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RESEARCH ARTICLE

FACTORS INFLUENCING FUELWOOD CONSUMPTION IN RURAL HOUSEHOLDS : A CASE STUDY OF JAWI DISTRICT, AMHARA REGION, ETHIOPIA

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ABSTRACT

This study investigates the key factors influencing fuelwood consumption among rural households in Ethiopia. The research aims to understand the role of fuelwood in household income and energy use, and to identify the determinants of its consumption and the adoption of alternative energy technologies. Given the critical importance of fuelwood in rural livelihoods, the study also explores the extent of household dependence on forest resources. Data were collected from 197 rural households using household surveys, focus group discussions, and key informant interviews. The results indicate that fuelwood is both a dominant income and energy source, with over 97.5% of households relying on it as their primary energy source. The average annual household income was 28,166.07 Ethiopian Birr, with fuelwood accounting for 63.8% (17,546.45 Birr). Crop production contributed 30.9% of income, and livestock only 5.3%. Fuelwood sources included own plantations (30%), community forests (40.5%), market purchases (9.6%), and mixed sources (19.4%). A multiple linear regression analysis showed that sex, age, marital status, livestock holdings, and access to information on alternative energy significantly influenced fuelwood income. Additionally, fuelwood consumption was affected by marital status, access to information, and distance from forest resources. A binary logistic regression model identified family size, land size, fuelwood income, crop income, and the presence of an independent kitchen as significant factors influencing the adoption of alternative energy technologies. The findings highlight the need for targeted policy interventions. These include promoting access to alternative energy sources, improving the dissemination of information, and supporting agroforestry and sustainable land-use practices. Such measures are crucial for reducing pressure on forest resources, enhancing household income diversity, and fostering environmental sustainability in rural communities.

KEYWORDS

energy adoption, binary logistic regression, fuelwood, fuelwood income, multiple linear regression

1. INTRODUCTION

Charcoal contributes a significant amount of income, supply energy, and provide multiple socioeconomic benefits to rural households' livelihoods (Andaregie et al., 2020 ; Bekele and Kemal, 2022 ; Smith et al., 2019 ; Tadesse et al., 2019 ; Thabane, 2020). Charcoal is produced by the combustion of wood under a limited supply of oxygen in a process known as carbonization (Koech et al., 2021). The global charcoal production and consumption trend increased from 17 million tons in 1964 to 53 million tons today, with Sub-Saharan Africa accounts 61 percent of the global charcoal production (Kenne et al., 2022).

One-third of the world's population relies on solid biomass for cooking and heating using unsustainable inefficient cook stoves. In Africa alone close to 195 million people or roughly 20 percent of the population in the continent engaged in charcoal production (Dam, 2017). In Kenya, 500,000 people are engaged in charcoal production activities (Njenga et al., 2013). Woodlands in many tropical countries, including Tanzania, and Mozambique, will regenerate within 8–30 years of trees being cut for charcoal (Chidumayo and Gumbo, 2013 ; Woollen et al., 2016).

Given increased urbanization, population growth, charcoal with little smoke and relatively less costly compared to modern energy sources, the demand for charcoal is expected to double in the coming decade (Doggart and Meshack, 2017 ; Neuberger, 2015 ; Raza et al., 2022). Similarly, in Ethiopia, charcoal production is a primary or secondary livelihood activity that brings immediate cash to millions of households in rural areas. Ethiopia is the third highest charcoal producer in the world after Brazil and Nigeria with an estimated amount of more than 4.4 million tons of charcoal (Dam, 2017). According to the Ethiopian forest action program, fuel wood including charcoal contributes 66% and 62% of the energy consumption in rural and urban areas, respectively (Abebe and Endalkachew, 2011 ; Endalew et al., 2022). Scientific studies also witness over 300,000 households with at least five family members and over 1.5 million people in Ethiopia depend on the charcoal business (MoWIE,

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2010). Moreover, the per capita consumption of Ethiopian urban households was estimated at 386 kg/head while in rural areas it was merely 9 kg/head (Djampou, 2019).

Nonetheless, charcoal has such important economic benefits and even expected to double its demand in developing countries in the coming decades, charcoal producers do not have access to knowledge or improved charcoal-making technology for sustainable charcoal production and use inefficient charcoal making kilns (Baumert et al., 2016 ; Bekele and Kemal, 2022 ; Ferede et al., 2019 ; Koech et al., 2021 ; Rodrigues and Junior, 2019 ; Zorrilla-Miras et al., 2018). Also there is no incentive or regulation to produce charcoal efficiently in subsharan Africa where food insecurity and poverty is sever (Bekele and Kemal, 2022).

Around 80% of Ethiopia's forests are currently classified as dry forests. These forests play a crucial role in Ethiopia's forest ecosystems, which span from the moist alpine woodlands of the Bale highlands in central Ethiopia to the hot, arid woodlands in the Borana rangelands of southern Ethiopia. A significant portion of Ethiopia's endemic wildlife inhabits dry forests, which contribute to a fragile balance of distinct ecosystems. Dry forest ecosystems in Ethiopia are facing the highest rates of deforestation. On a national scale, dry forests appear to contribute minimally to household incomes and export revenues. However, there are significant economic, social, and environmental reasons to manage and safeguard dry forests sustainably, which are often not well recognized by policymakers and the public. A common misconception is that dry forests play a minor role in Ethiopia's overall economy. These forests are characterized by lower vegetation density and less greenery, which leads to perceptions of them as less valuable. Moreover, products from dry forests are often poorly promoted, viewed as lower quality, and have minimal impact on generating formal employment or contributing to the formal economy. This misperception has accelerated the conversion of these forests to land uses considered more advantageous. Nevertheless, the benefits and services offered by dry forests, along with the investments made by local stakeholders in their management, have not been adequately documented, valued, or understood relative to other land uses like agriculture.

In Ethiopia, various development issues, such as temporary and chronic food insecurity, widespread poverty, and high unemployment rates, significantly impact many pastoralists, agro-pastoralists, and smallholder subsistence farmers (Lawry et al., 2015 ; Girma et al., 2022). Consequently, individuals from various economic backgrounds participate in the production of fuelwood, with poorer households more likely to engage in the charcoal and Fuelwood trade, primarily as a safety net to enhance other sources of income. However, the influencing factors that are driving the rural households towards fuelwood production in dryland regions is not well understood. This represents a critical obstacle to sustainably managing and utilizing dryland forests to ensure balanced supply and demand. Therefore, effective management of dry forests and the sustenance of local livelihoods rely heavily on the existing limited information available to inform policies and practices (Lawry et al., 2015).

