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Research Article

Analysis of Charcoal Producers Perceptions of Its Production, Forest Degradation, and Governance in Wolaita, Southern Ethiopia's Dry Afromontane Forests

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The purpose of this study was to assess charcoal producers' perceptions of forest degradation and investigate governance in the dry Afromontane forests of Wolaita Zone, Ethiopia. It also examines the socioeconomic contribution of charcoal production to livelihood improvement and the effect of charcoal production on forest degradation and biodiversity loss. Three Kebeles (smallest administrative subunits): Galda, Sere Esho, and Mancha Gugara were purposely selected based on their potential for charcoal production. Semistructured questionnaires were used for household surveys, while checklists were provided for the key informants and focus group discussions. From the total 4,739 charcoal producer households in the selected Kebeles, 98 households were randomly selected and interviewed considering time and budget limitations. Besides, 6 key informant interviews with elders, forestry experts, and farmers and 3 focus group discussions were conducted. A simple descriptive statistical tool was used to analyze descriptive statistical data and chi-square at $P < 0.05$ was used to describe the association of forest degradation with socioeconomic characteristics. The findings reveal that charcoal production is dominated by males (68.4%) compared to females, who were within the age range of 20–43 years. About 59.18% did not attend any formal education and 18.37% attended elementary education. Charcoal production (32.7%) is second, following agricultural expansion (39.8%) in its negative contribution to forest degradation. The majority (76%) of charcoal producers participated in charcoal production at all times throughout the year. The chi-square result shows a significant relationship between monthly incomes, educational status, family size, and gender with charcoal production and forest degradation at ($P < 0.05$). The indigenous trees, *Acacia tortilis* (34%), *Combretum mole* (22%), and *Terminalia schimperiana* (16%), were the most preferred tree species used for charcoal production. Overall, charcoal production has resulted in forest degradation. Charcoal producers have used traditional earth mound kiln technology. Providing alternative energy sources, training, starting rehabilitation programs, and implementing policies and legal frameworks are needed for the sustainable utilization of the resources and to improve the livelihood of the communities.

1. Introduction

The contribution of forest resources to the livelihoods of woodland communities has received greater attention during the last decade [1], and it includes both timber and nontimber forest products such as food, fodder, medicine, construction materials, fuel, and materials for charcoal production [2]. Among these, wood fuel is the main source of energy for communities in tropical woodlands and savannas [3]. Charcoal is a key contributor to the livelihoods of woodland and savanna communities and is widely used in urban and rural households for cooking because of its high heat value and smokeless characteristics [4]. In Eastern Uganda, for example, 98.8% of rural households use fuelwood for cooking food and then preserving it [5]. Charcoal producers can use free raw materials collected from natural forests or other sources and turn them into marketable commodities in high demand [6]. About 230,000 tons of charcoal are being used per year for domestic purposes in Ethiopia [6, 7]. This proves the significance that wood fuel plays in meeting the energy demand of developing countries [8], mainly Ethiopia, as the country's renewable energy sector is still in its infancy stage [9]. Charcoal, among the main products of woodland forests, is a critical source of energy in Africa, where close to 80% of the population uses it as the basic resource for cooking and heating [10–12]. However, poorly controlled production practices and aligned forest degradation have dampened woodland extraction potential [13]. On the other hand, there is a forecasted 40% upswing in biomass energy demand across Africa by 2040 [14]. Similarly, as [15, 16] indicated, about 90% of the Ethiopian population depends on biomass for its energy needs, of which wood fuel (fuelwood and charcoal) accounts for the greatest proportion [6, 17].

Charcoal production provides a significant portion of urban and rural households' energy needs and is also a source of livelihood for 10,000 rural households in the country [18]. In Ethiopia, charcoal is generally produced from state-owned (public) forests and woodlands and is traditional [19]. In Offa District, charcoal is mainly produced from communal lands, and its production is more traditional (using traditional earth kiln technology). More than 90% of the population uses firewood in rural and urban areas, 25% rely on firewood, and nearly 50% on charcoal [12]. As Mwampamba et al. [13] indicated, the economic significance and/or development of the charcoal sector have been growing through the direct employment of millions of people as producers, transporters, and traders. Accordingly, it offers employment to millions of people and thus fulfills an increasingly important role in economic development [12, 20].

