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Correlation of woodfuel production participation among rural households in the drylands of Ethiopia

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Woodfuel production and consumption have been a concern for multiple stakeholders involved in household energy use, deforestation, and climate change. While research into the underlying decision-making process is growing, it remains insufficient. Such a study offers opportunities to develop policies that enable diversification of household energy consumption and livelihood options away from woodfuel use. Policymakers often lack an understanding of factors correlated with households' participation in woodfuel production. Therefore, this study examined the correlation between household participation in woodfuel production and factors that influence households' participation in woodfuel production in dryland areas of Ethiopia. Data were collected from 1,114 purposively selected woodfuel-producing and non-producing households through household surveys, key informant interviews, and focus group discussions. The sample included 775 participant households and 339 non-participant households. The collected data were analyzed using descriptive statistics and a binary logistic regression model. The results revealed that drought and related shocks are the main factors that forced households to participate in woodfuel production. The model results indicated that age, education, landholding, livestock holding, production asset value, ownership of improved cook stoves, number of years lived in the area, distance from the forest, access to forest extension, and institutional membership are statistically significant factors that negatively influence household participation in woodfuel production. On the other hand, household expenditure and drought occurrence positively and significantly influence the participation of households in woodfuel production. The findings of the study suggest that sustainable management and utilization of dryland forest resources require considering socioeconomic, demographic, institutional, and environmental factors correlated with households' decisions to participate in woodfuel production. This can be achieved through sound institutional setups and policy frameworks in the sector.

KEYWORDS

charcoal, dryland, correlates, firewood, participation, woodfuel

1 Introduction

Woodfuel (charcoal and firewood) offers various benefits such as providing energy for over 40 million people globally (FAO, 2017). Woodfuel serves a crucial energy source for the developing world (Njenga et al., 2023), accounting for 50%−90% of household energy in developing countries (Singh et al., 2018). Approximately 70% of the population in sub-Saharan Africa rely on woodfuel as their primary energy source (Sola et al., 2017). Similarly, approximately 92% of the population in Ethiopia depends on woodfuel (Mondal et al., 2018). In both rural and urban Ethiopia, woodfuel is the primary source of energy for cooking and heating, and it is expected to remain a significant energy source in the future, not only in Ethiopia but also in developing countries worldwide (Tucho and Nonhebel, 2017). Currently, woodfuel production is increasing due to the preferences and demands of the growing urban population (Bekele and Kemal, 2022; Yalew, 2022).

In addition to serving as an important energy source, woodfuel is also a vital means of livelihood for rural households and plays a role in improving the assets of developing countries such as Ethiopia (Sola et al., 2017; Girma et al., 2022). In Ethiopia, woodfuel is the most important forest product, with a total volume of 116 million cubic meters consumed in 2013 (MEFCC, 2017). Ethiopia's woodfuel production and consumption in 2015 was estimated at 108,173,872 and 108,171,205 m^3 at the national level, respectively (UNEP, 2019). Woodfuel, specifically charcoal, provides regular household income and seasonal income during lean agricultural seasons. It serves as a safety net to mitigate economic shocks and contributes toward uplifting households from poverty (Obiri et al., 2014; Jones et al., 2016; Ndegwa et al., 2016; Smith et al., 2017; Brobbey et al., 2019). Woodfuel is essential for meeting a wide range of needs within rural household livelihoods, especially in dryland areas (Girma et al., 2022).

Despite its significant household economic and energy contributions, woodfuel has a negative impact owing to its correlation with adverse environmental effects. The over-dependency on woodfuel production and consumption from forests and woodlands leads to depletion of natural resources in developing countries, including Ethiopia (Yalew, 2022). Moreover, the exploitation of forest resources for woodfuel production is not properly managed and is unsustainable in Ethiopia (MEFCC, 2017; Tassie et al., 2021). It is estimated that 37 million cubic meters of woodfuel is produced through unsustainable extraction from natural forests. Unsustainable woodfuel production and consumption contribute to forest and land degradation as well as climate change impacts (Njenga et al., 2023). Charcoal production has a stronger negative correlation with forest and land degradation compared to firewood (Chidumayo and Gumbo, 2013; FAO, 2017). In Ethiopia, the annual forest degradation due to unsustainable woodfuel production is estimated to be between 0.58 and 0.87 million hectares (Yalew, 2022). According to Chidumayo and Gumbo (2013), greenhouse gas emissions from charcoal production in tropical ecosystems amounted to 71.2 million tons of carbon dioxide and 1.3 million tons of methane in 2009, which was equivalent to 7% of tropical deforestation. As a result of unsustainable woodfuel production and consumption, forest degradation accounts for approximately 46% of the total greenhouse gas emissions from the forestry sector (FDRE, 2011). Without new policy interventions, the number of people dependent on woodfuel production and consumption is expected to increase due to population growth and an increasing demand for biomass, exacerbating the negative impact (Rafaj et al., 2018).