Most of previous literatures focused on the negative effects and controversial issues of fuelwood production regarding deforestation and environmental degradation with limited studies on socio-economic impacts of fuelwood particularly dryland areas of Ethiopia (Ruuska, 2013 ; FAO, 2017 ; Kiruki et al., 2017). Likewise, energy policies and related programs have undermined the potential of fuelwood to contribute socio-economic aspects like income generation and livelihoods in SSA countries such as Ethiopia (Neufeldt et al., 2015 ; Doggart and Meshack, 2017 ; Smith et al., 2017). The absence of empirical evidence on the influencing factors that are driving rural households towards fuelwood production limits the understanding of its importance and hamper the development of policies and other interventions that seek to contribute to the improvement in wellbeing of the people in the in the study district.

This study therefore tries to address questions including, how do fuelwood productions affect the incomes of those who are engaged in the activities? What are influencing factors associated with fuelwood production and consumption? How does the income level of households, family size, and land size affect the rate of fuelwood production? What are the factors affecting adoption of alternative energy? The findings are important to future implementation of sustainable fuelwood production and sustainably meet households' fuelwood demand, livelihood and manage forests sustainably which is helpful to policy makers in Ethiopia and elsewhere with similar condition.

2. Materials And Method Of Data Collection

To conduct this this study data was collected using different data collection tools such as Note book, questionnaires of structured and semi-structured interview from different stallholders, primary and secondary data sources was considered from 15 August 2024 to 20 September 2024.

2.1 Description of the study areas

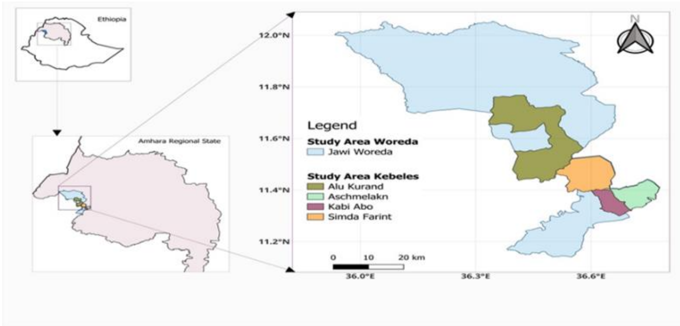

Figure 1 : Study area map source: EFD MRV2024

The research was carried out in the Jawi District, situated in the Awi Zone of the Amhara Regional State in Northwest Ethiopia. It is bordered on the west by the Benishangul-Gumuz Region, to the north by the North Gondar Zone, to the east by Dangila, to the south by the Metekel zone, and to the northeast by Achefer. The district is located within the geographical coordinates of 10038 to 11030 North and 360 to 370 east (Mekonen and Berlie, 2021). It spans an area of 515,000 hectares and is divided into 28 rural and 3 urban kebeles. Jawi is positioned 276 km from the regional capital, Bahirdar, and 160 km from the zonal administrative center, Injibara (JWMS, 2019). The annual average minimum and maximum temperatures range from 18.2 to 32.4°C. The long-term rainfall patterns are marked by significant variability and unpredictability. Factors such as deforestation, overgrazing, and inadequate soil and water conservation practices have led to a high incidence of drought in the area. The primary rainy season (kiremit) takes place from June to August, while the minor rainy season (belg) runs from March to May. Generally, the district's agricultural production relies heavily on the main rainy season. The climate in Jawi District is classified entirely as Kola Zone (hot). This region experiences a bimodal rainfall pattern: the major rainy season occurs in summer (June to August), with the peak in July, and the shorter rainy season from March to May rainfall amounts can range from 0 mm to 398.2 mm. The average temperature in the region is 25.26°C (JWMS, 2019).

The district's landscape is mostly characterized by flat land (512623 hectares or 99.5%), with hills and valleys covering 30 hectares (0.006%), and mountains comprising 2,347 hectares (0.494%) of the total area. The predominant agro-ecological zone of the district is lowland, or kola. Consequently, the majority of residents are located in flat terrain areas. There are 512623 hectares deemed suitable for farming, while 2,377 hectares are not conducive for cultivation. The prevalent soil type in the region is black. The elevation of the study area is 1,225 meters above sea level (JWADO, 2019). The total population of the Jawi District stands at 94,363, consisting of 49,244 males and 45,119 females. Out of this, 22,329 individuals, or 15.254%, live in urban areas, while the remaining population resides in rural settings. Over 85% of farming households practice mixed farming systems, and 93% employ traditional farming methods for cultivation. As a result, these communities are increasingly susceptible to the impacts of climate variability. Most residents are involved in mixed agriculture, which includes both crop cultivation and livestock rearing. Except in small, specific areas where vegetables are grown through traditional small-scale irrigation, all crop production is reliant on rainfall. The most commonly cultivated crops in the area include annual varieties such as teff, sorghum, rice, beans, maize, sesame, peanuts, and small millet (JWADO, 2019).

2.2 Study site selection

To select the sample plot of the study area reconnaissance survey was conducted to determine the representative sample plot and discussion was conducted with the district Environment and forest development office expert to take our sample at the target of the study area.

2.3. Sampling Technique

Following a reconnaissance survey, probability and non- probability sampling techniques was employed to select interviewers.

The study area was selected purposively based on different outlooks such as the condition charcoal consumption and closeness of Jawi forest. Accordingly, out 31 Kebles 4 Kebles are assumed to be representative for the study area namely, Kava, Arkuran , Simida and Asech was selected together with the experts.

Stratified sampling method was employed to select the sample size with the help of key informant, KII, FGD, Agriculture and Natural Resource Office and Environment, Forest and Climate Change Authority experts.

Stratified random sampling is useful method for data collection if the population is heterogeneous. In this method, the entire heterogeneous population is divided into a number of homogeneous groups, usually known as strata, each of this group is homogeneous within itself, and then units are sampled at random from each of this stratum. The technique of the drawing this stratified sample is known as stratified sampling. Then Sampling will be conducted separately in each stratum. Strata or subgroup are chosen because evidence is available that they are related to outcome. After stratification, sampling is conducted separately in each stratum. In stratified sample, the sampling error depends on the population variance within stratum but not between the strata (Singh &Masuku, 2014). Therefore, the study will employ stratified random sampling.

For this study, the researcher was focused on Charcoal producers, Charcoal consumer, agriculture and natural resource staff, Environment and Forest development authority staff supporting staff. This is because, the sustainability of the district forest will be realized by the carful and well integration of this stalk holders. The researcher was selected purposefully 4 Agriculture and Natural resource leader, 3 professional experts and 20 charcoal producers for interview by using purposive sampling techniques because the researcher was believed that these individuals are key informants for the effectiveness of this study.

2.4 Sample size and sample size determination

The study relies on probability and non-probability sampling, that is stratified random sampling and purposive sampling techniques. According to the study, sampling determination is the essential step of research methodology (Simarjeet, 2017). It is an act of choosing the number of observer/replicates to include in statistical sample. Additionally, mathematical estimation of the number of subjects/units to be included in a study needs to be neither excessively large nor too small. Therefore, optimum size determination must require for the following reasons; to allow for appropriate analysis, to provide the desired level of accuracy and to allow validity of significant test.