Despite its high socioeconomic contribution, charcoal production is considered the main cause of forest degradation, mainly because of the various illegal production, marketing, and/or trade activities by various bodies [13]. As reported by Baumert et al. [21], in Ethiopia, few conservation rules and regulations aim to regularly intervene. As indicated by Melaku and Girmay [19], while countries have shown the willingness and ability to develop policies at the national level, they have been found lacking in executing programs and taking action, especially at the district or regional level. In addition to establishing and harmonizing charcoal policies, countries also need to work towards simplifying the administrative structure, organizing the charcoal trade by setting up a transparent and differentiated revenue collection system, and ensuring that institutional capacity at local and district levels is strengthened [19, 21]. Although the demand for charcoal is increasing in Ethiopia, the availability of woody biomass is decreasing due to widespread net deforestation and degradation [22, 23], and producing it is not a cost-effective activity. Due to this, charcoal extraction is considered unsustainable, and its contribution to livelihood seems to have a negative image [24]. In addition, the marketing system for charcoal is mostly informal [25].

In Offa Woreda, charcoal production is the main source of households' livelihood options, followed by livestock keeping. In this area, communally owned farms and woodlands are the most favored areas for sourcing trees for charcoal production. This indicates that a considerable number of households produced charcoal from the community forest, though the community forest was severely degraded. The production system is more unsustainable, and traditional producers seem to have little awareness that charcoal can be produced efficiently with up-to-date technologies. Charcoal production supports the majority of the livelihoods of rural households and provides a significant portion of urban households' energy demand in the country, as well as being extensively produced in Offa Woreda. Despite this extensive charcoal production for livelihood improvement and energy demand requirements, studies on the assessment of its economic contribution and effect on forest degradation and biodiversity loss are limited generally in the country and particularly in Offa Woreda, Wolaita Zone, Southwestern parts of Ethiopia. In this regard, the present study specifically aims to assess (i) the perceptions of charcoal producers on the effect of charcoal production on forest degradation, (ii) the economic contribution of charcoal production for livelihood, and (iii) policies and legal frameworks for charcoal production. By providing information and knowledge, the study's findings will help communities, researchers, and policymakers manage the woodland and forest resources in the study area more sustainably.

2. Material and Methods

2.1. Study Area Description. This study was conducted in Offa Woreda of the Wolaita Zone located in the Southwestern parts of Ethiopia. It is one of the 16 Woredas of the Wolaita Zone, which comprises a total of 21 rural Kebeles. The study area is located at 6°37′13″–6°50′3″ N latitude, 37°24′21″–37°39′18″ E longitude (Figure 1), and 383 km away from Addis Ababa and 43.1 km from Wolaita Sodo.

The total population of Offa Woreda was 132,054 and it occupied 38,557 ha [26, 27]. Most of the households in the selected Woreda are dependent on charcoal production and marketing. The majority of the vegetation types found in Woreda are native species such as *Acacia tortilis*, *Cordia africana*, and *Ficus vaste*, as well as exotic species such as *Eucalyptus globules* and *Junipers procera*. As Julla et al. [28] indicated, farmers in the area grow cereal crops (*Zea mays*, *Hordeum vulgare*, *Eragrostis tef*, and *Triticum aestivum*), cash crops including *Coffea arabica* and *Manihot esculenta*, pulses such as *Pisum sativum*, *Phaseolus vulgaris,* etc., permanent crops such as *Persea americana*, *Mangifera indica*, and *Ensete ventricosum*, root crops such as *Solanum tuberosum*, *Ipomoea batatas*, and *Manihot esculenta*, and horticultural crops, particularly vegetables, e.g., *Allium cepa*, *Solanum tuberosum*, and *Brassica oleracea*. The study area ranges between 1,200 and 2800 meters above sea level