Previous evidence has shown that socioeconomic, demographic, and institutional factors play a critical role in shaping the outcomes of forest ecosystems, largely through their impact on human behavior and incentives for woodfuel production (Mulenga et al., 2015; Brobbey et al., 2019; Tassie et al., 2021). Furthermore, different types and levels of institutional arrangements interact with socioeconomic and demographic attributes in various ways, resulting in specific outcomes for forest use and conditions for manageable woodfuel production (Mulenga et al., 2015; Vollmer et al., 2017). This is particularly essential in the design and implementation of policies and programs aimed at achieving environmentally sustainable woodfuel production in the drylands of Ethiopia. A rural household, pursuing feasible livelihood strategies, is the ultimate decision-maker regarding the use of natural resources to carry out activities for achieving desired objectives (Abera et al., 2021). When making production decisions, smallholder rural households aim to maximize their livelihood benefits over time based on their existing resource assets. These decisions are influenced by the prevailing socioeconomic and policy environment. For example, a household's decision to engage in woodfuel production in dryland woodlands may be affected by various factors such as socioeconomic, policy, and natural elements (Brobbey et al., 2019; Tassie et al., 2021). It is worth mentioning that household poverty, food security status, and natural disasters such as drought can motivate households to participate in such activities.

This study aims to understand the factors that influence households' decision-making process regarding whether to produce woodfuel or refrain from it. This understanding is crucial for the success of any policy intervention in the woodfuel sector, directing interventions toward livelihood improvement, poverty reduction, and environmental conservation, specifically targeting woodfuel and other natural resources. This study provides opportunities to develop and refine policies regarding woodfuel that encourage people to transition from woodfuel use to renewable energy resources. However, the identification and analysis of these factors as well as the necessary information for practical policy and development actions are limited and lack concrete evidence from the primary population directly involved in woodfuel production activities. Therefore, a detailed analysis of the factors determining woodfuel production in the dry woodland areas of the country is necessary for better targeting and designing intervention strategies.

This study was conducted in the drylands of Ethiopia to (1) assess the motivation of households engaged in woodfuel production, (2) characterize different shocks that push households toward woodfuel production, (3) understand the factors that influence and motivate households to participate in woodfuel production, and (4) identify policy options that align with the interest of smallholders and the forest ecosystem. The results of this study contribute to designing appropriate policies and interventions by the government and development practitioners to achieve sustainable woodfuel production and consumption.

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TABLE 1 List of the surveyed sample districts from dryland areas of Ethiopia.

No.	Name of districts	Location
1	Jawi	Northwestern Ethiopia
2	Adami Tulu	Central Ethiopia
3	Boset	Central Ethiopia
4	Amibara	Central Ethiopia
5	Awash Fentale	Central Ethiopia
6	Ararso	Eastern Ethiopia
7	Kebribeyah	Eastern Ethiopia
8	Jeldesa	Eastern Ethiopia
9	Biyoawale	Eastern Ethiopia
10	Asseliso	Eastern Ethiopia
11	Abala Abaya	Southern Ethiopia

2 Materials and methods

2.1 Study area

The study was conducted in dryland areas of Ethiopia, with sample districts drawn from various regions. Three livelihood groups of the target population were included in the study: farming, agro-pastoral, and pastoral communities. The target population comprised woodfuel producers and nonproducers found in the dryland woodland areas. The study was conducted in the eastern Ethiopia, and it covered the Somali region and rural areas of Dire Dawa Administration Council from eastern Ethiopia, the Amhara region from northwestern Ethiopia, the Afar and Oromia regions from central Ethiopia, and the SNNPR from southern Ethiopia. These areas have the typical woodfuel producers, and the study covered 11 dryland districts (Table 1).

2.2 Sampling method

The target population consists of communities in dry woodland areas of the country. These communities further comprise four groups of households based on their participation in woodfuel production: households that participate in charcoal production, firewood production, and both charcoal and firewood production and households that do not participate in woodfuel production. We selected sample households from each of these population strata. We used the snowball sampling method for participating households and the stratified random sampling procedure for non-participating households. As a result, we sampled 775 participating households and 339 non-participating households, obtaining a total of 1,114 households.

2.3 Data collection and variable selection

The data were collected from primary and secondary sources. Surveys were conducted with individuals who indicated that producing and selling woodfuel (charcoal or fuelwood) is one of their activities as well as with nonproducers. A mixed-method approach was used, combining focus group-based rural appraisal tools and semi-structured interviews.

