

Research Article

Assessment of Household Fuel Wood Use, in the Mattu and Bedele Districts, of Southwestern Ethiopia

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In many developing countries, households heavily rely on fuelwood for cooking and heating. This study aims to contribute to the growing body of research on sustainable energy solutions in developing countries by exploring household fuelwood consumption patterns and preferred wood types for fuel use in the Mattu and Bedele districts of southwestern Ethiopia. The ultimate goal is to inform policy and program interventions that can improve environmental and socioeconomic outcomes in these communities. A comprehensive survey was conducted in 195 households using multistage sampling methods to collect information on fuelwood consumption levels, cooking habits, socioeconomic characteristics, and perceptions of different wood types. Fuelwood collection, storage, and use in households were observed to verify self-reported data. The amount of fuel consumed over 7 days was calculated using the weight method, and measurements of fuel wood were conducted to quantify consumption per capita. Data obtained from household surveys and direct measurements were analyzed using descriptive statistics such as frequency, percentage, mean, and multiple regression analyses. Key findings from the regression analysis revealed that factors such as age and size of the household, educational attainment, income, and proximity of fuel wood sources significantly influenced consumption patterns in these districts. Urban families consumed substantially less fuel wood (average of 2.56 kg/day) than their rural counterparts (average of 7.32 kg/day), resulting in a total consumption of approximately 187.3 tons of dry biomass which is an estimated 262 tons of CO₂ emissions. Six preferred tree species for firewood were identified: *Pouteria adolfi-friederici*, *Prunus africana*, *Albiza gummifera*, *Croton macrostachyus*, *Eucalyptus globulus*, and *Cupressus lusitanica*. The main challenges of household firewood consumption in the areas were identified as forest degradation, soil degradation, biodiversity loss, and climate change. To mitigate these challenges, regulatory bodies should enforce laws and regulations on reforestation initiatives, promote alternative cooking fuels and efficient cookstoves, plant fast-growing wood tree species, and implement community forest management initiatives.

Keywords: assessment; consumption; fuelwood; household; preferred

1. Introduction

Globally, a significant portion of households in developing countries relies on traditional biomass as a primary energy source for cooking and heating. This reliance predominantly manifests in the form of fuelwood, with various studies indicating its critical role in everyday energy consumption [1]. In sub-Saharan Africa, the situation remains particularly dire, where projections suggest that nearly 1 billion individuals will continue to depend on traditional biomass fuels by 2030 [2]. This dependence not only exacerbates

environmental concerns, namely, deforestation, but also poses serious health risks due to harmful emissions typically associated with solid fuel combustion [3].

The reliance on traditional biomass fuels, driven by factors such as affordability and accessibility, has profound implications for public health, especially for women, who are often the primary users of these energy sources [4]. Literature highlights that inefficient cook stoves and the use of biomass fuels have been linked to adverse health outcomes, including respiratory infections and cardiovascular disease, thus emphasizing the urgent

need for cleaner alternatives [5]. Recognizing these health impacts, initiatives promoting improved cook stoves have emerged as potential solutions. However, the effectiveness of promoting improved cook stoves depends on various factors, including stove design, fuel type, and consistent adoption by households. While improved cook stoves initiatives on the continent show promise in reducing health risks and environmental damage, their effectiveness depends on a thorough understanding of household fuelwood choices and consumption patterns, which are often influenced by socioeconomic factors and access to alternative energy sources [6]. Moreover, the drawbacks of traditional biomass usage are well-documented: It serves as an inefficient energy carrier, generates hazardous emissions, and is extracted unsustainably from natural resources [7].

Transitioning to cleaner fuels, such as liquefied petroleum gas (LPG) or electricity, offers potential solutions, as these alternatives minimize harmful particle emissions and provide better economic and community benefits compared to conventional fuels [4, 8]. Given the potential benefits of cleaner fuels, it is important to understand the barriers hindering their adoption and the factors driving the continued use of traditional biomass.

At the national level, Ethiopia exemplifies these challenges, with many households in regions like Mattu and Bedele still heavily dependent on firewood. Understanding the factors driving this continued reliance on fuelwood is essential for developing effective policies that address the dual issues of environmental sustainability and public health. Factors such as family income, access to alternative fuels, and various sociodemographic elements play a crucial role in determining fuel choices in these communities.

Thus, this study aims to examine the determinants influencing firewood use, identify preferred tree species for fuel, and quantify the extent of firewood consumption among households in Mattu and Bedele districts. By focusing on local contexts, the research seeks to provide actionable insights for policymakers and community leaders aiming to promote cleaner cooking solutions that align with families' needs.

2. Materials and Methods

2.1. Description of the Study Area. The study was conducted in the Mattu and Bedele districts of the Oromia region in southwestern Ethiopia. These districts were selected due to high reliance on fuel wood within the population and their location in a natural resource-rich districts facing environmental challenges.

2.1.1. Location. Mattu district, located at 8°18'N latitude and 35°35'E longitude, is far from the capital Addis Ababa approximately by 600 km. Its altitude is around 1605 m above sea level.

Bedele district lies between 8°14'30"N and 8°37'53"N latitude and 36°13'17"E to 36°35'05"E longitude, approximately 480 km from Addis Ababa.

2.1.2. Climate. Both Mattu and Bedele districts experience a tropical climate characterized by distinct and frequent wet seasons.

2.1.3. Vegetation. The natural landscapes in both Mattu and Bedele districts are diverse featuring grasslands, savannas, and deciduous trees like acacias, eucalyptuses, and oaks.

2.1.4. Population. Mattu district: The estimated population is 28,782 [9] with 14,400 men and 14,382 women.

Bedele district: The population is 19,517 [10], consisting of 9837 men and 9680 women. Figure 1 shows the map of the study areas.

2.2. Sampling Method and Sample Size. To ensure both relevance to the study objectives and statistical representativeness, a multistage sampling approach was employed, combining purposive selection at the initial stage with systematic random sampling in subsequent stages.

