the test material in the study area (Tigabu, 2014 and Tayech, 2019), which discovered that the majority of respondents were non-adopters, with 36.7% and 39% adoption rates, confirmed this result.

3.2 Summary Statistics for Continuous Variables

The standard deviation for adopters' and non-adopters' households was 5.80 and 6.05, respectively. The mean ages of the households for adopters and non-adopters were 33.58 and 33.36 years, respectively with statistical differences insignificant at p>5%. This result is consistent with (Sintayehu, 2022). The average family size of the respondent's households was 6.2 and 5.94 for adopters and non-adopters respectively with statistical differences insignificance. The livestock holding owned by the adopter households was 6.58 and 3.44 of the mean and standard deviation respectively. The livestock holding owned by the non-adopter respondents was 6.61 mean and the standard deviation 3.39 with positive and significant influence at less than 5% level of significance.

Table 4: Descriptive Summary statistics for continuous variables

Variables	Adopters	Std, dev Non-Adopters	Mean Adopters Mean	Non-Adopters Mean	t-test value
Age of the HH	5.80	6.05	33.58	33.36	0.22
Families size	1.63	1.66	6.2	5.94	0.94
Total livestock holding	3.44	3.39	6.58	6.61	0.045

Source: Survey data, 2023

3.3 Respondents' Perceptions on the Benefits of *Harari* Fuel-Efficient Stoves

To explore the most significant contributing factors for *Harari* fuel-efficient stove adoption in the study area, only *Harari* stove adopters (55 respondents) were asked. The following Table 5 illustrates the attitude of respondents toward the varied benefits of fuel-efficient cookstoves.

One sample t-test was applied to analyze the perception of households towards the benefit of the fuel-efficient stove (Asfaw, 2014; Sosina *et al*., 2020). A one-sample t-test was conducted to determine whether rural households' attitudes toward the advantages of fuel-efficient stoves varied from neutral, and a statistically significant difference resulted in a p-value of $p<0.001$ (Table 5). All the sample means are significantly greater than the population mean.

Table .5 Household Attitudes on Adopting *Harari* Fuel-Efficient Stoves

Benefit Harari fuel efficiency stoves	T	Df	Sig. (2-tailed)	Mean Difference	Std. Dev.
Improve households' health status for	3.495	151	0.000	1.625	2.204
reduced the number of fire-related accidents	3.523	151	0.000	1.644	2.256
Reduce fuel-wood consumption	3.647	151	0.000	1.664	2.246
Reduce indoor air and environmental pollution	3.322	151	0.000	1.585	2.172
Increased thermal efficiency for a long time	3.331	151	0.000	1.578	2.142

Source: Survey data, 2023

As Table 5 presents, out of 55 *Harari* stove adopters, 40(72.7 %) strongly agreed that *Harari* stoves perceived to reduce the number of fire-related accidents is the most essential reasonto adopt it.The role of the technology in reducing fuel-wood consumption 36(65.5%)strongly agreed is the reason to adopt it. Of the total respondents of 55 adapters, 33(60%), 31(56.2%), and 26 (47.2%) strongly agreed that improving households' health status, reducing indoor air and environmental pollution, and increasing thermal efficiency for a long time to *Injera* baking perception on Harari fuel efficiency stoves is the other reason to it respectively.

According to the respondents, their sources of knowledge regarding the benefits of the fuel-efficient stove were mainly development agents and health extension workers, and training was given by rural energy experts of Non-governmental CRS. This finding is similar to the previous studies (Bubendorfer, 2011 and Asfaw, 2014), which found that saving fuel wood consumption and reducing fire-related accidents are the main reasons

3.4 Barrier of Adopting *Harari* Fuel-efficient Stove

In the study area, from the total respondents, the majority of households 97(63.82%) were not found to be *Harari* stove adopters due to different barriers. As shown in Table 6, the majority of the respondents 42 (27.63% out of the total respondents) reported a lack of awareness about the benefits of the stove as their primary reason for not adopting fuel-efficient stoves and the absence of promotion regular and technical support by GOV and NGO like the Catholic Relief Service 26 (17.11%) and lack access and of information of *Harari* stoves 22 (14.47%) indicated that the main reason for not adopt fuel-efficient stove.

Table. 6 Barrier of Adopting *Harari* Fuel-efficient Stove

Reasons for not adopting	frequencies	%
Lack of awareness about '*Harari* stove's benefits	42	27.63
Lack of Interest (e.g. Spouse's lack of willingness)	28	18.42
size of kitchen	34	22.37
Absence of promotion regular and technical support by GOV and NGOs	26	17.11
Lack of access *to Harari* stoves and information	22	14.47

Total	152	100

Source: Survey data, 2023

The key informants also identified a lack of awareness, absence of promotion regular and technical support, and lack of access to information as the most likely barriers for the adoption of *Harari* stoves by the rural households. The collected data supports the results of the descriptive analysis as well. The main reasons for the low adoption rate of *Harari* stoves among rural households within the study area were the failure of the mandated government and NGOs to set up a system for promotion and awareness generation, as well as lack of availability and technical support.
Following the findings above, the cluster water and energy office report identified the most likely barriers to *Harari* stove adoption as being the lack of public awareness of the health, economic, and environmental benefits of the stove, as well as a lack of time and resources dedicated to its promotion. In addition, only a small portion of women received training, and lack ongoing support. The finding of the study is similar to the previous study of Massawe *et al*. (2015), which identified a lack of awareness of the relative advantages of improved cook stove technologies as a significant obstacle to adoption.