Semistructured interviews were conducted to gather quantitative data from households that produce and do not produce woodfuel. Focus group discussions (FGDs) and key informant interviews (KIIs) were performed to collect qualitative data regarding the reason for household engagement in woodfuel production and the occurrence and severity of different shocks. One FGD per kebele was conducted with a diverse mix of men and women who were actively engaged and not engaged in woodfuel production. A total of 44 FGDs were held, with each group consisting of 8–12 woodfuel producers and non-producers of mixed genders. In addition, 33 KIIs were conducted in each district with experts, elders, and religious leaders. Initial participants were selected by district and kebele experts, and subsequent participants were selected through snowball sequential sampling. Different participants were used for each rural appraisal exercise. In addition to addressing a core set of questions, the research also followed the interests and experiences of specific groups, resulting in some data being collected only from certain groups, as noted in the results section. The expected explanatory variables used in the model were listed from related literature (Table 2).

2.4 Data analysis and binary logit model specification

Before conducting data analysis, data management, data transformation, and diagnostic tests such as multicollinearity and correlation were performed. The collected dataset included both qualitative and quantitative data; descriptive statistical tools and qualitative narration were utilized for quantitative and qualitative data analysis, respectively. Quantitative data were analyzed using statistical tools such as frequency, percentage, mean, and standard deviation. Independent *t*-tests and chi-squared tests were used to analyze the correlation of continuous and dummy variables, respectively, with the households' decisions to produce woodfuel. Qualitative data collected through FGDs and KIIs were analyzed using text summaries and narratives and were subsequently triangulated with quantitative survey results.

Furthermore, the contributing factors of households participating in woodfuel production were analyzed using a binary logit model to identify and analyze the determinants of households' decisions to produce woodfuel. The selected model was suitable for the logistic nature of data distribution. For data analysis, STATA version 16 was used, and the results are presented in graphical, narrative, and tabular forms.

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TABLE 2 Variables used in the binary logit model.

Dependent variable	Category	Description of the variable	
Participation decision	Dummy	Households that participated in woodfuel production take a value of 1, and those that did not take 0.	
Explanatory Variables	Category	Description	Expected sign
Sex	Dummy	Sex of the household head, 1 = male, 0 = female	+
Age	Continuous	Age of the household head (years)	−
Education status	Dummy	Educational level of the household head, 1= literate, 0 = illiterate	+
Landholding	Continuous	Household-owned agricultural land size (ha)	−
Livestock(TLU)	Continuous	Total livestock unit in TLU	−
Annual income	Continuous	Total annual household income in ETB	−
Expenditure	Continuous	Total annual household expenditure in ETB	
Production asset value	Continuous	Total production asset value in ETB	−
Improved cookstoves (ICS) ownership	Dummy	Ownership of ICS (1= owned ICS; 0 = no ICS)	−
Market information	Dummy	Access to market information (1 = yes; 0 = no)	+
Access to forest extension	Dummy	Access of forest extension (1 = yes; 0 = no)	−
Distance to forest	Continuous	Distance from homestead to forest (km)	−
Drought occurrence	Continuous	Frequency of drought occurrence in the last 10 years	+
Livestock disease occurrence	Continuous	Frequency of livestock disease occurrence in the last 10 years	+
Crop pest occurrence	Continuous	Frequency of crop pest occurrence in the last 10 years	+
Number of years lived	Continuous	Number of years households lived in the area (years)	−
Institutional membership	Dummy	Membership status in formal or informal institutions (1= yes; 0 = no)	−

2.5 Binary logit model specification

The standard form of the logit model is given by Greene (2003). The logit formulas estimate the probability of Y to be 1 (decision to participate); the probability is referred to as follows (Equations 1 and 2).

$$Y = 0 \text{ is } 1 - q_{it} \text{ (decision to not participate)} \tag{1}$$

$$P\left(Y_t = \frac{1}{X_t}\right) = \frac{e^{\beta X}}{1 + e^{\beta X}} \tag{2}$$

An equivalent form can be stated as follows (Equation 3).

$$\frac{e^{\beta X}}{1 + e^{\beta X}} = \frac{1}{1 + e^{\beta X}} \tag{3}$$

This can be described as :

$$q_{it} = \beta X_{it} + u_{it} \tag{4}$$

where q_{it} = an unobservable latent variable for households participating in the production of woodfuel (Equation 4).

X_{it} = vector of explanatory variables,

β = vector of the parameter to be estimated,

$\mu_{it=}$ error term.

The observed binary (1, 0) indicates whether a household decides to participate in woodfuel production or not, as assumed in the usual logit model (Greene, 2004).

Now $Y_{it}/(1- Y_{it})$ is simply the odds ratio in favor of participating in woodfuel production, that is, the ratio of the probability that a household will participate to the probability that it will not participate. If we take the natural log of (4), we obtain as follows (Equation 4).

$$Li = \ln \frac{Y_t}{1 - Y_t} = qit = \beta_1 + \beta_{2X_{it}} + u_{it} \tag{5}$$

That is, L, the log of the odds ratio, is not only linear in X_{it} but also (from the estimation viewpoint) linear in the parameters (Equation 5).