Stage 1: Purposive District Selection. Mattu and Bedele districts were purposively selected from the Oromia region, Illu Aba Bor, and Buno-Bedele Zones, respectively. This selection was based on their documented high dependency of local communities on forest resources for livelihoods and their significant susceptibility to land degradation. This strategic selection ensured that the study focused on areas where fuelwood utilization and its environmental impacts are most pronounced and relevant to the research questions.

Stage 2: Simple Random Kebele Selection. From each of the two purposively selected districts (Mattu and Bedele), a comprehensive list of all kebeles (the smallest administrative units) was obtained from the respective district administrative offices. To ensure an unbiased representation of the diverse socioeconomic landscape, four kebeles were then randomly selected from each district using a lottery method.

- Mattu district: Kodohiri, Gaba Guda, Adele Gumar (rural kebeles), and Mattu Town (urban kebele).
- Bedele district: Dabana Deru, Yabala, Mirga Mute (rural kebeles), and Bedele Town (urban kebele).

Stage 3: Systematic Random Household Selection. Within each of the eight selected kebeles (six rural and two urban), a complete and updated list of all registered households was obtained from their respective administrative offices. This list served as the sampling frame. The target population for this study was specifically defined as households that utilize fuelwood for energy production, either through collection or purchase. To select households, systematic random sampling was employed in each kebele. A sampling interval (k) was determined by dividing the total number of households in each kebele by the proportional sample size allocated to that kebele. A random starting point

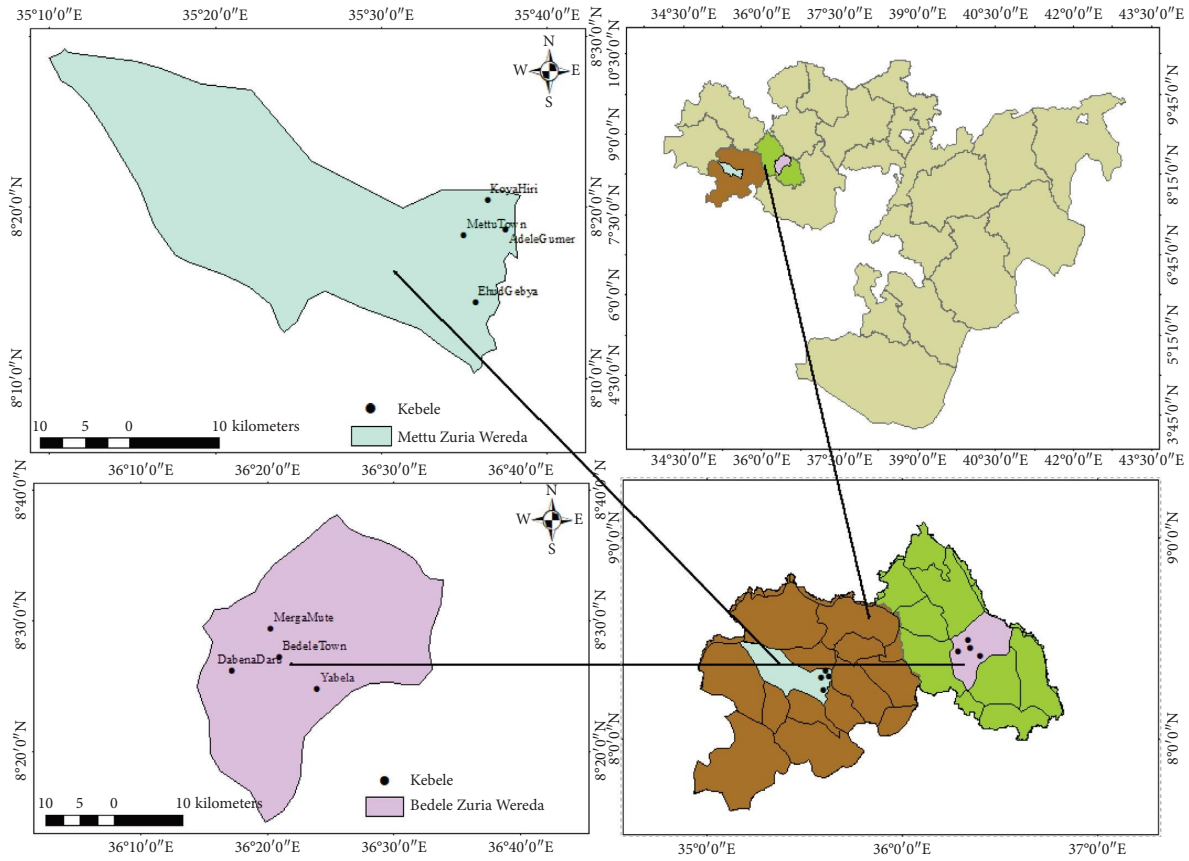


FIGURE 1: Map of the study area.

was selected from the first “ k ” households on the list, and subsequently, every k th household was chosen until the required sample size for that kebele was met.

Sample Size Determination: The total required household sample size (n) for the study was calculated using the following statistical formula for determining sample size for finite populations [11]:

$$n = \frac{NZ^2pq}{E^2(N-1) + Z^2pq} \quad (1)$$

where n is the required sample size; $p = 0.15$, which is a population reliability of 15% (for an estimated frequency in a sample size of n); $q = 1 - p$ ($1 - 0.15 = 0.85$); $N = 30,510$, total number of households in targeted kebeles; Z is the standard error corresponding to 95% confidence interval, that is, 1.96; and thus, using the above equation, the household sample size was 195. This sample size was then proportionally distributed among the selected kebeles based on their respective household populations to ensure fair representation.

2.3. Data Sources and Collection Methods. To comprehensively address the research objectives, the study integrated both primary and secondary data sources. Primary data collection focused on gathering specific, up-to-date information directly relevant to the research questions,

including household fuelwood consumption patterns, preferred species, and socioeconomic factors influencing energy choices. Secondary data provided contextual information on regional demographics, environmental conditions, and existing policies related to forestry and energy use.

2.3.1. Primary Data Collection. Primary data were collected through household surveys, key informant interviews, focus group discussions (FGDs), and direct measurements of fuelwood consumption.