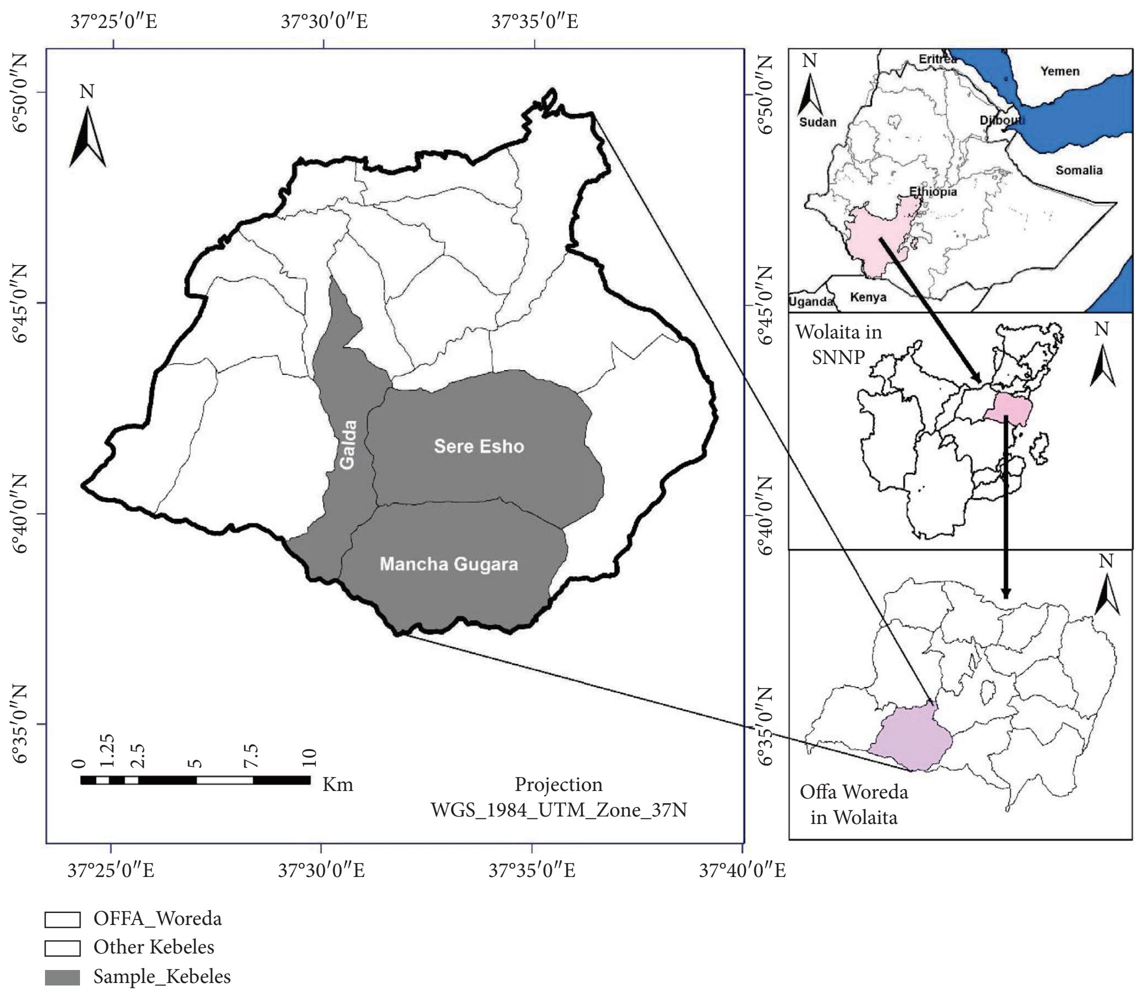

Figure 1: Location of the study area (source: author (2018/2019)).

(m.a.s.l.) [26]. The Woreda has maximum and minimum temperatures of 34°C–14°C and annual rainfall of 1,400–800 mm, respectively [29]. Cambisols, Vertisols, Luvisols, Lithosols, and Nitosols are the main soil types in the area [30, 31].

2.2. Data Sources. According to Thrift [32], the use of multiple data collection techniques and sources strengthens the credibility of outcomes and enables different interpretations and meanings to be included in the data analysis. We, therefore, used multiple data collection tools and sources to gather the required data for the study. Primary data were collected through a household survey questionnaire, key informant interviews, focus group discussions (FGDs), and field observation, while secondary data were collected from published literature, government reports, and policy documents. The fieldwork was conducted in (i) household surveys and key informant interviews using structured and semistructured questionnaires; (ii) FGDs were undertaken from October 2018 to January 2019; and field observation was conducted between February and March 2019.