As it is observed from Table 6, the majority of the respondents, 34(22.37%) households replied that the size kitchen is the reason we are non-users. This implies that the size of the kitchen is a constraint for the *Harari* stove adoption decision. The interviewed key respondents also identified a lack of Interest (for instance, spouse lack of willingness) 28(18.42%) about the benefit of the stove as one barrier faced by the rural community in order not to use the fuel-efficient stove.
In this community, the size of kitchen was constructed in a relatively very small size; this condition was familiar to the culture of the people for a long time. The communities believed that the small size of the kitchen was not appropriate for the improved cook stoves as the space was not enough. This is because of its fixed nature and larger size which requires larger space (Tayech, 2019). The findings of this study were similar to that found the household head's lack of interest in improving one barrier to adoption. The results of the study are also consistent with the findings of previous research conducted by Puzzolo (2013), which found the separate kitchen problem is one factor that hinders the use of fuel-efficient stoves.However, cultural preferences can change – particularly if non-governmental organization (NGOs) and government project raises awareness of environmental issues or highlights the health and economic benefits of using (FES) fuel-efficient stoves.

3.5 Econometric Model Results

3.5.1 Model Diagnosis Test Results

This study conducted most model diagnosis tests, before going to estimate the specified model, it is important to undertake different tests on whether the basic assumptions of the model are met or not, using STATA 16 software. Skewness and kurtosis tests for the normality test (sktest),

Table 7 Summary Model Diagnosis test

Model tests	Test names	Factors of adoption
VIF	Multi-collinearity	Mean = 1.66
Hottest	Heteroscedasticity	Prob > chi2 = 0.1158
Ovtest	Omitted variables	Prob > F = 0.2294
estat gof	Goodness-of-fit test	Prob > chi2 = 0.4269
Dwstat	Autocorrelation	1.86
sktest residual	Normality	Prob>chi20.3739
swilk residual	normal data	Prob>z =0.80630
linktest	Omitted variables	_hatsq P>|z| =0.487

Shapiro-Wilk W test for normal data (swilk), multi-collinearity test by using variance inflation factors (VIF), Breusch–Pagan/Cook–Weisberg test for heteroscedasticity (hettest), Ramsey RESET test for omitted variables (ovtest) carried out before running the logistic regression, and model fitness test by using the goodness of fit (estat gof), test for autocorrelation is the Durbin-Watson (dwstat) and link test for omitted variables (linktest) were conducted after running the logistic regression model estimating the potential effect of each independent variable on the dependent variable of *Harari* stove adoption. The results of these tests shows that no problems with multi-collinearity, heteroscedasticity, normality, and the model fitness test of the logistic justified the fact that the model is adequate to explain the dependent variable (Tables 7).

3.5.2 Factors Affecting Adoption of Harari Fuel Saving Stove

According to the binary logistic regression result only Education HH, Access to extension, Awareness of FES, and Kitchen service (Separate or inside) variables included in the model were statistically significant in influencing the likelihood that households in the study area would adopt *Harari* fuel-efficient stove. The odd ratio and the marginal effect of these powerful explanatory variables are interpreted.

Education HH

The results revealed that educational household has a positive and significant effect on household adoption decisions of *Harari* fuel efficiency stoves at less than a 1% significance level. The marginal effect result shows that educated household heads who are literate imply that the probability of *Harari* fuel efficiency stove adoption for literate HH increases by 9.8% as compared to illiterate.

Table 8 Determinants of Fuel-efficient Stove Adoption

Variable	coef	Odds Ratio	Sig.	M. effects (dy/dx)
Age of the HH	-0.074	0.929	0.186	0.012
Families size	0.286	1.33	0.163	0.042
Education HH	2.224	9.248	0	0.098
Marital status	0.087	1.091	0.922	0.178
Remittance	0.163	1.177	0.829	0.159
Total livestock holding	-0.160	0.851	0.133	0.022
Access to extension	1.638	5.147	0.008	0.140
Awareness of FES	1.168	3.217	0.014	0.099
Kitchen service	1.737	5.682	0	0.086
_cons	-1.556	0.211	0.332	
Number of obs = 152				LR chi2 (9) = 74.82
Prob > chi2= 0.0000				Pseudo R2 = 0.3760
Log likelihood = -62.07149				y = Pr(FESuse)(predict)=.290

The odd ratio result reveals that educated households are 9.248 times more likely to adopt the *Harari* stove than uneducated households. The finding of this study is similar to previous works Alamir (2014), which revealed that the household's head level of educational attainment was a significant contributing factor to a household's decision to adopt fuel-efficiency stoves.

