Research article

Determinte of sustainable charcoal procurement in AWI zone; the case of Fagita Lekoma district, Ethiopia

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ABSTRACT

In Ethiopia, the trend of production and consumption of charcoal is found to be increasing in the regions' major towns and cities, particularly in Fagita Lekoma district. However, little attention is given to sustainable charcoal production in the study area. Therefore, the main objective of this study was to assess determinants to sustainable charcoal production in the Fagita Lekoma district. The study used a cross-sectional survey design for data collection and analysis as well as a purposive sampling technique to select samples from the household. The required data for the study was collected from both primary and secondary sources by employing data collection instruments such as household surveys, key informant interviews, and focus group discussions. The collected data was analyzed by inferential statistics (binary logistic regression) to analyze the determinants of charcoal production and to determine whether there are any statistically significant differences between charcoal produced and non-produced in the study area. According to the survey results, the most significant challenges for charcoal production were a lack of land, improved production technology, and perception. The results of the logistic regression model reveal that age of the household head, education, and family size were found to significantly influence charcoal production at less than a 10% probability level, while perception, methods, and land holding size were significant at less than a 5% probability level. Responsible institutions and planners should focus on the effects of earth mound kilns charcoal production on environments'. Charcoal production methods should be improved, and the government should have to give attention to sustainable charcoal production to make economically viable and environmentally friendly to reduce emissions.

1. Introduction

Charcoal is the most important commercial fuel derived from wood by the process of carbonization (Ashizawa et al., 2022). The manner in which charcoal is produced depends on climatic conditions, vegetation cover, local demand, infrastructure and land ownership and use rights (Antala et al., 2022).

Global charcoal production and consumption have grown over the last fifty years, from seventeen million tons in 1964 to fifty-three million tons today, with Sub-Saharan Africa accounts 61% of current global charcoal production, primarily for domestic use in rural and urban households (Kenne, 2022). For 100 years, it has been serve as a source of fuel for the rapidly increasing population due to low cost compared to other fuels like kerosene and liquefied petroleum gas and etc (Wu et al., 2022).

Charcoal is a cheap source of energy for households, demand for charcoal is expected to double by 2030, with over 700 million Africans (Raza et al., 2022). Demand for charcoal is projected to increase in Sub-Saharan Africa (SSA) due to rapid population growth, thus availability of woody biomass is declining due to rapid deforestation (Vargas-salgado et al., 2022). The majority of the urban populations, those who request charcoal fuel on a daily basis, don’t have any understanding of how charcoal adversely affects the environment. However, unsustainable wood reaping for charcoal production cause forest degradation and deforestation, as well as increase emissions of greenhouse gases in the atmosphere. The large scale charcoal production in sub-Saharan Africa has been a worry to the population in the area due to its risk of effects on the forest, which has become a severe (Kenne, 2022).

In Ethiopia, charcoal production meets a significant portion of the country’s urban and rural households energy needs and provides em-

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ployment for a majority of rural households. Despite this, charcoal production increased per capita income and continues source of cooking and heating energy for many Ethiopian households. However, there is no general environmental policy that concerned by stakeholders (NGOs, rural agriculture and finance office as well as forest and land resources management office) that concern the environmental, economic, and social implications of charcoal production and consumption on environments. Also, no environmental rule and regulation that aims to regularly intervene on behalf of the government and its charcoal production system, which is more environmentally sustainable and modern charcoal production technologies (Chidumayo and Savanna, 2018). Moreover, charcoal production was clumsy and investment in production was not cost-effective (Ligus, 2017). As a result, charcoal extraction is no longer contribution to livelihood and it have been appears to a negative image in Ethiopia. In many charcoal-dependent developing countries like Ethiopia, comprehensive policies and legal frameworks governing charcoal production are often unclear, and ineffective.

Particularly, in study area, charcoal production is the major sources of households’ livelihoods, especially for generating income (Ayanwuyi et al., 2021). However, sustainable charcoal production is affected by notable socio-economic and institutional factors like a lack of new charcoal production technologies or kiln, efficient training and skills. Moreover, the sustainability factors arise from social norms, i.e., factors of public and shareholder pressures, regulation enforcement, community concerns and commitments to protect the environment, and attitudinal factors (Ali et al., 2022).