2.3. Sampling Techniques, Data Collection, and Analysis. For this study, quantitative, qualitative, and multistage sampling techniques and/or approaches were used. To begin, Offa Woreda was purposefully chosen among the Woredas because it is closest to or adjacent to the natural forest [33]. Following the same trend, out of 21 Kebeles (smallest administrative subunits), three representative Kebeles, namely, Galda, Sere Esho, and Mancha Gugara were purposefully selected due to the availability and distribution of forest resources, charcoal production, and marketing (Table 1; Supplementary table 1). Then, charcoal producer household heads (HHs) were identified with the help of Woreda and Kebele Agricultural, Environmental Protection, and Forestry Development Office experts, and respondents were selected randomly. A simplified formula provided by Yamane [34] was used to determine the required sample size of this study with a 90 percent confidence level. A total of 5,400 HHs were recorded from all the selected Kebeles (Supplementary table 1), and 4,739 were identified as charcoal producers (Table 1; Supplementary table 1). Accordingly, by considering cost and time limitations, a total of 98 households of charcoal producers

(Table 1; Supplementary table 1) were used for face-to-face interviews in this study.

$$n = \frac{N}{1 + N(e)^2} = \frac{4,739}{1 + 4,739\ (0.1)^2} = 98, \qquad (1)$$

where n = sample size, N = 4,739: total number of charcoal producer HHs in the selected Kebeles, and e = margin of error at 10%.

Additionally, 6 key resource persons who are well experienced in farming and charcoal production and 3 FGDs, each with 12 members from women, men, and young people, were used for primary data collection. The members discussed issues regarding their views and experiences on charcoal production, its socioeconomic benefit to livelihoods, its impact on forest degradation, and policies, rules, and regulations. During the entire discussion process, the researcher served as a facilitator while insiders fully participated in the dialogue [35]. For the household survey, 98 semistructured questionnaires were designed, and the interview was conducted in a native language (Wolaita). A one-day training was provided for the data enumerators who assisted us during data collection.

The local administration and community have given their consent for all the pictures to be published, and the interview was recorded and transcribed. Checklists were used to assess key informant interviews and group discussions. The charcoal business activity and its effect on forest degradation and biodiversity, as well as the economic contribution of charcoal production for livelihood, were the important concerns of the study. Primary data collection was complemented with secondary data and field observations that helped to describe the forest's history, location, and biophysical characteristics. Field trips were carried out with 8 individuals, comprising 2 researchers, 3 chairmen, and 3 development agent experts at the village level (one individual from each Kebele), to gather and assess data on preferred tree species, cutting and harvesting practices, technologies used, existing policies and regulations, forest cover change associated with charcoal production, and the socioeconomic benefit of charcoal in the sample sites (Figures 2–4). Participants were purposefully selected for their familiarity with the sociocultural conditions of the study area, which helped us collect the required data quickly. Secondary sources, including policy documents and regulations, were used as the main secondary source for the collection of policies and regulations for charcoal production in the study area.

2.4. Data Analysis. For this study, both quantitative and qualitative methods of data analysis were employed [36] and examined by employing a statistical package for social science (SPSS Statistics version 28). The qualitative technique of content analysis [35] was used to analyze data generated through FGDs and field observation. In this method, the data are categorized into different themes and organized and coded. Then, a list of major ideas was chronicled and transcribed verbatim. Moreover, descriptive and inferential statistics, including tables, frequencies, and percentages, were used to describe the economic contribution of charcoal production, the socioeconomic characteristics of sample respondents, and to summarize their responses. The chi-square test was used to analyze or examine associations or differences among respondents on socioeconomic characteristics and charcoal producers' perceived effect on forest degradation, among others. Policies and regulations on charcoal production and marketing were also analyzed qualitatively.

Table 1: Determination of sample households' size of the study Kebeles.

Study Kebeles	Total population	Sample respondents
Sere Esho	2,216	46
Galda	2,149	44
Mancha Gugara	374	8
Total	4,739	98

Source: Woreda agricultural and trade bureau (2018/2019).

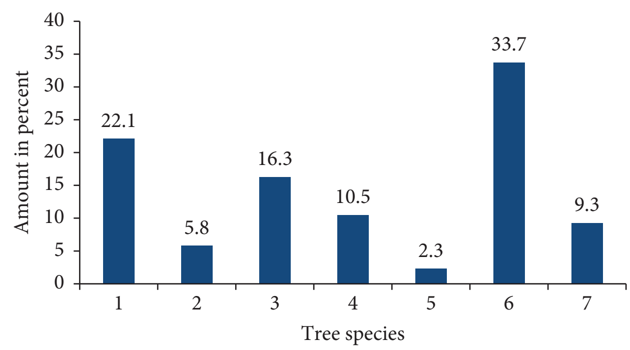

Figure 2: Preferred tree species for charcoal production at Offa Woreda. (tree species: 1 = *Combretum molle*, 2 = *Cuspidate cif*, 3 = *Terminalia schimperiana*, 4 = *Syzygium guineense*, 5 = *Olea capensis*, 6 = *Acacia tortilis*, 7 = *Acacia seyal*). source: field survey result (2018/2019).