The sample size of the study was determined by the sample size formula of (Yamane, 1967) as shown below. With a 93% confidence level. The researcher selects Yamane formula because of descriptive survey and finite population.

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

Where "n" is the sample size,

"N" is the population size, and

"e" is the level of precision (0.07).

$$n = \frac{5340}{1+5340(0.07)^2}$$

n = 197 sample size

Therefore, the representative sample size of this study was 197 respondents of sampled households was taken from the 4 kebeles such as Asechmelkan, Alukurand, Kabi Aboand Simida farint Sample household was selected using simple random sampling and stratified sampling techniques.

2.5 Method of data collection

To meet the objectives of this research, both primary and secondary data was collected, field and market survey was conducted, focus group and key informant interview was conducted. Mainly primary data was used to meet the predetermined objectives of this study. The primary data collected from charcoal producers, fuelwood business merchants and Fuelwood consumers through various tools from 15 August 2024 to 20 September 2024. Therefore, this study employed primary data sources to identify and analyze the influencing factors motivating rural households for fuelwood consumption in the study area.

2.6 Methods of data analysis

Descriptive statistics was employed to analyze the collected data. With regard to data analysis, responses in the questionnaire and interview and vegetation measurements was entered into SPSS and analyzed using STATA version 17 software. Percentage, Regression and arithmetic mean used to condense and study the variables for the purpose of analysis and interpretation. Furthermore, tables and graphs was used to facilitate the presentation of the result of the analysis and interpretation of data.

2.7 Multiple Regression Analysis

The study employed by applying multiple linear regression model as above explained, to examine the effect of socio-economic factors on fuelwood consumption by rural household in Jawi district multiple linear regressions model was applied. Multiple regressions, is a statistical technique that uses several explanatory variables to predict the outcome of a response variable.

As a predictive analysis, the multiple linear regressions was used to explain the relationship between one continuous dependent variable and two and more independent variables. The multiple linear regression model equation is shown as below.

A standardized multiple linear regression model transforms all variables into their standardized form (z-scores). This allows for direct comparison of the impact of each independent variable on the dependent variable.

Standardization Process:

Each variable is transformed as:

$$Z_X = \frac{X - \bar{X}}{\sigma_X} \quad (2)$$

Where:

- ZX is the standardized value of XXX
- X¯ is the mean of XXX
- σX is the standard deviation of XXX
- The term XXX represents a generic placeholder for any variable that is being standardized or XXX is just a placeholder for any variable in the model that undergoes standardization

2.7.1 Standardized Fuelwood Income Model

ZFIi=β1ZAgei+β2ZSexi+β3ZEducationi+β4ZDependencyRatioi+β5ZLivestocki+β6ZCropLandi+β7ZOffFarmIncomei+β8ZOnFarmIncomei+β9ZMarketDistancei+β10ZRoadDistancei+β11ZInfoAccessi+εi

Where:

- ZFIi_ = Standardized fuelwood income
- ZXi = Standardized independent variables
- jβj = Standardized regression coefficients

Since the model is standardized, there is no intercept (β0), as the mean of a standardized variable is zero.

2.7.2 Standardized Fuelwood Consumption Model

ZFCi=α1ZAgei+α2ZSexi+α3ZEducationi+α4ZDependencyRatioi+α5ZLivestockiZ+α6ZCropLandi+α7ZOffFarmIncomei+α8ZOnFarmIncomei+α9ZMarketDistancei+α10ZRoadDistancei+α11ZInfoAccessi+εi

Where:

- ZFCiZ = Standardized fuelwood consumption
- ZXiZ = Standardized independent variables
- αj = Standardized regression coefficients

Table 1: Definition and measurements of working variables for fuelwood consumption and income from fuelwood for multiple regression model

Variables	Measurement	Variable type
Age	Age of the household head in completed years.	Discrete
Sex	1 if head is male, 0 Otherwise	Dummy
Educational status	Education in years of schooling	Continues
Dependency ratio	Ratio	Continuous

Table 1 (cont): Definition and measurements of working variables for fuelwood consumption and income from fuelwood for multiple regression model		
Livestock ownership	TLU	Continuous
Size of crop land	Hectare	continuous
Off farm Income	EB	Continuous
On farm income	ETB	continuous
Market distance	Kilometer	continuous
Distance to main road	Kilometer	continuous
Information access	1 if yes, 0 otherwise	Dummy

2.8 Binary logistic model for adoption of alternative energy

This model was chosen because the primary objective is to examine what determines a household's transition away from traditional fuelwood use toward cleaner alternatives. The dependent and independent variables were selected based on empirical literature, socio-economic relevance, and data availability. Each variable is expected to influence the likelihood of adopting alternative energy technologies in the following ways: The model is specified to reflect the socio-economic and infrastructural determinants that significantly affect the decision to shift away from traditional fuelwood use, aligning with the goals of sustainable energy transition.

In this study adoption is the dependent variable that shows the alternative energy technology use for objective three. The dependent variable is adoption which takes (1) is code for adopter of alternative energy technology and (0) is code for non-adopter of alternative energy technology. Logistic regression is a probability estimation model applied when the dependent variable is binary and the independent variable is in any form of measurement scale (Cramer, 2003 ; Leech et al., 2005).

$$y = a + bx \tag{3}$$

$$P = \frac{1}{1+e^{-(a+bx)}} = e^{a} + \frac{bx}{1+e^{a}+bx} \tag{4}$$

Where P is the probability of the event occurring, X are the independent variables, e is the base of the natural logarithm and a and b are the parameters to be estimated by the model. As p is the probability of adopting an improved cook stove, 1- p is the probability of not adopting the alternative energy technology. Therefore

$$1\text{-p} = 1 + e^{a+bx} \tag{5}$$

To obtain the odds ratio of adopting the alternative energy technology will be

$$Ln\left(\frac{p}{1-p}\right) = a + bx \tag{6}$$

The logistic prediction equation or multiple variables the equation will be as follows

$$\ln\left(\frac{p}{1-p}\right) = \beta_0 + \beta_{1X_1} + \beta_{2X_2} + \cdots + \beta_{iX_i} + \epsilon_i \tag{7}$$

Where Y= adoption of improved cook stove technology (dependent variable) β0= constant (coefficient of intercept)

β1, β2, βi = parameters to be estimated

$X_1, X_2 .... X_i$ = the explanatory variables to fitted into the model

Table 2: Description of explanatory variables for alternative energy technology adoption model

Variable	Type	Description	Expected sign (positively related/+) (negatively related/-)
Age	Continuous	Age of household head in years	positive/+
Sex	Dummy	Sex of household head (0= female 1= male)	positive/+
Education level	continues	HH's educational level in year of schooling	Positive/+
Family size	Continuous	Total number of people in the house hold	Positive/+
Marital status	Dummy	In this study marital statusis a dummy which refers to the respondent's state of being single or married. (1=married,0=single)	Negatively/-
Income level	Dummy	Total annual income ofhousehold in ETB(1=high,0=low)	Positive/+
Independent Kitchen facility	Dummy	Presence or absence of Independent kitchen facility(1= presence, 0= absence)	Positive/+
Fuel wood	Dummy	It is about a household's main source of fuel-wood.1=withcharge,0=without charge	Positive/+ or Negative/-
Price	category	refers the end users cost to buy Mirt stove	Negative/-