3 Results and discussion

3.1 Results on demographic, socioeconomic, institutional, and shock characteristics

This section presents descriptive statistics and a discussion based on the dataset. Table 3 presents a summary of the sample household characteristics, resources owned, natural factors, and statistical test results regarding the relationship of these factors in the sample groups—participants involved in woodfuel production and non-participants. The results indicate that proportionately more participant households were headed by male heads compared to the non-participant households (Table 3). This suggests that among the total sample observations, only 24% were women while the remaining 76% were men. Out of the total surveyed households,

only 75.2% of men and 24.8% of women reported that they engaged in woodfuel production, whereas approximately 77.9% of men and 22.1% of women reported being non-participants in woodfuel production. Regarding the impact of education status, there is a statistically significant higher proportion of illiterate households among the woodfuel production participants compared to non-participants. The chi-squared test result indicates that households' decisions in woodfuel production participation had a statistically significant association with educational status at a 1% level of significance.

The independent mean comparison results for the continuous explanatory variables between the two sample groups are presented in Table 4. The results indicate that the mean age of non-participants was 41.77 years, while that of participants was 39.5 years. Although the mean age of non-participants slightly exceeded the mean age of participants, the difference was statistically significant at a 1% significance level. Similarly, the mean length of stay of households in the area was 31.9 years for non-participants and 7.6 years for participants. The difference between the two groups was statistically significant at a 1% significance level.

On average, the annual income was ETB 41,304.88 (±44,675.76) for non-participant households and ETB 51,317.26 (±56,004.45) for participant households. Similarly, the average production asset value of non-participant households was estimated to be ETB 1,423.40 (±5,671.39) while that of participating households was ETB 3,073.87 (±8,244.64). The mean expenditure shows that a participant household spent ETB 24,921.31 (±46,192.14), while non-participant households spent ETB 46,675.03 (±59,376.45). In addition, the land and livestock holdings of non-participant households were estimated at ETB 4.0334 (±5.59726) and ETB 22.2096 (±30.33310), while those of participant households were ETB 1.5378 (±1.66186) and ETB 6.2106 (±6.44613), respectively. The independent sample *t*-test for the mean difference in annual income, production asset value, expenditure, land holdings, and livestock holding between the two sample groups showed a statistically significant difference at a 1% level of significance.

The study further assessed the institutional factors associated with households' participation decisions. The χ^2 statistical test results indicate statistically significant correlations between participation decisions and access to market information, institutional membership, and access to extension services for woodland forests at 10%, 1%, and 1% levels of significance, respectively. In addition, the study found that households were more motivated to participate in woodfuel production during times of stress, such as droughts and outbreaks of livestock diseases. Households' participation in woodfuel production was confirmed to be strongly associated with their exposure to drought and livestock disease, with these associations being statistically significant at less than a 1% level of significance (Table 4).

3.2 Motivations of households' participation in woodfuel production

Figure 1 presents the main factors that motivated households to engage in woodfuel production in the study area. The survey results indicate that the majority (37%) of the sampled households were motivated to produce woodfuel because selling charcoal was their main livelihood activity, while 30% were motivated for obtaining firewood. The seasonal gap-filling function of woodfuel contributed to ∼17.7% of households engaging in firewood production and 15.6% of those engaging in charcoal production during times of food shortage. Similarly, woodfuel production was considered an alternative employment option due to the lack of other alternatives, as reported by 14.2% of charcoal producers and 10.9% of firewood producers. Approximately 16.3% of the respondents revealed that they engaged in woodfuel production, especially firewood collection, to cover unexpected expenses resulting from shocks such as crop failure and livestock disease.

Woodfuel is one of the vital forest products that provide a safety net, gap-filling, and income-smoothing functions to meet households' daily and seasonal requirements (Schure et al., 2014; Smith et al., 2017). Specifically, woodfuel production is an activity that rural households engage in to generate supplementary income during periods of low agricultural and livestock activities and seasonal food shortages, as well as to generate cash income for household expenditures. Safety-net activities refer to activities performed by rural households to earn additional income when experiencing shocks such as asset loss or illness (Brobbey et al., 2019). Scholars have also shown that the absence of alternative sustainable livelihood activities forces households to engage in woodfuel production (Alhassan et al., 2022).

FGD participants also noted that individuals primarily engage in woodfuel production owing to unexpected expenses related to shocks such as loss of family members or livestock deaths, crop failures, and loss of employment; in response to high urban demand for woodfuel, especially charcoal; and for seasonal needs such as purchasing food during periods of scarcity in dry months.

Woodfuel production was reported to be the primary source of income for all producers. Participants of the FGD prioritized woodfuel production as a viable livelihood source, alongside alternative strategies such as crop production and livestock rearing. During the FGD, it was revealed that income was the main motivation for people to engage in woodfuel production. Another finding indicated that trading natural products helps rural households generate subsistence, if not all, of their cash income (Angelsen et al., 2014). The data from this study illustrate that dryland woodfuel production is a significant source of rural livelihoods, supported by the findings of Schure et al. (2014). A major issue in the dryland area is the lack of income-generating opportunities for rural communities (Abebaw et al., 2012). The FGD participants also mentioned that the start-up capital required for other income-generating activities is substantial and unaffordable for the community. In contrast, the start-up capital required for woodfuel production is minimal. Therefore, according to the FGD, woodfuel production is a much-needed opportunity for those with access to resources and markets to generate income in the drylands of Ethiopia.