The majority of charcoal reviews rely on binary logit models to analyze dichotomous adoption decisions in which the dependent variable is binary. But most of charcoal productions studies used probit and liner model, but it is not appropriate to test statistical significance of estimated coefficients (Kremers et al., 2021). Unlike linear probability models, binary logit models guarantee to estimated probabilities increase but never step outside the 0–1 interval (Salsabilla et al., 2021). Thus, it is used to identify the determinants of charcoal production and before estimating the models, it was necessary to check if multicollinearity existed among the explanatory variables (Salsabilla et al., 2021).

In Fagita Lekoma district, the majority of charcoal producers in the study area were found to be among the poorest in the rural population, with little or no land to support their charcoal production and no improved kiln for sustainable charcoal production (Ligus, 2017). The charcoal production systems are highly inefficient and often very low yields with inconsistent quality, thus it contributes greenhouse gases to atmosphere (Gebre et al., 2022). Even though mindful of the potential environmental, economic, and social implications of charcoal production and consumption in the study area. Yet, there are few environmental policies that aim to regularly intervene on the part of the stakeholder like NGOs and office of forest natural resources management. As a result, this study is motivated to assess the challenges and opportunities of charcoal production in the Fagita Lekoma district. This aims to design of appropriate and relevant interventions by the local government and other development practitioners. The result of this study contributes to the design of appropriate and relevant interventions by the government and other development practitioners toward sustainable charcoal production methods in the study area.

2. Material and methods

2.1. Description of study area

Location: Geographically, the study was carried out in selected farming communities in the Amhara National Regional State of Ethiopia. It shares land borders with the Sudan in the West, Egypt, and Eritrea in the North, the Somila in the East, and Kenya in the South. The study areas are bordered to the west and south by the Benishangul-Gumuz Region, to the north by the North Gondar Zone, and to the east by West Gojjam. Fagita Lekoma district’s administrative center is Injibara town, which is located approximately 112 km from the regional capital, Bahir Dar, and 452 kilometers north-west of Addis Ababa. The astronomical coordinates of Fagita Lekoma-district are 100 48°’N-110 9’ N latitude and 360 40’°E-3700’° E longitude (Fig. 1). Agriculture is the dominant economic sector in the district. It is a major source of food, raw materials for local industries, and export earnings. The district has potential for the production of a variety of agricultural products both for domestic consumption and export (Fagita Lekoma-district report, 2021).

Population: According to the CSA (2017), the total population of the Fagitalokama district is about 144,518, out of which 71,493 were men and 73,025 were women; of these, about 13,186 were urban dwellers and the remaining were rural dwellers.

Socio-economic activity: Agriculture is the dominant economic sector in the district. The district has potential for the production of a variety of agricultural products both for domestic consumption and export. Cash crop production is the major agricultural activity in the district. Among these, coffee is vital to the cultural and socio-economic life and contributes 25%-30% of the country’s foreign exchange, half of GDP, 90% of exports, 85% of total employment in the country, and part of the culture; about 50% of the produced coffee is consumed domestically (Fagita Lekoma-district report, 2021). In 2012 and 2013, Ethiopia exported an increased volume of coffee to international market. However, the revenue generated from this large volume of coffee exports hasn’t increased significantly as a result of the reduced international market coffee prices.

Natural Vegetation: The major vegetation types in the study area are woody plants and herbs, especially Acacia dicranches and Eclatopsis, which are common trees used for charcoal production in the district. Also, about 6773.93, or 13200ha, of land is covered by Acacia Dicranches with grazing land and other shrubs, respectively. The types of vegetation in the study area are varied in terms of the agroecological zoning of the district. In Woina dega (Subtropical) agroecology, the dominant vegetation consists of Tid (Juniperus Procera) or Zigba (Podocarpus), Woiraita (Olaria Africana), Kosso (Hagenia Abyssiniana), and Kerkha (Arrundinarial). In Dega Agro-ecology, the most dominating indigenous vegetation species were known by their scientific names, like Albida Del (Gerbi in local name), as well as Acacia oerfota (Schwein in local language), and the Fabaceae plant family, Balanites Agypetica, etc. The vegetation species in the kola agroecology of the district with scientific names were as follows: Eucalyptus fulgens, Acacia dealbata, Allocaerasus, Coprosma quadrifida, and gallery (Bahri et al., 2021).