2.3.1.1. Household Survey. Structured questionnaires were administered to randomly selected household heads. The questionnaire consisted of closed and open questions covering:

- Household characteristics (gender, age distribution, education level, household size, distance to fuelwood sources, and monthly income).
- Fuelwood consumption patterns (quantity used daily, weekly, or monthly).
- Types of wood used (species and reasons for preference).
- Alternative energy sources.

2.3.1.2. Key Informant Interview. Key informants in this study were considered to be people who are knowledgeable

about the extraction of fuel wood from the forest, who know the selected types of wood used for fuel in the area, and who continue to live in the community for a long time. These were selected using the snowball method ([12], as cited in [13]). The interview participants were development organizations (DAs), private women, and heads of households who mostly collected fuel wood from open forests to gain insight, feelings, thoughts, and ideas. Twelve structured questions were designed to collect interview data.

2.3.1.3. FGDs. FGDs were held with relevant group members in each kebeles. The FGD aimed to obtain detailed information from different groups of people about their dependence on the use of fuel wood from forests. The main participants in the focus group discussions were the Development Agency (DA) development agents who had experience with the past and current trends in fuel wood use in the study areas, Kebeles leadership, Woreda energy experts, forestry and wildlife experts, and households that frequently use firewood and lived in the area for a long time to obtain detailed information on fuelwood use from community groups. A place to study participants focused on groups of 6–9 households from each kebeles. Focus groups were interviewed that lasts for 1:30 an hour using a structured checklist of no more than 10 questions.

2.3.2. Secondary Data Collection. Secondary data sources included published reports from national and international institutions, academic journals and books, government documents from the Mattu and Bedele district administrations, and state archives.

2.4. Data Analysis

2.4.1. Analysis of Household Data. Quantitative data from household surveys and direct measurements were analyzed using descriptive statistics (frequency, percentage, and mean) in Microsoft Excel 2019 and SPSS version 24.

2.4.2. Determinants of Household Fuelwood Consumption. Fuel wood use is expressed as a percentage of annual household consumption. Multiple regression analysis is a list of tools for analyzing the relationship between two or more variables. In this study, fuelwood use was used as the dependent variable, and the independent variables were sex, age, education, family size, monthly family income, and proximity to forests. A statistical method for assessing factors affecting household firewood use is regression analysis. The relationship is believed to take an extended form known as multiple regression models [14]. $Y = \alpha + \beta_1 \times 1 + \beta_2 \times 2 + \beta_3 \times 3 + \beta_4 \times 4 + \dots + \beta_n \times n + \varepsilon$, where α is the constant, ε is the error term, Y is the wood fuel consumption (kg) as dependent variable, and β_1 to β_n are the regression coefficients, women and 1 man), and X_6 = distance traveled to the fuel wood sources. Regression was tested at a 5% probability level. This model was chosen because it best describes the dependent variable. After all,

very few factors are the product of the same cause and effect of unique independent variables.

3. Results and Discussion

3.1. Socioeconomic Characteristics of Fuelwood Users. A total of 195 households were interviewed, with 55.4% headed by males and 44.6% headed by females (Table 1). The age structure analysis shows that the majority of household heads (46.2%) fell within the 31–42 age range, followed by 27.7% between 43 and 55 years old. Younger household heads aged 18–30 comprised 16.4%, while those aged 56–68 accounted for 8.7%. Only 1% of household heads were older than 69 years. This distribution indicates that most respondents were in economically active age groups. Regarding education levels, the largest proportion of respondents (26.7%) had attended primary school.

Household size was categorized as small, medium, or large. For the purpose of this study, these categories are defined as follows: small families consist of 1–5 members, with an average of 4 members. Medium families include 6–10 members, with an average of 7 members, and large families have more than 10 members, averaging 11 members. A small percentage of households (1.5%) were classified as large families.

Monthly household income in cash includes various sources: salaries, income from cash crops, trade profits, remittances from family members working abroad, and income from agricultural or nonagricultural labor. While all sources contribute, income from cash crops and agricultural labor were reported as the most common, particularly during harvest seasons. Regarding income distribution, the largest group of households (31.8%) reported earnings above 4500 Ethiopian Birr per month. A significant portion (27.7%) earned less than 500 Ethiopian Birr per month. The remaining households were distributed as follows: 17.4% in the 501–1500 Birr range, 14.4% in the 1501–2500 Birr range, and 8.7% in the 2501–4500 Birr range (Table 2). The distance households traveled to collect fuelwood from their primary source (state forest, roadside, private land, or communal forest) varied. The shortest distance reported was 1 km, while the longest distance was 3 km. The average distance to fuelwood sources across all households surveyed was 2.68 km.

3.1.1. Main Source of Energy. The primary energy source for households in the Mattu and Bedele districts is overwhelmingly biomass. Specifically, the survey results showed that the most common primary energy source was firewood (34.96%), followed by a combination of charcoal and firewood (23.58%), firewood and electricity (20.6%), and charcoal and electricity (13.55%). Less frequently used primary energy sources included electricity alone (3.79%), charcoal alone (1.63%), crop residue (1.08%), and LPG and kerosene (0.8%) (Figure 2). These energy sources are used to meet daily domestic needs for cooking, baking, and heating water.

Earlier studies in Ethiopia, such as Ezzati and Kammen [15] and Girma [16], reported that approximately 93% of

TABLE 1: Demographic characteristics of respondent households.

Parameter	Frequency	Percent (%)
Gender of household head		
Female	87	44.6
Male	108	55.4
Age of household head		
18–30	32	16.4
31–42	90	46.2
43–55	54	27.7
56–68	17	8.7
> 69	2	1.0
Educational level of household head		
None	40	20.5
Read and write	48	24.6
Primary school	52	26.7
Secondary school	35	17.9
College	13	6.7
University	7	3.6

Note: Source: Field Survey, 2024.

energy for household consumption nationwide came from fuelwood. While our study confirms the continued heavy reliance on biomass in the Mattu and Bedele districts, with approximately 58.54% using firewood solely or in combination with charcoal, it is noteworthy that this figure is somewhat lower than the historical national average. This suggests that while biomass remains dominant, there is a discernible, albeit gradual, shift toward the adoption of alternative energy sources like electricity, particularly in combination with traditional biomass fuels. This transition aligns with the “energy ladder” model, where households gradually shift from traditional biomass to cleaner fuels as their income and access improve, though this process is often slow and characterized by “fuel stacking” rather than complete substitution [17].