3.3 Occurrence of different shocks and severity levels in woodfuel production areas

The results of KIIs, FGD, and household surveys demonstrate the presence of different shocks in the study areas (see Figure 2).

TABLE 3 Chi-squared test of dummy variables correlated to woodfuel production.

Variables	Indicators	Non-participant		Participant		All sample		χ^2
		Freq.	%	Freq.	%	Freq.	%	
Sex	Female	75	22.1	192	24.8	267	24.0	0.909
	Male	264	77.9	583	75.2	847	76.0	
Education status	Illiterate	188	55.5	623	80.4	811	72.8	74.022***
	Literate	151	44.5	152	19.6	303	27.2	
Access to market information	No	180	53.1	366	47.2	546	49.0	3.253*
	Yes	159	46.9	409	52.8	568	51.0	
Access to ICS	No	310	91.4	715	92.5	1,025	92.2	0.361
	Yes	29	8.6	58	7.5	87	7.8	
Membership in different institutions	No	83	24.5	478	61.7	561	50.4	130.508***
	Yes	256	75.5	297	38.3	553	49.6	
Access to woodland forest extension	No	264	77.9	679	87.6	943	84.6	17.207***
	Yes	75	22.1	96	12.4	171	15.4	

*** and * present a 1% and 10% level of significance, respectively.

TABLE 4 *t*-test comparison of continuous variables correlated to woodfuel production.

Variables	Non-participant			Participant			T	*P*-value
	N	Mean	SD	*N*	Mean	SD		
Age	339	41.77	11.40	775	39.50	11.98	2.952	0.003***
Number of years living in the village	338	31.90	14.32	775	7.61	13.31	27.353	0.000***
Total annual income	339	41,304.88	44,675.76	775	51,317.26	56,004.45	3.177	0.002***
Production asset values	339	1,423.400	5,671.39	775	3,073.87	8,244.64	3.863	0.000***
Total expenditure	339	46,675.03	59,376.45	775	24,921.31	46,192.14	6.607	0.000***
Land holding	339	4.0334	5.59726	775	1.5378	1.66186	11.328	0.000***
Livestock (TLU)	339	22.2096	30.33310	775	6.2106	6.44613	13.986	0.000***
Distance to forest resource access	339	4.1698	4.79021	775	3.6772	7.38043	1.129	0.259
Drought	338	1.9497	1.91367	775	3.9045	2.87485	−11.443	0.000***
Livestock disease	337	1.9436	1.91790	775	3.0181	2.54767	−6.934	0.000***
Crop pest	339	1.6372	1.80103	774	1.6034	2.05904	0.262	0.794

***presents 1% level of significance.

The analysis of frequency of shock occurrences indicated that drought was the most common shock, occurring more frequently than other shocks (see Figure 2). Additionally, reduction in agricultural output prices, crop diseases, and family illnesses were identified as the three most important shocks that occurred frequently after drought. Similarly, livestock diseases, increase in agricultural input prices, floods, lack of sustainable household businesses, unemployment, and conflicts were also identified as problems related to shock occurrences, based on their frequency levels in the study areas (Figure 2).

The results of the FGD revealed that various shocks occurring in the dryland areas influenced the livelihoods of households. FGD participants from woodfuel producer households reported that drought is the major problem affecting the different livelihood components of woodfuel producers. Consequently, they were forced to engage in woodfuel production to survive and as an alternative livelihood option. The KIIs also stated that households mainly engage in woodfuel production during times of shock occurrence, which affects their common livelihood resources, mainly livestock and crops. This finding is supported by previous studies. For example, Vollmer et al. (2017) demonstrated that charcoal income serves as a means to alleviate rural poverty. Charcoal income is positively correlated with valuable household assets and increases resistance to chronic shocks (Roussy, 2013; Vollmer et al., 2017). Furthermore, literature shows that woodfuel is used as a coping strategy for shocks that interrupt households' income components by affecting various valuable assets such as livestock (Schure et al., 2014; Jones et al., 2016; Brobbey et al., 2019).