2.2. Research design

Mixed research design is combinations of the qualitative and quantitative technique in order to meet its objective in the research (Hypp, 2018). The qualitative approaches applied for a detailed description of the data collected from model farmers, forest and climate change expert and etc. This method was also used in this study to gain a better intuition and understanding of the challenges, opportunities, and perceptions of households’ heads toward sustainable charcoal production and to broaden the depth of analysis from the findings of the study. In relation to this, Akimowicz et al. (2018) explain that agricultural researchers and economists would benefit from using mixed research methods to boost the extent and depth of their analysis. The quantitative method was also used to describe continuous variables’ in these research like ages and family size of household heads using the independent t-test and chi-square test as well as by using the, frequency distribution. In this regard, the authors intended to use the mixed research method because it is the best method to assess potential challenges, perceptions, and opportunities of charcoal production associated with producers and non-producers in the study area. The comparison group comprised household heads age, sex, and education level, with
two groups in the study area. To arrive at the conclusions, all necessary data were gathered through household surveys, key informant interviews, focus group discussions, and a review of various documents related to sustainable charcoal production. The gathered data was analyzed using both qualitative and quantitative methods of data analysis and presentation.

2.3. Sampling technique and sample size

A multistage sampling technique was used for this study. In the first stage, Fagitallokoma district was selected randomly because the district is known for its production of charcoal among the districts found in the Awi Zone. In next stage, out of twenty charcoal producing kebeles in Fagitallokoma district, four kebeles (smallest administrative units in Ethiopia), namely, Endawetsha, Gafera, Azaamch Gula, and Amesha, were selected purposively due to the volume of charcoal production that has been observed in past years. In addition to that, the researcher considers into account factor such as, time, topography, accessibility, and availability of the transport: because these factors increase the chance of sample, coverage as well as responses error. Furthermore the factors are critical to increase representativeness of the sample population. Finally a total of 207 sample household heads (135 producers and 72 non-producers of charcoal) were selected from four kebeles by using proportionate sampling methods.

2.4. Data collection tools

In this study, required data was collected using key informant interviews, household survey questionnaires, and focus group discussion.

**Questionnaire**: A questionnaire is one of the most popular data collection tools to cover large samples at least cost. In this study, the investigators used similar questionnaires for all household heads at each kebele, and each of these actor groups was surveyed using an open-ended and close-ended questionnaires. So the mixture of closed and open ended questions was prepared to collect data on the socioeconomic status of the household’s heads, the challenges as well as opportunities of charcoal production. Six enumerators were recruited based on their proficiency in communicating in the Amharic language, educational background, and prior experience in data collection. The investigators trained the enumerators on how to present and explain each question to the household heads.

**Key informants interviews**: A key informant is person from a household participate in the face-to-face interview. Interviewing is a powerful, but labor-intensive data collection technique. This session was carried out in order to gain a deeper understanding of the challenges and opportunities of sustainable charcoal production in the study area. The interview was held with district agriculture and finance office experts, forest and natural resources management experts, model farmers, culture and tourism bureau officers, charcoal merchants, and Kebele administration. Thus research ask question like what are most serious challenges of the charcoal production in study area, do you think it have opportunities. A total of six key informants from each kebele were interviewed to gain a synopsis of the challenges of charcoal production in the study area. The key informants were interviewed once, with recruitment taking place between November 2020 and May 2020.