The observed difference in biomass reliance compared to older national figures might be attributed to increased access to electricity in the study area, possibly reflecting the expansion of Ethiopia’s national grid or the proliferation of off-grid solutions, compared to the national average at the time of the previous studies [18]. However, the high prevalence of combined fuel use (e.g., firewood and electricity) indicates that electricity is often supplementary, used for lighting or charging devices, rather than a primary cooking fuel. This implies that households are still heavily exposed to the detrimental impacts associated with traditional biomass use.

The continued overwhelming reliance on biomass fuels has significant environmental and public health implications. Environmentally, it contributes to deforestation, land degradation, and the depletion of forest resources in the region, exacerbating climate change impacts through the release of greenhouse gases [19]. From a public health perspective, the combustion of biomass indoors exposes household members, particularly women and children, to high levels of indoor air pollution (IAP), leading to various respiratory illnesses, eye infections, and other non-communicable diseases [20]. These findings underscore the urgent need for targeted interventions to promote cleaner and more sustainable energy alternatives in rural Ethiopian

districts, balancing energy access with environmental sustainability and public health.

3.1.2. Reasons for Household Use of Fuelwood. As shown in Figure 3, the predominant reason for fuelwood use among households (40%) is its perceived low cost and affordability. Another significant proportion of households (31.79%) indicated that fuelwood is readily and consistently available. A smaller percentage cited the lack of alternative energy sources (14.36%) and the dual benefit of fuelwood for both cooking and heating the house (13.95%) as their reasons for use. This aligns with previous research [16, 21], which highlights the relative affordability of biomass fuels compared to modern energy sources, particularly for lower-income populations in developing countries.

However, the perception of low cost often only accounts for the direct monetary expense, neglecting the significant hidden costs associated with biomass use. These include the time and labor spent, primarily by women and girls, on fuelwood collection, contributing to “time poverty” and limiting opportunities for education or income-generating activities [22]. Furthermore, the unquantified costs of health impacts due to IAP and environmental degradation are substantial [23].

While respondents cited the “readily and consistently available” nature of fuelwood, this perception may mask underlying issues of deforestation and the sustainability of current harvesting practices unique to the local context. In many parts of Ethiopia, biomass resources are under increasing pressure due to population growth and unsustainable extraction rates, leading to localized fuelwood scarcity and longer collection times [24]. The perceived availability in the study area might reflect access to remaining forest patches, but without sustainable management, this availability is finite.

The reported “lack of alternative energy sources” (14.36%) is a critical impediment to energy transition. This often stems from a combination of factors including limited infrastructure for modern fuels (like LPG distribution networks), high upfront costs for appliances, and a lack of awareness or cultural acceptance of new technologies [25]. The dual benefit of fuelwood for both cooking and heating, while practical for households, particularly in colder seasons, suggests a lack of access to more efficient and cleaner heating solutions and often points to inadequate housing insulation, further contributing to IAP [26].

Collectively, these reasons underscore a complex interplay of economic necessity, resource availability, infrastructural deficits, and cultural practices that entrench the reliance on traditional biomass. Addressing these deep-rooted challenges necessitates a multifaceted approach, including promoting access to affordable clean cooking solutions (e.g., improved cookstoves and LPG subsidies), expanding reliable electricity grids specifically for cooking, and implementing robust sustainable forest management practices to mitigate environmental damage.

3.2. Household Fuelwood Consumption. Household surveys revealed a significant difference in fuelwood consumption between urban and rural areas. The average daily fuelwood

TABLE 2: Household family size, monthly income, and distance to fuelwood source.

Parameter	N	%	Minimum	Mean	Maximum
Household family size					
Small (1–5 members)				4	
Medium (6–10 members)				7	
Large (more than 10 members)				11	
Household monthly income (ETB)					
< 500	54	27.7			
501–1500	34	17.4			
1501–2500	28	14.4			
2501–4500	17	8.7			
> 4500	62	31.8			
Distance to fuelwood source (km)					
Distance			1.00	2.68	3.00

Note: Source: Field Survey, 2024.

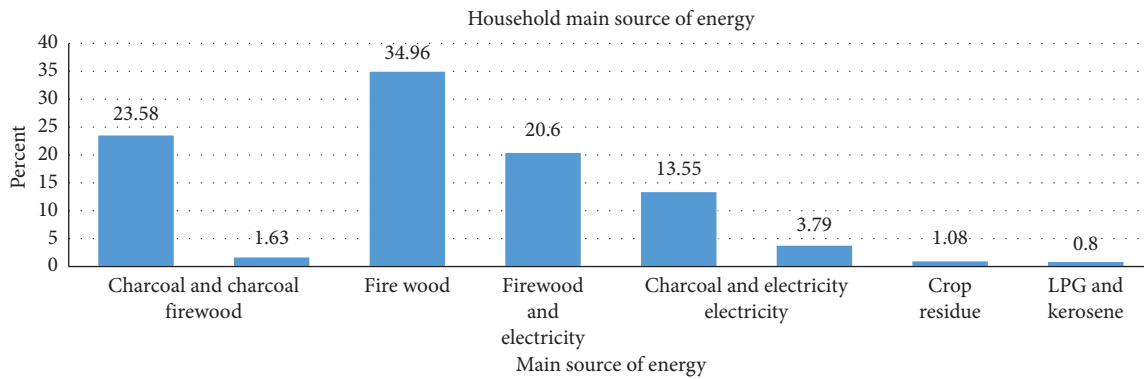


FIGURE 2: The main source of energy in the study area.