The econometric analysis in the study provides an initial framework for assessing the socio-economic determinants of fuelwood consumption and income, as well as the adoption of alternative energy technologies. However, to enhance the robustness, reliability, and theoretical grounding of the findings, several improvements are necessary

2.8.1 Theoretical Justification of Variables

The selection of independent variables for both the multiple regression and logistic regression models aligns with empirical literature but requires stronger theoretical justification. Variables such as age, sex, education, household size, income levels, and access to infrastructure are commonly used in energy consumption studies. However, their inclusion should be grounded in established economic and behavioral theories (e.g., utility maximization, household production theory, or energy ladder hypothesis). This will clarify the rationale behind the expected direction of influence and guide the interpretation of results.

2.8.2 Endogeneity and Multicollinearity

The current model assumes exogeneity of explanatory variables, which may not hold in practice. For example, income could be simultaneously determined with fuelwood consumption, leading to endogeneity bias. Similarly, access to information may be correlated with both education and income. Such issues can distort parameter estimates and weaken the conclusions drawn from the model. Appropriate diagnostic tests, such as the Variance Inflation Factor (VIF) for multicollinearity and the Durbin-Wu-Hausman test for endogeneity, should be employed. If endogeneity is detected, instrumental variable techniques or simultaneous equation models may be necessary.

2.8.3 Validation of Model, Data, and Parameters

Model validation is another critical area requiring attention. Currently, the model does not appear to have undergone any form of validation such as goodness-of-fit tests (e.g., R-squared, adjusted R-squared for regression models), significance testing (p-values, confidence intervals), or predictive accuracy assessments (e.g., ROC curve for logistic regression). The assumptions of linearity, homoscedasticity, and normality of residuals in the multiple regression model also need verification.

Likewise, data quality should be examined for accuracy, completeness, and representativeness. Sample size adequacy and sampling methodology should be explained clearly to justify the generalizability of the results.

3. Results

3.1 Socio-economic characteristics of respondents

Table 3 presents the sex and marital status of households. The data from the household survey revealed that 52.8% the respondents were male-headed households and the rest 47.2% were female-headed. Table 4.1shows that out of 154 surveyed households, 166 (84.3%) of respondents were married. The marital statuses of the remaining 15.7% of respondents were single.

Table 3: Sex and marital status of respondents

Variable	Category	Frequency	Percent
Sex of respondents	Male	104	52.8
	Female	93	47.2
	Total	197	100.0
Marital status	Single	31	15.7
	Married	166	84.3
	Total	197	100.0

The mean age of the household headed was 43.91 year with a range of 19 - 89 years old (Table 4). The average family size in one household was 5.7 person with 1 and 11 person minimum and maximum respectively. The educational status of a household headed by schooling year averagely was 4.8 with the range of 0 - 12 years minimum and maximum schooling years.

Table 4: Age, education and family size of households

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Age of the respondent	197	19	89	43.91	14.172
Educational level	197	0	12	4.80	4.275
Total family size	197	1	11	5.70	2.149

The overall average landholding of the respondent was 7.96 hectare /household (Table 5). The sample respondents also had averagely 0.68 hectare of woodlot land size with a maximum of 7 hectare. Fuelwood Regarding livestock holding, sample respondents had averagely 4.19 TLU with a maximum and minimum of 9.1 and 0.8, respectively.

Table 5: Livestock and land holding size

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Total land size in hectare	197	.0	12.0	7.96	1.99
Woodlot size in hectare	197	.0	7.0	0.68	0.54
Livestock holding (TLU)	197	.8	9.1	4.19	1.92

The households' settlement far from the main fuelwood source of forest that is either plantation or natural forest averagely was found 39.35minutes with the range of 60- 420 minutes in the study area (Table 6). The result also shows that the households' settlement far from the residence to market place averagely was found 36.97 minutes with the range of 40- 240 minutes.

Table 6: Distance from market and forest

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Distance from residence to fuelwood source of forest in minute	197	60	420.0	39.35	36.02
Distance from residence to market in minutes	197	40	240.0	36.97	19.46

3.2 Contribution of fuelwood for household income

Table 7 presents sources and contribution of household income in the study area. The result revealed that reported that households in their sample earned total yearly cash income of 28166.07 Birr from all income sources Table 7. Total income from fuelwood (charcoal and Fuelwood) was the highest which estimated 17546.45 birr. The second income sources of the household were crop production which accounts averagely 8496.2208 birr followed by livestock production (1450.3198 birr). In the study Wereda, fuelwood contributes 63.8% to the households' total cash income. This means that 63.8% of the forest's income comes from fuelwood. In the study area, crop contributes 30.9% all total family income. Livestock also contributes 5.3% of the total household income which is very small proportion compared with other sources. The result implies that fuelwood is the dominant contributor of household income in the study area.

The FGD and KII participants also reported that fuelwood including charcoal and Fuelwood is the most important source of livelihood income. The order of importance for the contribution of forest for households' livelihood indicates fuelwood production and selling account major annual household income. Annual income contribution of fuelwood production is the largest amount of income recorded followed by annual income from crop production while the thread rank occupied by income from livestock play important role in generating annual income. This means that, fuel-wood contributed more to community livelihoods than income from other sources of the respondents in the study area.

Table 7: Different sources of household income

Income sources	N	Mean	Std. Deviation	Contribution to total HH income (%)
Fuelwood income	197	17546.4467	23479.37409	63.8
Crop income	197	8496.2208	10564.31168	30.9
Livestock income	197	1450.3198	3111.44140	5.3
Total income	197	28166.0736	26818.13344	100

3.3 Determinants of fuelwood income for annual household income

The contribution of fuelwood production for annual income estimated by using multiple linear regressions and the result discussed as follow. The multiple linear regression model was used to analyze the factors affecting household income derived from fuelwood production (Table 8). This model was significant at (P = 0.0000) with a higher value of R2 (0.559/55.9%) which indicates that the larger proportion of the variation of fuelwood products income is explained by the explanatory variables.

Sex: The multiple linear regression result indicated that male household headed has engaged less on fuelwood production income than female headed. The model result revealed that sex of household head has negative association with fuelwood income and it is significant at 10% level of significance. This implies that female headed households are engaged more on the income of fuelwood than male headed household heads.

Age: The age of the household was negative and significant at a 1% level of significance (P<0.01). The negative sign indicated that an increase in each unit of household age will have a decrease in the income level derived from fuelwood products. The reason for this result could be the high labor-intensive nature of fuelwood for production make the older aged household engaged less in fuelwood production compared to younger households. Older households do have not enough labor for labor-intensive activities of fuelwood production.