**Focus Group Discussion**: The focus group discussion was conducted to identify the challenges of charcoal production as well as its opportunities for households in the study area. Thus to reveal these researcher ask the question like what are most serious challenges of the charcoal production in study area, do you think it have opportunities. This discussion provides insights and additional perspectives that may not be revealed through personal interviews and questionnaires and further insight about challenges of the charcoal production. Although opinions differ on optimal sizes, focus groups are generally not large. Some suggest between eight and 12 people (Tahaee et al., 2022), while others argue that smaller groups of five to seven participants might be more appropriate for an in-depth conversation (Kitzinger, 1994). By considering this, focus group discussions were conducted with a group of people that constituted six individuals at each kebele. The participants of the focus group discussion were purposively selected based on their experiences of charcoal production from each kebele. The reason for purposive selection of these participants was due to the fact.

![Study Area](image)
that they have more knowledge about challenges and opportunities of charcoal production than those who do not have an experience of charcoal production. This discussion provides some filling in the information gap that may not be revealed through questionnaires. Moreover, focus group discussions provide a reasonably effective and inexpensive tool for easily gathering a broad range of opinions.

2.5. Data analysis and interpretation

The collected data was analyzed by employing both quantitative and qualitative methods of data analysis. The qualitative data was analyzed descriptively in the form of narration and qualitative combined methods depending on the obtained data, for explaining, refuting, enriching, and confirming data. For quantitative data, descriptive statistics like frequency, percentage, mean, standard deviation, and graphs were used. Moreover, the T-test was used to determine whether there are any statistically significant differences between charcoal produced and non-produced, and the mean of two or more independent variables was applied to test the average prices of charcoal in the selected kebele. Finally, a binary logistic regression model was used to study the variables influencing the decision of households' heads to produce or not produce charcoal in study area.

2.5.1. Econometric model specification

For this particular study, the variance inflation factor was used for continuous variables. The larger the value of the variance inflation factor, the more troublesome (Schenck, 2021). As a rule of thumb, if the variance inflation factor of a variable exceeds 10 (this will happen if R²
i exceeds 0.95), that variable is said to be highly collinear (Alquier et al., 2022). The variance inflation factor is given as: VIF (X
i) = \frac{1}{1 - R²
i}. Where, R²
i is the coefficient of determination, X
i is regressed on the other explanatory variables. To detect this problem, coefficients contingency were compounded as follows (equation (1)).

\[ P_i = E(Y = 1|X_i) = \frac{1}{1 + e^{-\beta_0 + \beta_1 X_1}} \]  (1)

For ease of exposition, we write (1) as (equation (2)).

\[ P_i = \frac{1}{1 + e^{-Z_i}} \]  (2)

The probability that a given household is food secure is expressed by (2) while, the probability for adopter is (equation (3)).

\[ 1 - P_i = \frac{1}{1 + e^{-Z_i}} \]  (3)

Therefore, we can write (equation (4)).

\[ \frac{P_i}{1 - P_i} = \frac{1}{1 + e^{Z_i}} = e^{Z_i} \]  (4)

Now, (Pi/(1-Pi)) is simply the odds ratio in favor of adoption charcoal production. It indicates the ratio of probability that a household will be adopter to the probability that it will be non-adopter (equation (5)).

\[ L_i = Ln \left( \frac{P_i}{1 - P_i} \right) = Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n \]  (5)

Were Pi= is a probability of being adopter of sustainable charcoal production, ranges from 0 to 1

Zi= n descriptive variables x articulated as (equation (6)).

\[ Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n \]  (6)

\[ \beta_0 \] is an intercept
\[ \beta_1, \beta_2 \ldots \beta_n \] are slopes of the equation in the model
Li = is odds ratio
Xi = is vector of relevant household characteristics

If the disturbance term (Ui) is introduced, the log it model becomes (equation (7)).

\[ Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + U_i \]  (7)

Variables with a contingency coefficient of less than 0.75 have weak associations, while values greater than 0.75 have strong associations (Al-Tarawneh and Al-Qahatani, 2022). A goodness of fit metric is a review statistic that represents the model’s accuracy in observed data (Magrini, 2022). Since the dependent variables of the models were qualitative, accuracy was judged in terms of the fit between the calculated probabilities and observed response frequencies, the likelihood ratio index, and log-likelihood functions for this study. The parameters of the models were estimated using the iterative maximum likelihood estimation to sustainability of the charcoal production. This method is better than ordinary least square because of the assumption about the probabilistic nature of the disturbance term and ordinary least square does not make any assumptions about the probabilistic nature of the disturbance term in logistic regression. The maximum likelihood method is a very general method and most effective way of estimating problems that involve limited dependent variables. Thus, researcher used maximum likelihood to estimate the model coefficients and information in a sample to find the parameter estimates that are most likely to have produced the observed data. This method yields as a function of the unknown parameters a and β (Aliyu et al., 2021).