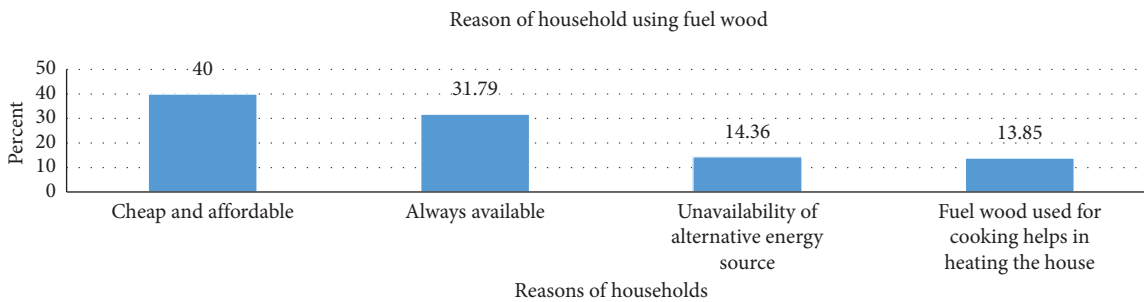


FIGURE 3: Reasons why HH uses fuel wood.

consumption in urban areas (mean = 2.56 kg/day) was approximately one-third of that in rural villages (mean = 7.32 kg/day). This aligns with findings from Zélolo et al. [27], which attribute higher rural consumption to the greater availability of fuelwood near surrounding forests and the limited access to alternative energy sources. This pronounced urban–rural disparity is a central finding, underscoring the persistence of traditional energy sources in less developed areas and reflecting a classic phenomenon often described by the “energy ladder” concept, where households transition from biomass to cleaner fuels (e.g., LPG and electricity) as income and access improve [28]. In our study

area, rural households remain largely at the lower rungs of this ladder, heavily reliant on readily available, but often unsustainably harvested, biomass.

The overall mean daily fuelwood consumption per capita was 0.89 kg (326.3 kg per person per year), and the average daily household consumption in the study area was 6.13 kg of dried biomass (Table 3). The variation in fuelwood consumption across different areas within the study site was also notable. The lowest average daily per capita consumption was observed in Mattu Town (0.5 kg), while the highest was in Yabela Kebele (1.13 kg). These figures are consistent with the range of 0.7 kg–1.2 kg per day reported in

TABLE 3: Quantity of fuel wood consumed in the study area.

Consumption	Quantities kg									
	Rural	Urban	Mettu town	Bedele town	Dabena Daru	Mirga Mut e	Yabela	Gaba Guda	Kodahiri	Adele-Gumer
Daily/household	7.32	2.55	2.51	2.6	6.93	7.53	8.25	7.56	6.51	7.2
Daily/individual	1.02	0.51	0.5	0.52	1.06	1.08	1.13	1.03	0.92	0.93
Weekly/household	51.25	22.5	20	25	49	53	58	52.92	46	50.5
Annual/household	2672	933	916	949	2530	2822	3011	2759.4	2376.2	2628
Annual/individual	372.3	186.2	182.5	190	387	394	376	412.5	336	339.5

Note: Source: Kitchen Measurement, 2024.

previous studies [7, 29]. For example, Gaya et al. [30] reported a weekly household fuelwood consumption of 54.1 kg in rural areas. The total estimated annual fuelwood biomass consumption by households in the study area was 187,026.3 kg (187.03 tons).

Based on established conversion factors, burning 1 kg of fuelwood releases approximately 1.518 kg of carbon, 1.406 kg of CO₂, 0.084 kg of CH₄, and 0.028 kg of N₂O. Therefore, the estimated emissions from burning 187.03 tons of fuelwood in the study area annually amount to 295.5 tons of carbon, 262 tons of CO₂, 15.7 tons of CH₄, and 0.48 tons of N₂O. This represents a significant contribution to greenhouse gas emissions and highlights the environmental impact of relying on fuelwood as a primary energy source. Beyond climate change contributions, the scale of consumption and associated emissions point to several critical implications. Environmentally, such high demand for fuelwood likely accelerates deforestation and forest degradation in the surrounding areas, impacting biodiversity, soil stability, and water resources [31]. The reliance on biomass also perpetuates IAP, a major public health concern. Burning solid fuels in poorly ventilated homes exposes household members, particularly women and young children, to high levels of particulate matter and other harmful pollutants, leading to increased incidences of acute respiratory infections, chronic obstructive pulmonary disease, and other non-communicable diseases [32]. Furthermore, the time and labor involved in fuelwood collection, predominantly undertaken by women and girls in rural settings, contribute to “time poverty,” diverting them from education, income-generating activities, or other productive endeavors [33]. Addressing this consumption pattern is thus crucial not only for climate mitigation but also for improving public health, promoting gender equality, and fostering sustainable livelihoods in the region. Further research should investigate the long-term effects on carbon sequestration and assess the specific health burden attributed to IAP in the study area.

3.3. Factors Affecting Fuelwood Consumption. The multiple correlation determinations show that R squared is 0.524, meaning that approximately 52.4% of the variability in the amount of fuel wood is accounted for by variables in the model (Table 4). The adjusted R-squared indicates that approximately 50.9% of the variability in the amount of fuel wood was accounted for by the model even after considering the number of predictor variables. The *p* value of the F-test to determine if the overall model fit is less than 0.05 indicates that the model is statistically significant. Understanding these influencing factors is critical for designing targeted and effective interventions aimed at promoting sustainable energy transitions and reducing reliance on fuelwood.

The multiple linear regression model reveals that household age, education level, monthly income, and distance to fuelwood sources negatively influence per capita fuelwood consumption, while household size has a positive influence. This aligns with findings from Tariku et al. [34] in Ethiopia, which also demonstrated a positive correlation between household size and fuelwood consumption and

a negative correlation between education level and fuelwood consumption.

Household age: The negative coefficient (−0.107) suggests that older households tend to consume less firewood. This could be attributed to a combination of factors. As household members age, family size might decrease due to children leaving home, thus reducing overall energy demand. Additionally, older individuals might have accumulated more resources over time, allowing them to invest in more efficient cooking technologies or transition to alternative energy sources. This phenomenon aligns with observations of household life cycles influencing energy choices [35].