Marital status: The marital status correlated positively with fuelwood income. The result revealed that marital status has significant effect on fuelwood income at 5% level of significant. The model result indicated that if the household becomes married, the probability of driving income from fuelwood increased by 7672.666 Ethiopian Birr. The plausible reason may that a person get to married there is a probability of get children which increases the income from fuelwood.

Livestock: The association between livestock and income from fuelwood was negative. This shows that livestock holding influenced the household income from fuelwood significantly at 5% level of significant. This implies that households who have more livestock lead to engaged in fuelwood production and derived less income from fuelwood. As shown in Table 4.6, the negative sign indicated that an increase in each uniof livestock holding will have a decrease in the income level derived from fuelwood products by 1248.924 Ethiopian birr.

Information on alternative energy sources: Association between information about alternative energy sources and fuelwood income shows positive correlation. The result shows that information about alternative energy sources had statistically significant effect at 1% level of significance. The finding implies that if households have information on alternative energy sources, the probability of income driving from fuelwood increased by 12966.002 Ethiopian birr. This shows that as households have information about alternative energy sources they will generate more income from fuelwood.

Table 8: Determinants of fuelwood income from multiple linear regression model

Variables	B	Std. Error	Beta	t	Sig.
(Constant)	31240.255	10243.488			
Sex of the respondent	-6448.673*	4019.517	-.137	-1.604	.010
Age of the respondent	-348.115**	139.663	-.205	-2.493	.014
Educational level of household	-393.738	462.783	-.071	-.851	.396
Total family size of household	-573.296	875.741	-.052	-.655	.514
Marital status1	7672.666**	5122.747	.119	1.498	.0136
Total land size	-89.181	196.883	-.030	-.453	.651
Livestock holding in TLU	-1248.924**	878.584	-.102	-1.422	.0157
Distance from fuelwood source in minutes	32.794	41.254	.055	.795	.428
Distance from market in minutes	19.137	43.634	.030	.439	.661
Independent kitchen facility	-2882.546	3843.969	-.051	-.750	.454
Information alternative energy sources	12966.002***	2229.716	.396	5.815	.000
Crop income	-.090	.152	-.041	-.592	.554
Livestock income	-.120	.516	-.016	-.233	.816

Note: ***,** and * presents significance at 1%,5% and 10 level of significance

3.4 Factors affecting fuelwood consumption

In the study area, biomass energy is mainly used for cooking and baking purposes which are the two main activities more frequently undertaken on a daily bases at the rural households in the study area. These two types of main activities consume the majority of the biomass energy demand. This section presents the main energy sources by type of activities as well as the main source of biomass energy; domestic energy consumption patterns of the total sample households and the adopter and non-adopter households in the study areas.

As shown in figure 2 below, rural households mainly used two types of energy sources for baking and cooking in the study area while Fuelwood is the most important energy source which is often used by more than 97.5% of the sample households. The result also revealed that charcoal was the second source of energy which accounts 42.2% followed by crop residue (36.8%) and animal dung (24.3%).

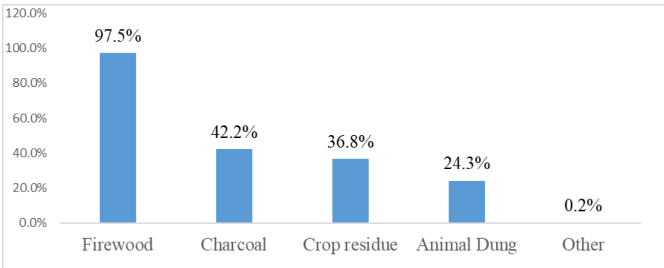

Figure 2: Types of biomass fuel used

Rural households in the study area obtain traditional biomass energy for domestic energy use from various sources. As shown in figure 3 below, the result reveals that 30% of the sample households obtain their fuelwood demand for household energy use from their own plantation, and 40.5% excessively depends on community forest, 9.6% purchasing, while the rest 19.4% combine own plantation and community forest. The households who do not have fuelwood source were negligible. The result clearly implies that the dominant fuelwood source for the majority of the households for domestic energy use in the study area was the community forest.

Collecting fuelwood from the forest in an unsustainable way exacerbates the deforestation and forest degradation. Furthermore, especially women's and children's lost an ample amount of time for fuelwood collection that can be used for other productive activities. However, there is an inspire finding that is a significant number of households also had their own plantation for fuelwood sources. This practice should be encouraged to solve the problem of fuelwood scarcity and to ensure the sustainable fuelwood harvest in the study area and other similar areas.

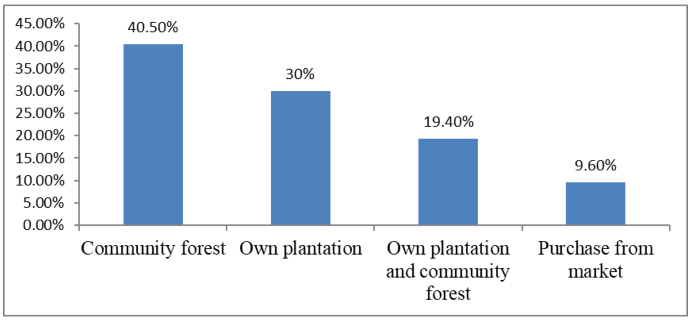

Figure 3: Sources of fuelwood for domestic energy use in the study area

The annual fuelwood consumption among households in the study area, revealing considerable variation in usage levels. On average, households consumed a substantial amount of fuelwood each year, highlighting its significance as a primary energy source. The data also indicates a wide range between the lowest and highest levels of consumption, suggesting differences in household size, access to forest resources, economic status, or energy needs.

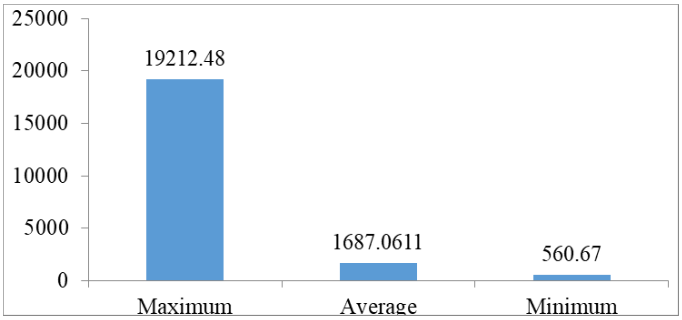

Figure 4: Estimation of fuelwood consumption

These variations imply that while some households rely heavily on fuelwood, others may use it more sparingly, possibly due to alternative energy sources or limited availability. Overall, the findings underscore the central role of fuelwood in meeting household energy demands and reflect the diversity in consumption patterns across the community.