2.6. Definition and hypotheses of the variables

A. Dependent variable

It is a dummy variable that the household heads are participating or not participating in charcoal production activity. It is represented as (producer and non-producer).

B. Independent variable

Independent variable for the study were identified and listed based on previous, theoretical, empirical, as well as personal observations. This variable was assumed as a factor influencing sustainable charcoal production and was grouped under socio-demographic, bio-physical, and economic factors. Hence, the following major explanatory variables were hypothesized to influence sustainable charcoal production (Table 1).

3. Results and discussions

3.1. Description of socio, demographic and economic characteristics of sample household heads

A t-test was run to check whether there was a significant mean difference in ages between charcoal producers and non-producers. As indicated in Table 2, the mean ages of charcoal producers was 42.09 and 36.38 for non-producers, with a standard deviation of 11.94 and 13.35, respectively. As per the survey results, the average family size for charcoal producers and non-producers was 4.82 and 5.81, with a standard deviation of 1.93 and 2.638, respectively. Moreover, the average land holding size (in hectare) for charcoal producers and non-producers are 1.72 and 2.36, hectare with a standard deviation of 1.170 and 1.68, respectively. Furthermore, the distance (in km) between a charcoal producer and a non-producer is 4.19 and 4.44 km, respectively, with standard deviations of 1.469 and 1.58, respectively. The result shows that ages of household heads, family size, and land holding size were statistically significant with charcoal production, whereas distance from farm land is not important factors in charcoal production. As a household’s age increases, so does its ability to charcoal production because the farmer gains more experience as his age increases, as indicated by the above hypothesis. As land holding sizes decrease the charcoal production is also decrease (Gebre et al., 2022).
Table 1. Definition of variable and hypotheses.

| Variable code | Variable definition | Unit of Measurement | Type of variable | Hypothesized r/ship |
|---------------|---------------------|---------------------|------------------|---------------------|
| Explanatory variables |
| AGEHH | Age of household head | Year | Continuous | +VE |
| FAMILYSIZEHH | Number of family size | Number | Continuous | +VE |
| FARMSIZEHH | Size of cultivated land | Hectare | Continuous | +VE/-ve |
| AV. INCNTR | (Ethiopian Birr) | Income | 2020 (in market price) | Continuous | +VE |
| DISTA | Distance from farm land | In km | Continuous | -ve |
| SEXHH | Sex of household head | 0, if HH is female; 1, male | Dummy | | +VE |
| EDU HH | Educational status of household head | 0, illiterate, 1 literate | Dummy | | +VE |
| PERCEPTION | Perception toward charcoal production | if 0 = negative perception; 1, positive perception | dummy | | +VE/-ve |
| CREDIT ACCE | Market Access | if 1 = yes, 0 = No | dummy | | +VE |
| METHOD | Method of charcoal processing adopted by household head | if 1= Traditional, 0= otherwise | dummy | | +VE/-ve |

Notes: +ve/-ve positive and negative relationship of hypothesized variables.

Table 2. Age, family size, land holding size and distances.

| Variables | Non-producer Mean | SD | Producer Mean | SD | Me/Diff. | T | Sig. (2-tailed) |
|-----------|------------------|----|---------------|----|----------|---|----------------|
| Age HH    | 36.38            | 11.94 | 42.09        | 13.35 | -5.71   | -3.03 | .003**         |
| Family size | 4.82          | 1.93   | 5.81         | 2.638  | -.995  | -2.82 | .005**         |
| Land holding size | 1.72     | 1.170 | 2.36         | 1.686  | -2.64  | -2.88 | .002**         |
| Distance farm land (km) | 4.19 | 1.469 | 4.44        | 1.582  | .268  | 1.110 | .268Ns        |

Notes: (*) p < 0.01%, and **p=0.05% significant level respectively. Sources: Household survey, 2020.