Education level: The negative coefficient (−0.25) indicates that higher levels of education are associated with lower fuelwood consumption. This is likely due to increased awareness of the health and environmental impacts of fuelwood use, as well as greater access to alternative energy sources and more efficient cooking technologies, which aligns with Danlami [36]. More educated households may also prioritize time-saving and cleaner energy options. Particularly, women with higher levels of education may have less time to invest in fuelwood collection due to their involvement in other activities. This finding strongly implies that investments in education, particularly for women, can serve as a powerful catalyst for adopting cleaner energy solutions, contributing to both environmental sustainability and improved public health outcomes.

Monthly income: The negative coefficient (−0.087) suggests that higher monthly income leads to decreased fuelwood consumption. This is consistent with the expectation that wealthier households can afford and utilize alternative energy sources, reducing their reliance on fuelwood. This result is a fundamental tenet of the energy ladder model, where increased affordability directly translates to a shift away from traditional biomass fuels [37]. Policies aimed at poverty reduction and income generation could therefore indirectly, yet significantly, contribute to reduced fuelwood dependency.

Distance from fuelwood source: The negative coefficient (−0.181) indicates that households located further from fuelwood sources consume less firewood. This is intuitive, as increased distance translates to higher time and effort costs associated with fuelwood collection, incentivizing households to either use less fuelwood or switch to alternative energy sources. This highlights the practical barriers faced by remote communities and underscores the need for localized energy solutions or improved access to sustainable alternative fuels to alleviate the burden of collection.

Family size: The positive coefficient (0.215) indicates that larger families consume more firewood, reflecting the greater energy demands for cooking, heating, and other household activities. This direct relationship emphasizes the cumulative impact of population growth on forest resources in areas reliant on fuelwood. While larger households might benefit from some economies of scale in cooking, the overall increased demand remains a significant driver of consumption. Therefore, demographic trends and family planning initiatives could indirectly influence fuelwood demand in the long term.

TABLE 4: Factors affecting fuel wood consumption in the study area.

Model	Unstandardized coefficients		Standardized		Sig.	95.0% interval for B	Confidence
	B	Std. error	Beta	T		Lower bound	Upper bound
(Constant)	0.617	0.100	6.200		0.000	0.421	0.814
Household age	−0.107	0.021	−0.291	−4.988	0.000	−0.149	−0.065
Household family size	0.215	0.036	0.326	5.927	0.000	0.144	0.287
Educational level	−0.025	0.012	−0.110	−2.169	0.031	−0.049	0.002
Household monthly income	−0.087	0.013	−0.456	−6.856	0.000	−0.112	−0.062
Household sex	−0.039	0.035	−0.059	−1.121	0.264	−0.108	0.030
Distance	−0.181	0.043	−0.251	−4.227	0.000	−0.265	−0.096
$R^2 = 0.524$							
R^2 Adjusted = 0.509							
F value = 34.514							
F probability = 0.000 ^b							

Note: Dependent variable: quantity of fuel wood consumed by households per day. The “b” appended to the p value is a footnote or flag generated by the statistical software used for the analysis SPSS. It indicates that the actual p value is a very small, nonzero number that has been rounded to three decimal places, resulting in the displayed value of 0.000.

3.4. Tree Species Preference for Fuelwood. The study revealed distinct preferences for fuelwood species across the study areas, with the top three preferred tree species in Bedele town and surrounding village communities identified as *Croton macrostachyus*, *Eucalyptus globulus*, and *Cupressus lusitanica*. Conversely, in Mattu town and its surrounding communities, the most preferred species were *Pouteria adolfi-frederick*, *Prunus africana*, and *Albizia gummifera*. This preference, consistently identified through triangulated evidence from focus group discussions, key informant interviews, and household surveys, indicates a strong community consensus on preferred fuelwood species (Table 5). Observational evidence from the daily supply of burning wood from the forest further corroborated these stated preferences.

Beyond mere abundance, the selection of these species is rooted in a combination of factors, including their superior energetic properties such as high calorific value, low moisture content, minimal ash production, and desirable burning characteristics (e.g., producing less smoke and burning for longer durations). For instance, species like *Croton macrostachyus*, *Pouteria adolfi-frederick*, *Prunus africana*, and *Albizia gummifera* are often traditional choices, valued not only for their fuel qualities but sometimes also for their cultural significance or ease of processing. The rapid growth rates of exotic species like *Eucalyptus globulus* and *Cupressus lusitanica*, despite potentially having different burning characteristics compared to native species, make them readily available and thus highly utilized, particularly in areas where indigenous forests are depleted or protected [38]. Our findings resonate strongly with other studies in Ethiopia, such as Bahru et al. [39], who similarly identified *Pouteria adolfi-frederick*, *Prunus africana*, *Croton macrostachyus*, and *Cupressus lusitanica* as highly preferred wood fuel species, underscoring the regional consistency in these preferences driven by local availability, growth characteristics, energetic properties, and long-standing traditional practices.

This selective pressure on a limited number of preferred species carries significant ecological implications. The sustained harvest of high-demand species, particularly slow-growing indigenous trees like *Pouteria adolfi-frederick*,

TABLE 5: Tree species preferred by households in the study area.

s/n	Tree species preferred for fuelwood	Percentage
1.	<i>Pouteria adolfi-frederici</i> (qararo)	20
2.	<i>Prunus africana</i> (Hoomi)	15
3.	<i>Albizia gummifera</i> (hambabesa)	14
4.	<i>Croton macrostachys</i> (Makkanisa)	10
5.	<i>Millettia ferruginea</i> (sotallo)	9
6.	<i>Acacia abyssinica</i> (Laaftoo)	8
7.	<i>Eucalyptus globulus</i> (Baargamo Adii)	7
8.	<i>C. lusitanica</i> (Gaaitira Faranji)	6
9.	<i>M. lanceolata</i> Forssk (Abayyii)	5
10.	<i>Cordia africana</i> (Waddeesa)	3
11.	<i>Ficus sur</i> (Harbu)	2
12.	<i>Podocarpus falcatus</i> (Birbirssa)	1

Note: Source: field survey, 2024.