Three variables used in the model significantly affected the consumption of fuelwood by households in the study area (Table 9; P < 0.01). This regression result showed that fuel wood consumption is positively correlated with marital status and access to information about alternative energy sources. However, the result reveals that wood consumption is negatively correlated with distance from forest access.

Marital status: The marital status correlated positively with fuelwood consumption. The result revealed that marital status has significant effect on fuelwood consumption at 10% level of significant. The model result indicated that if the household becomes married, the probability of fuelwood consumption increased by 955.647 kg. The plausible reason may that a person get to married there is a probability of get children which increases the consumption of fuelwood consumption demand.

Distance from forest: The distance from forest correlated negatively with fuelwood consumption. The result revealed that forest distance has significant effect on fuelwood consumption at 10% level of significant. The model result indicated that as the distance of households 'residence from forest increased by 1 minute, the probability of fuelwood consumption decreased by 7.684 kg. The plausible reason may that a person far away from the forest access which leads to save fuelwood consumption due in availability of more fuelwood every time due to distance. This shows that when distance of households' residence far from forest area, they may save fuelwood consumption for the purpose of time and energy saving.

Information about alternative energy: Association between information about alternative energy sources and fuelwood consumption shows negative correlation. The result shows that information about alternative energy sources had statistically significant effect at 5% level of significance. The finding implies that if households have information on alternative energy sources, the probability of fuelwood consumption decreased by 768.802 kg. This shows that as households have information about alternative energy sources they will use less fuelwood. This is due to that when they have information about alternative energy sources, they may use fuel saving energy technologies in order to save fuelwood consumption.

Table 9: Determinants of fuelwood consumption from multiple linear regression model

	B	Std. Error	Beta	t	Sig.
(Constant)	-109.085	1424.568			
Sex	643.783	558.996	.104	1.152	.251
Age	-19.035	19.423	-.086	-.980	.328
Educational level	58.753	64.360	.081	.913	.363
Total family size	124.670	121.790	.087	1.024	.307
Marital status	955.647*	712.423	.113	1.341	.081
Land size	-3.584	27.381	-.009	-.131	.896
Livestock holding in TLU	-114.334	122.185	-.071	-.936	.351
Distance from fuelwood source in minutes	-7.684*	5.737	.098	-1.339	.082
Distance from market in minutes	-7.624	6.068	-.092	-1.256	.211
Independent kitchen facility	282.658	534.583	.038	.529	.598
Information about the Alternative energy	-768.802**	310.088	-.179	-2.479	.014
Crop income	.003	.021	.011	.146	.884
Livestock income	.023	.072	.023	.323	.747

Note: ***, ** and * presents significance at 1%, 5% and 10 level of significance

3.5 Determinants of alternative energy adoption

To identify the major determinants of alternative energy adoption, the binary logistic regression analysis was performed and the findings were presented in Table 10 below. The results indicated that among the independent variables fitted into the model, five variables were statistically significant. Variables such as family size, land size, fuelwood income, crop income and independent kitchen facility were found statistically significant at p-value < 0.01. The binary logistic regression analysis results also revealed that the model performance or omnibus tests of the model coefficients for all the explanatory variables fitted into the model was found statistically significant (chi-Squared=73.31766, Prob > chi2 = 0.0000 and p< 0.001).

Family size: The result of the study shows that family size positively and significantly influences the adoption of alternative energy. This could be due to that as a family size increase; there is adequate labor to collect Fuelwood. In the study, the link between accesses to Fuelwood has a negative influence on the adoption of alternative energy. Therefore, the existence of family labor in surplus resulted in not adopting alternative energy. The odds in favor of adopting alternative energy decreases by the factor of 1.239 units as family size increases by one person

Land size: Household farm size of land has negatively significant effect on the decision of adoption of alternative renewable energy source positively at 1% level of significance. This implies that household's farm size of land is increased by one; the probability of adoption of renewable energy source will be decreased by the odds of 0.713

Crop income: Household annual income has positively significant effect on the decision of adoption of renewable energy source positively at 1% level of significance. This implies that household's annual income is increased by one; the probability of adoption of renewable energy source will be increased by the odds of 1 (Table 4.8).

Fuelwood income: As the odd ratio of this variable indicates that the probability of adoption on alternative energy increased if fuelwood income of the household was increased. Which means that higher income household can afford advance payment for alternative energy.

Independent kitchen facility: Independent kitchen facility associated positively and significantly with adoption of alternative energy. The result revealed that independent kitchen facility was significantly influenced the adoption of alternative energy sources at 5% level of significance. This implies that as the HH have independent kitchen facility, the probability of their adoption of alternative energy increased by the odds of 2.997.

Table 10: Determinants of alternative energy adoption

Variables	B	S.E.	Wald	Sig.	Exp(B)
Sex	-.615	.473	1.690	.194	.541
Age	-.019	.017	1.367	.242	.981
Education status	-.020	.053	.143	.705	.980
Family size	-.214**	.101	4.463	.035	1.239
Marital status	.669	.572	1.368	.242	1.953
Land size	-.338*	.193	3.068	.080	.713
Livestock size (TLU)	.147	.103	2.046	.153	1.158
Distance to market in minutes	-.001	.005	.039	.843	.999
Fuelwood income	.000***	.000	14.129	.000	1.000
Crop income	.000***	.000	13.803	.000	1.000
Livestock income	.000	.000	1.331	.249	1.000
Independent kitchen facility	1.098**	.473	5.394	.020	2.997
Constant	-.994	1.150	.747	.387	.370

Note: ***,** and * presents significance at 1%,5% and 10 level of significance

4. Discussion

4.1 Socio-economic Characteristics of Respondents

The study found that fuelwood consumption in Jawi District was influenced by both household characteristics and access to alternative energy information. Specifically, marital status and distance from fuelwood sources showed a weak but notable effect, while access to information on alternative energy significantly reduced fuelwood consumption. Moreover, the adoption of alternative energy was positively associated with larger family size and access to independent kitchen facilities, while high crop and fuelwood income influenced adoption decisions. These findings underscore the importance of targeted awareness, infrastructure improvements, and economic support to promote sustainable household energy use.

The study revealed that 52.8% of the surveyed households were male-headed, while 47.2% were female-headed (Table 3). This distribution is relatively balanced compared to similar studies in Ethiopia, where male-headed households typically dominate (Mekonnen and Köhlin, 2019). The high proportion of female-headed households could indicate increasing participation of women in household decision-making, possibly due to male migration or widowhood.

In terms of marital status, 84.3% of respondents were married, while 15.7% were single. This pattern aligns with national demographic trends, where marriage is a fundamental social institution contributing to household stability and economic activities (Tadesse et al., 2021).

The mean age of household heads was 43.91 years, with a range of 19 to 89 years (Table 4), suggesting that the study area has a mature and experienced farming population. This is consistent with findings in rural Ethiopia, where middle-aged farmers dominate household leadership (Derero et al., 2023). Additionally, the average family size was 5.7 persons per household, higher than the national average of 4.6 (CSA, 2021), indicating a high dependency ratio. A larger household size may have both positive and negative implications—on one hand, it provides labor for agricultural and fuelwood collection, but on the other hand, it increases pressure on household resources.