Table 3. Sex, education and training.

| Variables | Non-producer (72) | % | producer (135) | % | Total (207) | % | Chi-square | p-value |
|-----------|------------------|---|---------------|---|-------------|---|------------|---------|
| SEXHH     |                  |    |               |    |             |   |            |         |
| Male      | 55               | 34.8 | 103             | 65.2 | 158          | 76.3 | .000a      | .988 Ns |
| Female    | 17               | 34.7 | 32             | 65.3 | 49           | 23.7 |            |         |
| EDU HH    |                  |    |               |    |             |   |            |         |
| Literate  | 22               | 24.4 | 68             | 75.6 | 90           | 43.5 |            |         |
| Illiterate| 50               | 42.7 | 67             | 57.3 | 117          | 56.5 | 7.502      | 0.006*  |
| Credit access |            |    |               |    |             |   |            |         |
| Yes       | 21               | 20.8 | 80             | 79.2 | 101          | 48.8 |            |         |
| No        | 51               | 48.1 | 55             | 51.9 | 106          | 51.2 | 17.01      | 0.00*   |
| Methods prod |              |    |               |    |             |   |            |         |
| Earth mound kiln |        | 9.3 | 72             | 50.7 | 142          | 68.6 |            |         |
| Casamance kiln |            | 3.1 | 63             | 96.9 | 65           | 31.4 | 41.99      | 0.00    |
| Perception of the households head | | | | | | | |
| Positive  | 72               | 47.3 | 78             | 52.7 | 148          | 71.5 |            |         |
| Negative | 2                | 3.4 | 57             | 25.1 | 59           | 28.5 | 35.85      | 0.00*   |

Not significant = Ns, Significant at (p < 0.01)* and (p < 0.05)** probability level. Sources: household survey, 2020.

According to the survey results (Table 3), households’ heads perceptions, methods of charcoal production, credit access, and education have an influence on charcoal production in the study area. However, the sex of the household heads is found to be insignificant (Hinton et al., 2003).

Sex: According to survey results, out of the 207 sample households heads, 76.3% were male- households’ heads and the rest (23.7%) were female- households heads (Table 3). The number of female-households head in both producers and non-producers were 65.3% and 34.7%, respectively. The number of male-headed households’ heads for producers and non-producers is 65.2% and 34.8%, respectively. In line with the hypothesized relationship, the result indicates that there is a significant association between the sexes of the household heads in both groups, although charcoal production is not found at a significant level.

Education is an important characteristic that determines a farmer’s ability to communicate, acquire information, and adopt new technologies too. Among the sample farmers, less than half of the household heads (43.5%) were literate, while only about 56.5% were illiterate (p = 0.006. This result reveals that there is a statistically significant mean difference between the two groups in education (Table 3).

Credit access: credit access is tracing value added in global production chains and access of eagers to lend money at a lower interest rate if he or she approach buys charcoal at a more fitting price, therefore enabling them to earn considerable income with a further commerce (Amendologaine et al., 2019). Based on the results in (Table 3), 48.8% of households heads have access to credit, while the remaining about 51.2% of households heads do not have access to credit. The Chi-square tests (2 = 17.01, p = 0.000) also indicate that there are significant associations between charcoal producers and non-producers

Methods charcoal production: The results of the survey showed that about 68.6% of the households heads engaged by using earth mound kilns charcoal production methods whereas 31.4% of the household heads replied that they use casamance kiln of charcoal production. The Chi-Square tests (2 = 41.99, p = 0.000) indicate that there is a significant difference between the two groups within charcoal production methods. This implies that the majority of the household’s heads methods of the charcoal production are earth mound kilns. Therefore, the methods of production have a positive influence on the determinants’ of sustainable charcoal production. This may enhance society...
have achieve great income and other livelihood sources of the benefit through charcoal production.