Access to Extension Services

The results showed that the frequency of extension contact positively and significantly affected the adoption of *Harari* fuel-efficiency stoves at less than a 1% significance level (Table 8). The marginal effect indicates, that each additional day a farmer contacts the extension agents, the likelihood of them adopting *Harari* fuel-efficient stoves increases by 14% withkeeping all variables constant. The odd ratio of this variable shows that the *Harari* stove adoption probability for a household that regular contact with development agents and health extension workers is 5.147 times higher than a household that no contact The results indicated that households with more frequent interactions with extension agents have a higher likelihood of adopting improved stoves compared to those with less contact. This is because regular interactions with Kebeles development agents and health extension workers raise the likelihood that people will learn and access information about the advantages of utilizing *Harari* fuel-efficient stoves and expand their awareness of and familiarity with using these technologies. This result is consistent with Amogne (2014), who indicated that the kebeles development agents and health extension workers were their sources of information regarding the benefits of the *Mirt* stoves, especially the health-related benefits.

Awareness of Fuel-Efficient Stoves

The results of the binary logistic regressions revealed that the level of awareness has a positive and significant effect on household adoption decisions of fuel-efficient stoves $p<0.05$ significance level. The odd ratio of this variable indicates that the probability of households who have awareness about fuel-efficient stoves adopting the stove is 3.217 times higher than the people who do not have awareness about the stove. The marginal effect shows that as they have awareness is important for the probability of them adopting fuel-efficient stoves increase by 9.9% than household who do not have awareness about *Harari* fuel-efficient stoves while holding other variables constant. The finding of this study is similar to

the previous work of Tigabu (2017), which also showed that awareness is an important factor affecting the use of improved fuel-efficient stoves. This finding also supports the diffusion of innovation theory which pointed out awareness as one of the major factors that determine the rate of new technology adoption.

Kitchen Service

As Table 8 shows, as was expected separate kitchen house was found a positive significant factor that affects *Harari* stove adoption decision with p< 0.001 and odd ratio of 5.682, respectively. The odds ratio can be interpreted as the odds of a household that has a separate kitchen house adopting a fuel-efficient stove is 5.682 times higher than a household that has kitchen service inside the living house. The marginal effect is 0.086 which indicates that the variable of *Harari* stove adoption for a household having a separate kitchen increases by 8.6% as compared to a household that has no separate kitchen with other variables constant. As it was discussed in the descriptive analysis, one of the reasons for the need for a separate kitchen for *Harari* stoves is its fixed nature. The other explanation may be because of its larger size as compared to traditional cookstoves, the *Harari* stove requires larger space as well as size kitchen is important for *the Harari* stove adoption decision. The finding of this study is in line with previous studies by Puzzolo (2013) and Axen (2012), which revealed that separate kitchen house has a significant positive impact on a household's improved cookstove adoption decision in rural areas.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

This study investigated factors affecting rural households' *Harari* fuel efficiency stove adoption decision in Dire-Dawa Administration rural kebeles by taking 152 household respondents systematically from the households' frame. Based on the data collected and analyzed from the 152 household respondents, the adoption of improved *Harari* fuel efficiency stoves in the study area was found to be very low as compared to traditional cookstoves (non-adopters 63.82%).

The results of one sample t-test revealed that rural households do have positive attitudes over the benefits of fuel-efficient stoves mainly in reducing the number of fire-related accidents and reducing fuel-wood consumption were found to be the main reasons to adopt *Harari* fuel-efficient stoves. In the study area, since lack of awareness about '*the Harari* stove's benefits have been identified as a critical factor barrier in the area not using fuel-efficient stoves, both Governmental and Non-governmental organization have to take their part in making public awareness creation about stove benefits related with health and environment. The problem of kitchen service (inside) and the size of the kitchen were found to be the other most likely barriers to *Harari* stove adoption in the study area.

The results from the maximum likelihood estimation of the logistic model revealed that access to extension, awareness of fuel-efficient cookstoves, kitchen service, and education households had a significant positive association with households' decision to adopt *Harari* fuel-efficient stoves.

Adoption of a *Harari* fuel-efficient stove is more possible if the public is made aware of its benefits and if promotional actions are implemented. Furthermore, people's perceptions of the stove are generally positive, even among those who have not adopted it.

4.2 Recommendations

- Regular and continuous awareness-raising programs, through promotion and information dissemination about *Harari* fuel-efficient stove technology, should be strongly continuous. It contributes to changing community attitudes towards the benefits of fuel-efficient stoves.
- Generally, a collaborative effort among the local government sectorial offices and other stakeholders is crucial in addition to strong and regular follow-up and technical support from partners' staff.
- The result showed that the adoption of an improved stove was positively and significantly influenced by extension contacts. To increase households' awareness of how to improve health and environmental pollution, development agents and health extension workers should provide training and awareness creation to households.
- The government also encourages NGOs and associations with those who work on this technology to enhance *Harari* stove technology adoption.

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