Figure 3 presents the results of the household survey indicating the severity of different shocks. Approximately 42% of the

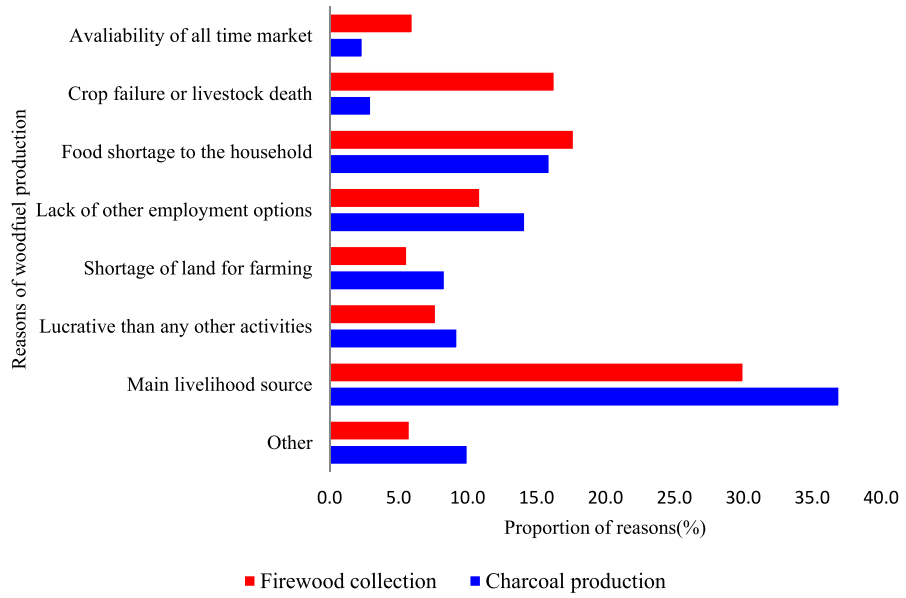

FIGURE 1
Reasons for households' engagement in woodfuel production.

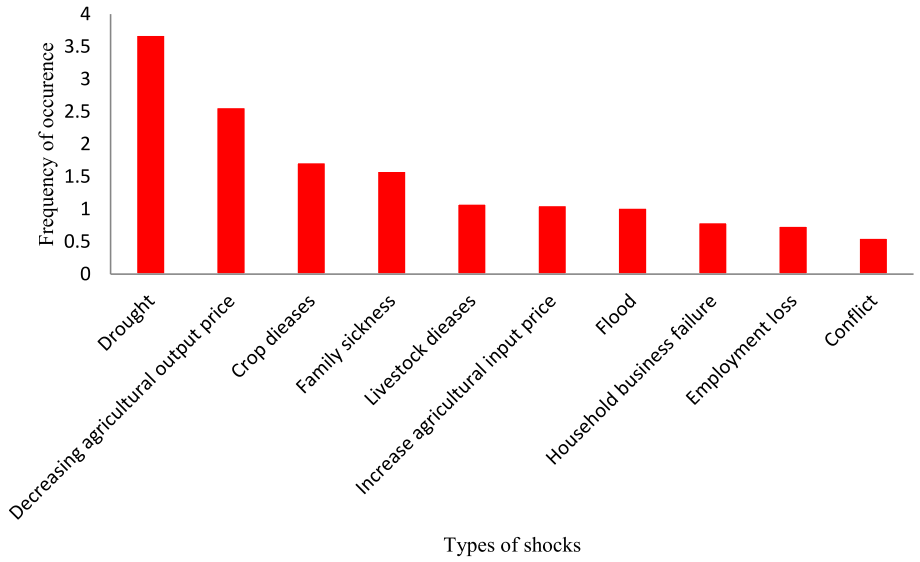

FIGURE 2
Types of shocks in woodfuel production areas.

households reported that drought was highly severe compared to other shocks in the study areas. In addition, increase in food prices, crop diseases, and livestock diseases were significant factors that adversely affected woodfuel producers (Figure 3). Other severe factors mentioned included food and agricultural input price increases.

Findings from FGDs and KIIs revealed that there has been an increase in drought in dryland areas of the country, causing severe damage to household livelihoods. Drought had high and severe effects on livelihood resources, particularly due to water and fodder shortages, which are the main sources of cash income. The effects of drought have forced households to shift toward woodfuel production for their survival. Woodfuel production, especially charcoal, serves as a means to enhance households' ability to withstand various shocks, such as poverty (Zulu and Richardson, 2013; Vollmer et al., 2017).

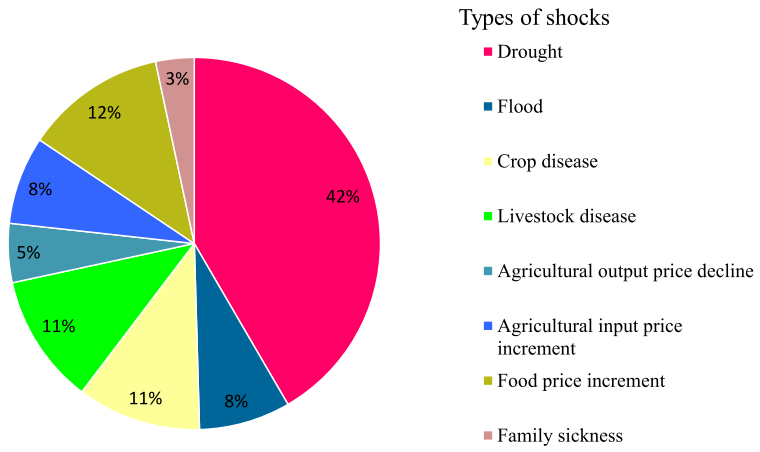

FIGURE 3
Severity levels of different shocks in the study areas.