**Perception of the household:** The results of the surveys in Table 3 indicate the variation in the farmer’s perception of sustainable charcoal production in the study area. Accordingly, out of total household heads, 28.5% and 71.50% stated a negative and positive perception of charcoal production, respectively. The chi-square ($\chi^2 = 35.85$, $p = 0.000$) shows the significance association between producers and non-producers in the area (Table 3). Similarly, Fitwangile (2017) reported that the farmer’s perception toward charcoal production was constrained by a complex set of factors, which have been considered as one of the limiting forces to the farmer’s negative perception of sustainable charcoal production methods like improved kiln due to lack of capital during establishment, poor extension support, and etc.

Results from focus group discussion (FGD) acknowledged that the charcoal production activity needs more land and capital access. It is frequently difficult for poor and inexperienced households heads to use improved kilns to produce more with fewer emissions (Schmidt and Tadesse, 2017). As a result, most of the key informants and focus group participants claimed that the earth mound kilns (Fig. 2) had a negative impact on the environment especially on soil. Furthermore, the results of focus group discussions (FGD) show that the major constraints to sustainable charcoal production in the study area were drying and dry seedlings for charcoal, a lack of improved production methods, land, a high government tax, labor, and capital intensiveness. Also, key informants reported that households’ heads that had no land for charcoal production had a partial effect as an increase in the proportion of households heads that rented a plot for many years to grow Acacia trees for charcoal production.

The earth mound kilns method produces green gases which are not filtered in the chimney as it is done. So it contribute significantly to environmental degradation because it use a large amount of energy (Jansen and Kumschick, 2022). The earth mounds a kiln have a high air content entering the kiln and the faster carbonization (Butaitė et al., 2018). This method of charcoal production completely reduced, in both the quantity and quality of the charcoal. The quality of charcoal made from earth mound kilns is significantly different in terms of time of carbonization and weight of charcoal. However, consistency and quality of charcoal in the casamance kiln is generally higher than earth mound kiln charcoal production methods. Improved charcoal making requires a small quantity of wood to produce the same quantity of charcoal as produced in the earth mound kilns. The casamance and retort kilns reduces the emission of harmful volatile substances into the atmosphere by up to about 75% (Nabukalu and Gier, 2019).

Results of key informants confirm that advantages of the earth mound method, such as expediency and high yield of charcoal production, may be reasons for the continuous use of the method. The finding is in line with (Wurster et al., 2010). However, the inefficiency of kilns also results in heavy smoke containing greenhouse gases and particles such as methane, carbon monoxide, nitrous oxide, and carbon dioxide particulate matter that are harmful to the environment and people (Ndewa et al., 2016).

### 3.2 Econometrics result and discussions

Based on hypothesized explanatory variables which are included in the binary logistic analysis, the overall percentage of correct predictions is 77.8%. Another indicator of the fit of the model was that the omnibus
Table 4: Interpretation of significant explanatory variable in binary logit model.

| Variables    | B     | S.E. | Wald  | Df  | Sig.  | Exp(B) |
|--------------|-------|------|-------|-----|-------|--------|
| SexHH        | -0.160| 0.453| 1.124 | 1   | 0.294 | 0.317  |
| AgeHH        | 0.029 | 0.016| 3.530 | 1   | 0.060 | 1.000  |
| EDUHH        | 0.775 | 0.451| 2.950 | 1   | 0.086 | 2.171  |
| FamsiHH      | 0.155 | 0.087| 3.196 | 1   | 0.074 | 1.168  |
| FarmsHH      | 0.314 | 0.156| 4.021 | 1   | 0.045 | 1.368  |
| DistanceHH   | 0.139 | 0.149| 0.869 | 1   | 0.351 | 1.000  |
| Credit HH    | 0.052 | 0.051| 0.004 | 1   | 0.951 | 1.000  |
| Income HH    | 0.000 | 0.000| 0.017 | 1   | 0.897 | 1.000  |
| PercepiHH    | 1.948 | 0.910| 4.588 | 1   | 0.032 | 1.000  |
| Methods HH   | 2.525 | 0.886| 8.124 | 1   | 0.004 | 0.287  |
| Constant     | -8.613| 1.625| 28.079| 1   | 0.000 | 1.000  |