The average schooling year of household heads was 4.8 years, with a range of 0 to 12 years (Table 4), indicating relatively low literacy levels. Education is a key factor in adopting improved agricultural and forest management practices, accessing markets, and diversifying income sources (Babulo et al., 2008). The low education levels in the study area suggest a need for capacity-building initiatives in sustainable forest management and alternative livelihood strategies.

Regarding landholding, the average land size per household was 7.96 timad (Table 5), which is relatively larger than the national average of 1.2 hectares (CSA, 2021). This suggests that land access is relatively better in the study area, allowing for both crop cultivation and woodlot management. The presence of woodlot holdings (0.68 timad on average) indicates that some households are engaged in on-farm fuelwood production, which can be a sustainable alternative to forest extraction (FAO, 2010).

The average livestock holding was 4.19 TLU per household, which is comparable to findings from other rural Ethiopian studies (Derero et al., 2023). Livestock plays a crucial role in household resilience, but its contribution to income (5.3%) in this study suggests that it remains secondary to fuelwood and crop production.

The results also show that the average travel time to collect fuelwood was 39.35 minutes, with some households traveling up to 420 minutes (Table 6). This highlights the increasing difficulty of accessing fuelwood, which could indicate forest degradation and unsustainable resource use (Mekonnen and Köhlin, 2019). Similarly, the average travel time to the market was 36.97 minutes, with a maximum of 240 minutes. Limited market access can restrict income diversification opportunities and hinder the adoption of alternative energy sources (Tadesse et al., 2021).

Overall, the findings suggest that households rely heavily on fuelwood as a primary income source, with land and livestock playing a secondary role. The relatively low educational levels and long distances to forests and markets indicate potential challenges in adopting sustainable forest management and livelihood diversification strategies. Policy interventions such as community-based forest management, improved market access, and promotion of alternative energy sources could help address these challenges and enhance household resilience.

4.2 Contribution of Fuelwood to Household Income

The results indicate that fuelwood (including charcoal and firewood) contributes significantly to household income, accounting for 63.8% of the total cash income. This aligns with findings from recent studies indicating that fuelwood remains a dominant source of income for rural households in many developing countries (Mekonnen et al., 2022). Similar research found that in Ethiopia, fuelwood contributes between 60% and 70% of total household income, particularly for low-income families (Asfaw et al., 2021). The dependency on fuelwood suggests a heavy reliance on forest resources, which may pose sustainability concerns. Crop production was the second most significant source of income, contributing 30.9% to total household earnings. This is consistent with findings who reported that while agriculture remains an essential livelihood strategy, non-farm income sources, particularly forest products, play a crucial role in household economic stability (Teshome and Zeleke, 2020). The relatively lower contribution from livestock (5.3%) supports the findings of recent studies indicating that livestock production in Ethiopia is often constrained by land availability and feed shortages (Bekele and Worku, 2019).

Results from focus group discussions (FGDs) and key informant interviews (KIIs) confirm that fuelwood is the primary income source, reinforcing the idea that forest dependency is highest among vulnerable households. The findings corroborate previous studies that suggest that woodfuel extraction and sales remain the most viable livelihood options for resource-poor households in Ethiopia and other developing countries (Mohammed et al., 2023).

4.3 Determinants of Fuelwood Income for Annual Household Income

The multiple linear regression model, which was statistically significant ($p = 0.0000$) with an R^2 of 55.9%, shows that several socio-economic factors influence fuelwood income. The significant role of these explanatory variables is comparable to studies by Alemu and Tadesse (2021), who found that household characteristics and access to alternative livelihoods significantly impact fuelwood dependency.

The negative association between sex of the household head and fuelwood income suggests that female-headed households are more engaged in fuelwood collection than male-headed households. This is consistent with findings from recent studies (Gebre & Mulugeta, 2022), which indicate that women are more involved in informal forest product trading due to economic necessity and limited employment opportunities.

Age was also negatively associated with fuelwood income, with older households earning less from fuelwood than younger ones. This aligns with the findings who suggested that younger households have a greater capacity for labor-intensive activities such as firewood collection (Tesfaye et al., 2022). Marital status showed a positive association with fuelwood income, implying that married households generate more income from fuelwood sales. This may be due to increased household labor availability and greater economic responsibilities. Similar findings reported who noted that married individuals tend to participate in more diverse livelihood activities, including forest product sales, to support their families (Kassa et al., 2023).

The negative correlation between livestock ownership and fuelwood income suggests that households with larger livestock holdings rely less on fuelwood collection. This is in line with studies who found that livestock-rich households have alternative income streams, reducing their dependency on fuelwood (Workneh and Assefa, 2020).

Interestingly, access to information on alternative energy sources was positively correlated with fuelwood income, which contradicts the assumption that awareness leads to lower dependence on fuelwood. This could be explained by the fact that households involved in fuelwood trade may also seek information on alternative energy sources to expand their market opportunities. A study found that knowledge about alternative energy solutions does not always translate into immediate adoption due to economic barriers (Berhanu et al., 2022).

4.4 Factors Affecting Fuelwood Consumption

Biomass energy remains the dominant source of energy for rural households in the study area, primarily used for cooking and baking. The results indicate that 97.5% of households rely on firewood, followed by charcoal (42.2%), crop residue (36.8%), and animal dung (24.3%). This aligns with findings by Bekele et al. (2023), who reported that in rural Ethiopia, firewood remains the primary cooking fuel due to its accessibility and affordability. Similarly, despite efforts to introduce alternative energy sources, traditional biomass fuels still dominate household energy use (Teka and Woldemariam, 2022).

The findings reveal that 40.5% of households primarily depend on community forests for fuelwood, while 30% rely on their own plantations. This is consistent with a study which found that community forests remain the predominant source of biomass fuel in Ethiopia (Damte et al., 2021). Likewise, similar patterns in Tanzania, where the majority of rural households collect firewood from natural forests and plantations (Lema and Mekonnen, 2022).

The regression results indicate that marital status significantly influences fuelwood consumption. Married households tend to consume more fuelwood due to larger family sizes, which is consistent with the findings who reported that household size positively affects fuelwood demand (Alemayehu and Tesfaye, 2021).

Households farther from forests consume less fuelwood, likely due to the inconvenience of collection. This finding is supported by research which found that proximity to forest resources is a key determinant of household fuelwood consumption in Ethiopia (Getachew et al., 2023).

Households with access to information on alternative energy sources consume significantly less fuelwood. Similar findings were reported who found that awareness programs on improved cook stoves and alternative fuels reduce dependency on traditional biomass energy sources (Mesfin and Belay, 2022). These findings highlight the importance of sustainable fuelwood management and the promotion of alternative energy solutions to mitigate environmental impacts and reduce reliance on biomass energy.