3. Results and Discussions

3.1. Socioeconomic and Demographic Characteristics of Respondents. The majority of charcoal producers (68.4%) were male-headed households, which dominate charcoal production (Table 2; Supplementary table 2). In the study area, charcoal production is a labor-intensive activity and requires a lot of energy input during kiln preparation, especially for arranging huge, bulky wood stems, which is attributed to the dominance of the male age group and low engagement by females. Similarly, findings by different authors [8, 37–41] confirmed the involvement of more men than women in charcoal production due to the need for intensive labor in Narok-South Subcounty (Kenya), Niger state, Oyo state (Nigeria), Injibara, and South Omo (Ethiopia), respectively. In Ghana, male-headed households are more engaged in charcoal production than female-headed households [42]. The chi-square test of independence showed that there was a significant association between gender and forest degradation (χ^2 = 13.225) at a 5% ($P < 0.05$) level of significance. In most of the charcoal producers (54.08%), the age ranged from 20 to 43 years,

(a) (b) (c) (d) (e)

Figure 3: Various stages in the preparation of traditional earth mound kiln in Offa Woreda: (a) prepared bench mark hole of the kiln; (b) felled/stacked woody tree into a kiln; (c) wood covered with herbaceous vegetation; (d) complete kiln covered with soil and burning slowly; (e) fired kiln. source: observations (field photos by author (2018/2019)).

followed by an age group of 44–67 years (22.4%) (Table 2; Supplementary table 2). This indicates the requirement of an energetic and active age group in human life during charcoal production [6, 8, 38, 39] in Narok County, Niger State, Oyo State, and Mecha District, respectively. The chi-square test of independence showed that there was no significant association between age and forest degradation ($\chi^2 = 3.234$) at the $P > 0.1$ significance level.

Charcoal production seems to be driven by large family size (69.39%) (Table 2; Supplementary table 2), low monthly income (54.08%), and low educational status (59.18%) (Table 2; Supplementary table 2). The chi-square test of independence showed that there was a highly statistically significant association between family size and forest degradation ($\chi^2 = 27.674$) at a 1% ($P < 0.01$) level of significance. It suggests that larger family households are more likely to participate in charcoal production than smaller family households. Farmers with larger families are more likely to join an enterprise since they have the labor available and also the need to cover their day-to-day expenses. Charcoal

Figure 4: Illegal cutting of tree/shrub species from forest stands in Offa woodlands. source: observations (field photo by author (2018/2019)).

Table 2: Socioeconomic characteristics of the sampled household heads/charcoal producers and their association with forest degradation in Offa Woreda, Wolaita Zone ($n = 98$).

Socioeconomic variable	Category	Frequency	Percentage (%)	χ^2	P-value
Age class	≤19	8	8.16	3.234 NS	0.215
	20–43	53	54.08		
	44–67	22	22.45		
	≥68	15	15.31		
Gender	Male	67	68.40	13.225*	0.038
	Female	31	31.60		
Family size	≤4	11	11.22	27.674**	0.001
	5–8	68	69.39		
	≥9	19	19.39		
Educational status	Nonformal	58	59.18	35.678**	0.001
	Primary/elementary	18	18.37		
	Secondary	15	15.31		
	Tertiary	7	7.14		
Level of association	Yes	55	56.12	2.894 NS	0.234
	No	43	43.88		
Occupation	Farmers	81	82.65	26.786*	0.02
	Trader	5	5.10		
	Civil servant	10	10.20		
	Investor	2	2.05		
Ancestry	Native	56	57.14	2.562 NS	0.165
	Non-native	42	42.86		
Monthly income (Ethiopian birr)	<400	53	54.08	38.676**	0.001
	400–800	31	31.63		
	800–1,200	8	8.16		
	>1,200	6	6.12		

Note. (**) significant level at 1%; (*) at 5%; (NS) indicate nonsignificance levels, respectively. source: survey result (2018/2019).