2 Log likelihood ratio = 117.912* Chi-square value = 89.569 Correctly predicted producer = 70.8 Correctly predicted non-producer = 81.5 Over all correctly predicted = 77.8a Not significant =Ns, Significant at (p< 0.01)*and (p< 0.05)**probability levels. Sources: model output, 2020.

test of model coefficients was significant (chi-square = 89.56, DF = 11, p = 0.000), indicating that the model was able to distinguish between the production of charcoal and those that were not. The logit model’s sensitivity (correctly predicted producer) and non-producer) are 81 and 71%, respectively. According to Aliyu et al. (2021), if Hosmer Lemeshow test value of P is less than 0.05 significance level, we accept null hypothesis (HO), hence it is enough evidence to indicate the hypothesized model fits the data set used in prediction adequately.

AgeHH: The estimated coefficient and the odds ratio of the variable were 0.114 and 1.120, respectively. This means that as the age of a farmer increases by one year, the tendency to charcoal production increases by a factor of 1.12%. This may be because older people are often better experienced and endowed with more assets to devote to long-term investments in sustainable charcoal production, lower risk aversion, and longer planning horizons to justify investments in charcoal production activity.

EDUHH: It is positively and significantly correlated at a 0.05% probability level. The odds ratio indicates the probability that farmers who have education would adopt a sustainable charcoal production method by a factor of 5.62 (Table 4).

FamsiHH: Family size was positively correlated with charcoal production and was significant at the 0.05% level. This implies that as the family size increased by one unit, the probability of charcoal production in the households increased by 2.27%. This justifies charcoal production as a labor-intensive practice. Therefore, having a relatively large number of family members in a household is expected to have more yield of charcoal and income than having fewer family members in a household (Malimbwi and Zabahu, 2009).

FarmsHH: As expected, large farms tend to have more charcoal production than smaller ones, and it significantly and positively affects the probability of charcoal production for households at a 10% significance level. The addition of one hectare of land brought a 2.4% increase in the probability of charcoal production. This means as farm size is large it probably allows to households heads to plant more trees for charcoal production than a small farm size (Wurster et al., 2010).

PercepiHH: This variable affected sustainable charcoal production negatively at a 10% significance level. A household that got training decreased its charcoal production by 4.7%. This justifies that households who get training may prefer sustainable charcoal production over untrained households (Odoo, 2012).

Methodch: This variable positively influences the charcoal production decisions of households. It is statistically significant at a 10% significance level. This finding is in line with Nahayo et al. (2015) who conducted a study in Kenya on sustainable charcoal production, and he found that improved methods of charcoal production technologies such as casamance and improved pit Liberia kiln that were considered more productive than earth mound kilns.

4. Conclusion and recommendations

Conclusion
Charcoal is an essential source of fuel for millions of people around the world, and it is one of the most commercialized woody resources in Sub-Saharan Africa. However, policies to effectively govern the sector are lacking in many countries. As a result, countries around the world tend to have a habit of environmental problems. This is true in most parts of Ethiopia, and particularly in the study area, due to the lack of an improved kiln such as resort kiln with low-cost and locally available materials that has the potential to become sustainable and contribute significantly to generating income from charcoal production. As a result, main purpose of this research was to assess the determinates of sustainable charcoal production in the study area. More specifically, it aims analyzed the main challenges and opportunities, as well as perceptions of sustainable charcoal production in the study area. Besides, several influencing factors of sustainable charcoal production was hypothesized and analyzed. The result shows that the majority of the hypothesized factors were found to positively and significantly influence sustainable charcoal production in the study area. The study recommended that responsible institutions and planners should focus on the effects of earth mound kilns. Charcoal production methods should be made more environmentally friendly and the local government should have to regulate the sector that is economically viable and environmentally friendly to reduce emissions.

Declarations

Author contribution statement

Berhanu Bekele: Designed the paper, reviewed a related literature and methodology, collect data, analysed and interpreted the result and wrote the final paper.

Abdo W Kemal: Wrote methodology, code, analysed and interpreted the results.

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The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.
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