Prunus africana, and *Albizia gummifera*, contributes directly to the depletion of their populations and overall forest degradation. Such targeted extraction can lead to a shift in forest composition, favoring less desirable or faster-growing species, and ultimately reducing the ecological resilience and biodiversity of the forest ecosystem [40, 41].

As perceived by the community members in our study, this over-reliance on fuelwood, largely supplied by the identified preferred species, manifests as significant environmental challenges within the study areas. Respondents indicated that this practice leads to 36.06% forest degradation, 29.41% soil degradation, 21.48% biodiversity loss, and 13.04% exacerbation of climate change. The removal of forest cover for fuelwood directly contributes to soil erosion by exposing topsoil to the erosive forces of rainfall and wind, thereby diminishing soil fertility and agricultural productivity [40]. Furthermore, the loss of specific tree species, which often play critical roles as keystone species or provide essential ecosystem services, leads to a significant decline in overall biodiversity and disrupts complex ecological processes, impacting habitat for other flora and fauna. The cumulative effect of deforestation for fuel, releasing stored carbon into the atmosphere, directly exacerbates local and

regional climate change impacts, aligning with broader findings on the global contribution of household solid fuel combustion to environmental deterioration and habitat loss [8, 42].

These findings underscore the urgent need for integrated sustainable forest management practices and the promotion of alternative energy sources to mitigate the adverse environmental impacts observed. Understanding community preferences for fuelwood is vital for developing targeted and effective interventions. These could include promoting sustainable harvesting techniques for preferred species, establishing community woodlots with fast-growing alternatives like improved Eucalyptus varieties, and supporting the adoption of fuel-efficient stoves. Such multifaceted approaches are essential to simultaneously address the energy needs of local communities and reduce the prevailing deforestation pressures, thus contributing to both environmental sustainability and community well-being [42].

4. Conclusions

The study found that firewood is the primary source of power for most families in both rural and urban areas, as the majority can afford biomass fuel. The high demand for firewood is influenced by various socioeconomic factors, including household age, family size, household income levels, limited access to alternative energy sources, and the distance between houses and sources of firewood in forests. The study quantified household fuelwood consumption in rural areas (7.32 kg/day) compared to towns (2.56 kg/day), indicating that rural households consume more fuelwood than urban households. Approximately 187.3 tons of dry biomass was burned in the areas, resulting in an estimated 262 tons of CO₂ emissions. The study also identified the most popular tree species for firewood consumption in the study area (*Pouteria adolfi-frederick*, *Prunus africana*, *Albiza gummifera*, *Croton macrosstachys*, *Millettia ferruginea*, *Acacia abyssinica*, and *Eucalyptus globulus*), leading to excessive forest degradation, soil degradation, biodiversity loss, and climate change. To address these challenges, regulatory bodies may enforce laws and regulations on reforestation initiatives, poverty alleviation programs, promoting alternative cooking fuels, planting fast-growing wood tree species, and community forest management initiatives.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Conflicts of Interest

The authors declare no conflicts of interest.

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References

- [1] Y. Addis Alemayehu, "Status and Benefits of Renewable Energy Technologies in the Rural Areas of Ethiopia: A Case Study on Improved Cooking Stoves and Biogas Technologies," *International Journal of Renewable Energy Development* 4, no. 2 (2015): 103–111, <https://doi.org/10.14710/ijred.4.2.103-111>.
- [2] IEA, *World Energy Outlook WEO* (OECD/IEA, 2010).
- [3] J. Kyayesimira and F. Muheirwe, "Health Concerns and Use of Biomass Energy in Households: Voices of Women From Rural Communities in Western Uganda," *Energy Sustainability and Society* 11, no. 1 (2021): 42, <https://doi.org/10.1186/s13705-021-00316-2>.
- [4] I. Das, P. Jagger, and K. Yeatts, "Biomass Cooking Fuels and Health Outcomes for Women in Malawi," *EcoHealth* 14, no. 1 (2017): 7–19, <https://doi.org/10.1007/s10393-016-1190-0>.
- [5] B. A. Franklin, R. Brook, and C. Arden Pope III, "Air Pollution and Cardiovascular Disease," *Current Problems in Cardiology* 40, no. 5 (2015): 207–238, <https://doi.org/10.1016/j.cpcardiol.2015.01.003>.
- [6] R. Bailis, M. Ezzati, and D. M. Kammen, "Mortality and Greenhouse Gas Impacts of Biomass and Petroleum Energy Futures in Africa," *Science* 308, no. 5718 (2005): 98–103, <https://doi.org/10.1126/science.1106881>.
- [7] J. N. Kamau, "Fuel-Wood Consumption Patterns Among Low-Income Households in Nakuru County, Kenya," *Journal of Energy in Southern Africa* 25, no. 3 (2014): 245–255, <https://doi.org/10.1080/10242694.2014.1101045>.
- [8] S. C. Anenberg, K. Balakrishnan, J. Jetter, et al., "Cleaner Cooking Solutions to Achieve Health, Climate, and Economic Co-Benefits," *Environmental Science and Technology* 47, no. 9 (2013): 3944–3952, <https://doi.org/10.1021/es304942e>.
- [9] Mattu Administrations and Municipal Offices (2024).
- [10] Bedele Administrations and Municipal Offices (2024).
- [11] C. R. Kothari, *Research Methodology: Methods and Techniques* (New Age International, 2004).
- [12] H. R. Bernard, *Research Methods in Anthropology: Qualitative and Quantitative Methods*, 3rd ed. (AltaMira Press, 2002).
- [13] S. Eshetu and Y. Tesfaye, "Contribution of Fuel Wood Income From Natural Forests to Household Economy in Delanta District, Northeastern Ethiopia," *International Journal of Financial Research* 2024, no. 1 (2024): 1–15, <https://doi.org/10.1155/2024/8768568>.