3.4 Determinants of household participation in woodfuel production

In this section, we focus on understanding some of the major factors affecting household participation in woodfuel production using a binary logit model. Table 5 presents binary logit estimates of the factors influencing household participation in woodfuel production. The last column of Table 5 displays the marginal effect of each independent variable on a household's probability of participating in woodfuel production, holding all other factors constant. The results from the binary logit model show that out of the 17 explanatory variables entered in the model, 11 were significant at 1% and 5% significance levels.

Age of the household head was a significant factor affecting the participation decision at a 1% significance level. The negative sign for the age of the household head suggests that households with relatively older heads were less likely to participate in woodfuel production. The marginal effect indicates that as the age of the household head increases by 1 year, the probability of household participating in woodfuel production decreases by 0.5%, holding all other factors constant. This result agrees with the previous studies (e.g., Mulenga et al., 2015; Jones et al., 2016; Brobbey et al., 2019). A negative and significant relationship was found between education and the likelihood of households participating in woodfuel production at a 5% significance level. The marginal effect result shows that as households attain higher levels of education, the probability of participating in woodfuel production decreases by 8.2% compared to those with no education. This is largely because education provides access to a wider range of income-generating activities and opportunities. Education expands the potential for labor and employment. By contrast, households with lower levels of education may be more economically vulnerable and, therefore, more likely to depend on income from woodfuel (Mulenga et al., 2014, 2015). The result of this study is inconsistent with other findings; for example, Brobbey et al. (2019) found that educated households were more engaged in charcoal production.

Many studies on factors influencing household participation in woodfuel production have identified a lack of wealth or household resources as a major driving factor (e.g., Mwitwa and Makano, 2012; Mulenga et al., 2015). In this study, four wealth indicators, namely, land holding, livestock holding, total annual household income, and the value of production assets owned, were included in the model estimation. The model output confirms the findings in the literature, indicating that households with greater wealth are less likely to engage in woodfuel production. The households' decision to participate in woodfuel production and landholding had a negative and statistically significant relationship at a 5% significance level. The model results indicate that as the land holding size increases by 1 ha, the probability of household participation in woodfuel production decreases by 1.3%. This result aligns with the findings of previous research. For example, Mulenga et al. (2017) and Tassie et al. (2021)demonstrated that households with large landholdings are less likely to participate in woodfuel production.

The model results also indicate that livestock holding and the probability of household participation in woodfuel production are associated negatively and significantly at a 1% significance level. This implies that as livestock holding increases by one TLU, the probability of household participation reduces by 0.9%, while holding other factors constant. Similarly, the value of production assets was found to have a negative and significant relationship with the probability of household participation in woodfuel production at a 5% significance level. The result indicates that an increase of 1 birr in asset value reduces the probability of household participation in wood fuel production by 2.6%. This result is consistent with the findings of Mulenga et al. (2015), which demonstrated that as the asset value of households improves, the probability of their engagement in woodfuel production decreases.

TABLE 5 Binary logit model estimation on factors affecting households' participation in woodfuel production.

Participation	Coef.	Std.Err.	Z	P>z	Marginal effect
Sex	−0.337	0.346	−0.97	0.330	−0.040
Age	−0.041	0.013	−3.15	0.002***	−0.005
Education	−0.629	0.285	−2.20	0.027**	−0.082
Landholding	−0.107	0.044	−2.43	0.015**	−0.013
Livestock(TLU)	−0.077	0.014	−5.38	0.000***	−0.009
Income	−0.104	0.117	−0.89	0.374	−0.012
Expenditure	0.569	0.107	5.30	0.000***	0.067
Production asset value	−0.217	0.090	−2.41	0.016**	−0.026
ICS ownership	−1.630	0.401	−4.06	0.000***	−0.191
Market information	0.103	0.267	0.38	0.701	0.012
Access to forest extension	−0.383	0.310	−1.24	0.216	−0.045
Distance to forest	−0.110	0.025	−4.40	0.000***	−0.013
Drought occurrence	0.281	0.071	3.95	0.000***	0.033
Livestock disease occurrence	0.014	0.070	0.20	0.842	0.002
Crop pest occurrence	0.031	0.072	0.44	0.663	0.004
Number of years lived	−0.093	0.010	−9.57	0.000***	−0.011
Institutional membership	−2.730	0.358	−7.63	0.000***	−0.330
_cons	10.986	1.679	6.54	0.000	
Observation	1,114				
LR $chi^2(17)$	690.10				
Prob > chi^2	0.0000				
Pseudo R^2	0.6260				
Log likelihood	−206.11403				

*** and ** present 1% and 5% significance levels, respectively.

Moreover, the ownership of improved cook stoves (ICS) is negatively associated with household participation in woodfuel production at a 1% significance level. The marginal effect also indicates that as households gain access to ICS, the probability of their participation in woodfuel production decreases by 19.1%. The result is in agreement with the findings of Sola et al. (2019), which revealed that ICS are a demand-side option for forest management by reducing the consumption of biomass in both rural and urban communities.