4.5 Determinants of alternative energy adoption

The results of the study show that family size has a significant negative effect on the adoption of alternative energy. Larger family sizes are associated with more household labor for collecting firewood, which reduces the incentive to switch to alternative energy sources. This finding is consistent with recent studies, such as those who found that larger households tend to rely more on traditional energy sources due to the availability of family labor (Zhang et al., 2021). As family labor increases, households are less motivated to invest in alternative energy technologies, as they can rely on readily available fuelwood. Land size also negatively influences the adoption of alternative energy. Households with larger farms have better access to firewood and other natural resources, making them less likely to adopt alternative energy sources. This is in line with findings who observed that larger landholdings reduce the need foR renewable energy adoption, as households can use their own resources for traditional energy needs (Awas et al., 2022). In contrast, households with smaller land sizes may face greater energy insecurity, increasing their likelihood of seeking alternative energy options.

Crop income was found to have a positive effect on the adoption of alternative energy. Higher crop income increases the financial capacity of households, enabling them to afford the initial costs of renewable energy technologies. Studies also found a positive relationship between income and the adoption of alternative energy, as households with higher incomes are more likely to invest in energy-efficient technologies that offer long-term savings (Khanna et al., 2021). This suggests that increasing household income through agricultural productivity can be a key driver for adopting alternative energy solutions.

Fuelwood income similarly has a significant positive effect on alternative energy adoption. Households with higher fuelwood income are more financially able to invest in renewable energy technologies, as they can afford the upfront costs. This finding is consistent with recent research who highlighted that wealthier households, particularly those with income from fuelwood, are more likely to transition to alternative energy (Smith et al., 2022). These households have the financial flexibility to make investments in cleaner, more sustainable energy sources, even if they are initially more costly.

The presence of a Independent kitchen facility was also positively associated with the adoption of alternative energy. Households with Independent kitchen facilities are more likely to adopt renewable energy solutions such as biogas or solar cookers, as they have the necessary infrastructure to support these technologies. Recent studies found that independent kitchen facilities facilitate the installation and use of alternative energy technologies, as they provide a dedicated space for cooking that is compatible with cleaner energy sources (Kumar et al., 2022). This suggests that improving household infrastructure could play a critical role in promoting renewable energy adoption.

Other variables, such as sex, age, education status, livestock size, and distance to market, were not found to significantly influence the adoption of alternative energy. These factors may have less impact on energy choices compared to the socio-economic variables of income, family size, and land size. The lack of significant associations with sex and age suggests that gender and generational factors may not be as influential in energy adoption decisions as previously assumed. Similarly, education and livestock size did not show a meaningful relationship with energy choices, indicating that practical factors such as income and resource availability may outweigh the influence of education or livestock in this context.

Overall, the findings highlight that socio-economic factors, particularly income, family size, and landholdings, play a critical role in determining the likelihood of adopting alternative energy in rural households. These results emphasize the importance of addressing these factors in policy initiatives aimed at promoting renewable energy adoption.

The findings from Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs) revealed several cultural and policy-related barriers to the adoption of improved cookstoves in the study area. A strong cultural preference for traditional stoves was evident, as many participants noted that they felt more comfortable using them, especially for cooking traditional meals, which modern stoves were perceived to inadequately replicate in taste and texture. Additionally, a lack of awareness about the benefits and proper use of improved cook stoves was frequently mentioned. Many rural households, particularly in remote areas, were unaware of alternative energy technologies or did not fully understand the long-term economic and environmental advantages of switching from fuelwood to cleaner alternatives. This lack of awareness was exacerbated by inadequate information dissemination from both governmental and non-governmental organizations. Furthermore, the absence of financial incentives or government subsidies for improved cook stoves was highlighted as a significant challenge in promoting adoption. Most households, particularly those with limited income, viewed the initial cost of purchasing an improved cook stove as prohibitively expensive, and no formal support systems such as subsidies or micro-credit schemes were in place to ease this financial burden. Without addressing these cultural preferences, information gaps, and policy limitations, the transition to sustainable energy technologies will likely remain slow, as households continue to rely on fuelwood despite its environmental and health impacts.

5. Conclusion And Recommendation

The study focused on the contribution of fuelwood for rural house hold income, examine factors affecting the consumption fuelwood by rural households and explore factors affecting the adoption of alternative energy sources by rural households. The major energy sources often used for baking and cooking purposes are animal dung and fuelwood at rural household in the study area.

This study highlights the crucial role that fuelwood plays in the economic stability of rural households, contributing a significant portion (63.8%) to the total cash income. The dependency on fuelwood underscores the importance of forest resources to rural livelihoods, particularly for low-income and vulnerable households. The findings from this study corroborate those of previous research, showing that forest products, particularly fuelwood, remain the most viable source of income in many developing countries, including Ethiopia.

Despite the centrality of fuelwood to household income, the study also reveals the socio-economic determinants that influence fuelwood income, including household characteristics such as sex, age, marital status, and livestock ownership. The results indicate that female-headed households, younger households, and married individuals tend to be more involved in fuelwood collection and sales. Moreover, households with larger livestock holdings appear to be less dependent on fuelwood. This suggests a complex relationship between fuelwood income and other livelihood strategies, such as agriculture and livestock production.

The positive correlation between access to information on alternative energy sources and fuelwood income, though counterintuitive, suggests that information dissemination may play a role in expanding market opportunities rather than reducing fuelwood dependency. Therefore, while awareness of alternative energy solutions is important, economic factors and market dynamics must be considered when promoting sustainable energy alternatives.

Biomass energy, particularly firewood, remains the main energy source for rural households, driven by accessibility and affordability. Community forests and household plantations are the primary fuelwood sources, with marital status and distance from forests affecting consumption. Access to information on alternative energy significantly reduces fuelwood use.

The study found that family size, land size, crop income, fuelwood income, and independent kitchen facility significantly influence the adoption of alternative energy. Larger family sizes and landholdings decreased the likelihood of adoption, while higher crop and fuelwood incomes positively influenced it. The presence of a Independent kitchen facility also facilitated the adoption of renewable energy technologies. These socio-economic factors are critical in determining energy choices in rural households.

The study recommends reducing dependency on biomass by promoting modern energy sources such as LPG, biogas, solar, and improved cookstoves, alongside strengthening forest conservation through reforestation, agroforestry, and controlled harvesting. It highlights the need for community empowerment, gender-sensitive policies, and diversified income sources, particularly for vulnerable households, to reduce reliance on fuelwood. Supporting livestock production, expanding agroforestry, and providing incentives for household and community woodlots are also emphasized. Additionally, policies should make alternative energy technologies more affordable and accessible through subsidies, awareness campaigns, and infrastructure development, while ensuring equitable access to forest resources and promoting sustainable resource management.

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Conflict Of Interest

The authors declared that there is no any financial or personal conflict of interest.

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