- [14] S. Pachauri, "An Analysis of Cross-Sectional Variations in Total Household Energy Requirements in India Using Micro Survey Data," *Energy Policy* 32, no. 15 (2004): 1723–1735, [https://doi.org/10.1016/s0301-4215\(03\)00162-9](https://doi.org/10.1016/s0301-4215(03)00162-9).
- [15] M. Ezzati and D. M. Kammen, "Indoor Air Pollution From Biomass Combustion and Acute Respiratory Infections in Kenya: An Exposure-Response Study," *The Lancet* 358, no. 9282 (2001): 619–624, [https://doi.org/10.1016/s0140-6736\(01\)05777-4](https://doi.org/10.1016/s0140-6736(01)05777-4).
- [16] H. Girma, *Environment Law in Ethiopia: International Encyclopedias of Laws* (2000).
- [17] V. Modi, S. McDade, S. Mutiga, G. Gardner, S. Hon, and J. Wakasa, *Energy Access for the Poor: The New York State Task Force on International Energy Affairs* (United Nations Development Programme (UNDP), 2006).
- [18] G. Bekele and K. Bekele, "Renewable Energy Resource Potentials in Ethiopia: Future Prospects for Energy Development," *Energy & Environment* 23, no. 1 (2012): 133–152.
- [19] Z. Gebreegziabher, A. Mekonnen, and G. Köhlin, "The Impact of Household Energy Choices on Deforestation in Rural Ethiopia: A Choice Experiment Approach," *Forest Policy and Economics* 85 (2017): 23–33.
- [20] S. B. Gordon, M. Ezzati, and S. Ezzati, "Cardiovascular Effects of Household Air Pollution," *Current Environmental Health Reports* 1, no. 4 (2014): 273–287.
- [21] D. F. Barnes, L. Halpern, and G. Fitzgerald, *The Energy Access Situation in Developing Countries: A Review Covering the Least Developed Countries, Sub-Saharan Africa, and Selected Developing Countries* (The World Bank, 2010).
- [22] UNDP, *Human Development Report 2016: Human Development for Everyone* (United Nations Development Programme, 2016).
- [23] WHO, *Burning Opportunity: Clean Household Energy for Health, Sustainable Development, and Wellbeing* (World Health Organization, 2016).
- [24] H. Shifera, M. Tadesse, and B. Birhanu, "Forest Encroachment and Its Drivers in Bale Mountains National Park, South-eastern Ethiopia," *Journal of Ecology and the Natural Environment* 9, no. 4 (2017): 81–91.
- [25] Z. Gebreegziabher, "Household Demand for Improved Cooking Technologies in Rural Ethiopia," *Climate Policy* 17, no. S1 (2017): S101–S114.
- [26] M. Mecha, M. Tesfaye, and A. Haileselassie, "Household Energy Use Patterns and Implications for Forest Resources in Ensaro District, Ethiopia," *Journal of Energy in Southern Africa* 28, no. 3 (2017): 63–74.
- [27] J. A. Zélolo, S. C. Ogochukwu, and C. G. Okwu, "Rural-Urban Differentials in Fuel-Wood Consumption in Kenya," *Renewable Energy* 93 (2016): 141–149, <https://doi.org/10.1016/j.renene.2016.02.019>.
- [28] World Bank, *Household Cookstoves, Environment, Health, and Climate Change: A New Look at an Old Problem* (World Bank, 2011).
- [29] S. Bhattacharyya and S. Das, "Determinants of Household Fuel-Wood Consumption in the Indian Sub-Continent," *Energy Policy* 81 (2015): 132–141, <https://doi.org/10.1016/j.enpol.2015.02.014>.
- [30] A. Y. Gaya, A. Mustapha, A. B. Mohammed, et al., "Determinants of Fuel Wood Consumption in Rural and Urban Farming Households of Kano State, Nigeria," *Renewable* 3, no. 1 (2023).
- [31] FAO, *The State of the World's Forests 2020: Forests, Biodiversity and People-Inseparable* (FAO, 2020).
- [32] WHO, *Household Air Pollution and Health* (World Health Organization, 2018).
- [33] UN Women, *The Gendered Impacts of Climate Change: A Review of Research in Developing Countries* (UN Women, 2018).
- [34] A. Tariku, T. Dinku, and A. Zewdie, "Socio-Economic Factors Influencing Household Fuel-Wood Consumption in Ethiopia," *Energy for Sustainable Development* 38 (2017): 1–9, <https://doi.org/10.1016/j.esd.2017.02.001>.
- [35] M. A. Janssen, M. C. Lemos, and E. F. Moran, "Understanding Human-Environment Interactions: A Framework for Integrated Analysis," *Ecology and Society* 10, no. 1 (2005): 33.
- [36] A. H. Danlami, "Assessment of Factors Influencing Firewood Consumption in Bauchi State, Nigeria," *Journal of Sustainability Science and Management* 14, no. 1 (2019): 99–109.
- [37] R. Heltberg, "Fuel, Forest, and Poverty: A Note on the Energy Ladder in Developing Countries," *Environmental Economics and Policy Studies* 6, no. 3 (2004): 225–231.
- [38] A. Mekonnen and N. J. Kohls, "Forest Resource Dependence and Household Energy Use in Rural Ethiopia," *Environmental and Resource Economics* 36, no. 3 (2007): 321–343.
- [39] S. Bahru, M. Tadesse, and T. Mengistu, "Wood Fuel Consumption and Its Impacts on Forest Resources: The Case of Boricha Woreda, Sidama Region, Ethiopia," *Journal of Forest and Livelihood* 19, no. 1 (2021): 1–12.
- [40] Y. Chanie, G. Genanew, and Y. Fikiru, "The Contribution of Wood Fuel Consumption to Deforestation and Forest Degradation in Ethiopia: A Review," *Journal of Agricultural Environmental and Social Sciences* 1, no. 1 (2013): 1–8.
- [41] H. G. Zewdie, S. W. Gebremedhin, and A. T. Beyene, "Assessment of Forest Degradation and Its Drivers in Ethiopia: A Review," *Journal of Ecology and the Natural Environment* 12, no. 1 (2020): 1–13.
- [42] E. Mulugeta, A. Melaku, and E. Lulekal, "Wood Fuel Production and Consumption Systems and Their Implications for Sustainable Forest Management in Ethiopia: A Review," *Journal of Forest and Livelihood* 17, no. 1 (2019): 1–10.