Household expenditure also showed a positive and significant relationship with household participation in woodfuel production at a 1% significance level. An increase of 1 birr in household expenditure increases the probability of household participation in wood fuel production by 6.7%, holding other factors constant. This implies that households with higher expenditures are more engaged in woodfuel production.

The distance from the household's residence to the forest and household participation in woodfuel production were found to be negatively and significantly associated at a 1% significance level. The marginal effect result shows that as the distance to the forest increases by 1 km, the probability of household participation in woodfuel production decreases by 1.3%, holding other factors constant. This result is likely because when households are located far from the forest and in a place where there is no road infrastructure, they will be discouraged from traveling long distances. Hence, their participation in woodfuel production activities will be obviously reduced.

The study results further indicate that the occurrence of drought and household participation in woodfuel production are positively and significantly associated at a 1% level of significance. The model also demonstrate that when the frequency of drought occurrence increases by one, the probability of household participation in wood fuel production increases by 3.3%, holding other factors constant. This result is consistent with the findings of Brobbey et al. (2019), which indicated that households that consider income from charcoal production to be seasonally important are more likely to engage in charcoal production. Furthermore, drought directly influences the quantity of charcoal produced as it was observed that during drought years, a larger quantity of charcoal is produced to cater to reduced agricultural and other income (Kiruki et al., 2020). This has also increased the dependency on woodfuel for livelihood. Other

scholars demonstrated that the effects of natural hazards such as drought on common livelihood sources have forced households to engage in woodfuel production for the composition of their livelihood (Alhassan et al., 2022).

The length of time that households lived in the area was also considered in the analysis. The model result shows a negative association of this variable with the probability of household participation in woodfuel production, which was statistically significant at a 1% significance level. The marginal effect indicates that for every additional year that a household lives in the area, the probability of participating in woodfuel production decreases by 1.1%, holding other variables constant. This suggests that households that had lived in the area for a longer period are less likely to rely on woodfuel production compared to those who had lived in the area for a shorter time.

Institutional membership was expected to be an important factor in reducing the degree of household participation and dependency on woodfuel production. The results show that as households become members of different institutions, whether formal or informal, the probability of participating in woodfuel production decreases by 33%, while other variables are held constant.

4 Conclusion

This study aimed to understand the factors that influence the decision of rural households to engage in woodfuel production. Understanding these factors is crucial for identifying the key point for successful interventions in the utilization and management of dryland forests. The results revealed that the majority of households were motivated to produce woodfuel because charcoal and firewood were their primary sources of income. These resources were used to fill seasonal gaps, provide alternative employment options, and cover unexpected expenses resulting from shocks such as crop failure and livestock disease. Households primarily engaged in woodfuel production during times of shock that affected their main livelihood resources, such as livestock and crops. The results also showed that drought was the most common shock, followed by decreased agricultural output prices, crop diseases, and family illness, livestock diseases, increased agricultural input prices, floods, lack of sustainable household businesses, unemployment, and conflicts. These factors forced households to engage in woodfuel production as a means of survival and an alternative source of income.

The results of the binary logit model indicated that age, education, land holding, livestock holding, production asset value, ICS ownership, number of years lived in the area, distance from the forest, access to forest extension, and institutional membership all had a negative and statistically significant correlation with the participation of households in woodfuel production. These findings suggest that households' decision-making regarding woodfuel production is influenced by these variables. On the other hand, household expenditure and drought occurrence had a positive and statistically significant correlation with household participation in woodfuel production.

The study's results highlight that the importance of considering different socioeconomic factors, livelihood resources, and options, as well as addressing the occurrence of various shocks. Furthermore, improving the productivity of livestock, crops, and other alternative income sources is important for ensuring sustainable management of dryland forests and resource utilization. In addition, shifting from traditional energy consumption to renewable energy use is of paramount significance in reducing pressure on dryland forests. Overall, designing alternative energy consumption and livelihood options is crucial for creating a sustainable environment rather than relying on woodfuel.

Data availability statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Ethics statement

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

GG wrote the proposal, performed data collection, analyzed the data, and wrote, reviewed, and edited the manuscript. AS designed and wrote the proposal, designed the data collection tools, and performed data collection, reviewed, and edited the manuscript. TA wrote the proposal, performed data collection, and data entry. DB, AA, and AB performed data collection and data entry. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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