producers that have a larger number of active members, particularly males, can produce a higher volume of charcoal and increase their income than households that have fewer members [8, 42, 43] in Kenya and Ghana, unlike in Injibara, Awi Zone (Ethiopia), as reported by Andaregie et al. [40], where most of the household size was in the range of ≤4, which seems to be the lower family size. Regarding monthly income, the majority of charcoal producers (54.08%) received a monthly income of 400 or less in Ethiopian Birr (ETB), followed by 31.63%, who received a monthly income of between 400 and 800 ETB (Table 2; Supplementary table 2). This is in accord with the findings of Kibet [8], Tetteh et al. [44], and Schure et al. [45] that charcoal and firewood are sold by rural households in Kenya, Ghana, and the Democratic Republic of Congo (DRC), respectively, for cash income. In Ghana, rural households consider charcoal deluxe and instead use firewood as their source of energy [44]. The chi-square test of independence showed that there was a highly statistically significant association between monthly income and forest degradation ($\chi^2 = 38.676$) at a 1%

($P < 0.01$) level of significance. Meaning that farmers who have a lower monthly income from other activities are more likely to participate in charcoal production, which has a considerable effect on forest degradation. The money that they require for their day-to-day activities is covered by charcoal production. The majority (82.65%) of charcoal producers are farmers, followed by civil servants (10.2%) (Table 2; Supplementary table 2). This result is consistent with that of [6] in Mecha District (Ethiopia), where they reported that most charcoal producer farmers' primary occupation was charcoal production following farming activity. This is described by the high contribution of charcoal to household cash income and supports the declaration by Angelsen et al. [1] that forest income contributes more to regular household income than is otherwise known. The chi-square test of independence showed that there was a significant association between occupation and forest degradation ($\chi^2 = 26.786$) at a 5% ($P < 0.05$) level of significance. Indicating that households, where farming is their main occupation, depend on charcoal production for their survival.

Concerning the level of education, the majority of charcoal producers (59.18%) attended nonformal education, followed by primary school (18.37%), and secondary school (15.31%) (Table 2; Supplementary table 2). The chi-square test of independence showed that there was a highly statistically significant association between educational status and forest degradation ($\chi^2 = 35.678$) at a 1% ($P < 0.01$) level of significance. This indicates that an increase in the educational status of charcoal producers is more likely to improve their perception of the effect of charcoal production on deforestation. The lower the education status, the more likely someone is to engage in charcoal production and thus directly contribute to deforestation. This finding is supported by different authors [6, 39, 46–48] who argue that charcoal producers' low level of education hurts forest sustainability. At a lower educational status, farmers may not have access to other income-generating options, and thus the required money is covered through charcoal production and sale. Similarly, studies [47, 49, 50] found that educational level tends to decrease farmers' reliance on forests because those educated once had a wider range of job options, making fuelwood collection and charcoal production unprofitable due to the higher opportunity costs involved. A positive effect of schooling on productivity in the charcoal sector was also reported previously [51] in Madagascar. On the other hand, a lower level of education causes charcoal producers to enter the enterprise early since skill acquisition does not require a rigorous process, and this will make them more experienced in the business. This study correlates with Adejumobi and Eniola [52] and Adebayo et al. [39] findings that charcoal producers in Oke-Ogun and Oyo have lower educational levels. Likewise, in Kenya and Madagascar, farmers who have lower educational levels are more likely to participate in charcoal production than other livelihood alternatives like agriculture, trade, etc. [8, 51].

3.2. The Economic and Social Contribution of Charcoal Production. Charcoal production provides several economic and social benefits to the lives of many charcoal producers who are directly and indirectly involved in the business in Offa Woreda (Figure 5). All of the charcoal producers have realized the high-income contribution of charcoal production among other livelihood options in the study area. Different studies (e.g., [2, 45, 53–55]) have estimated the contribution of charcoal to household income from the perceived share of overall income.

Similarly, as [1, 6, 40, 43, 55] further stated, charcoal production and sales provide a considerable share of household income in their global study (Ghana), Mecha District, and West Gojjam Zone, respectively. Charcoal production contributes 38% and 75% of the total household income in the DRC [4, 45] and is the main source of income for all producers in southern Malawi and Kenya [2, 8]. Also, the welfare from charcoal production enables them to get basic items that are necessary for their sustenance (Table 3; Supplementary table 3). They acquired assets, including bicycles, motorbikes, and roofing materials, with charcoal money. This result agreed with the findings made by the authors [20, 56] that charcoal is a major function for some rural and urban dwellers, thus improving household resilience, serving as a safety net function for some households, and as a source of funding for agricultural production.

The charcoal business offers job opportunities for the majority of the youth (Table 3; Supplementary table 3). In the study area, about 74.49% of charcoal producers employ 1–3 employees, while 25.51% of producers employ 4–6 employees. Likewise, Kibet [8] and Schure et al. [45] indicated the high possibilities of charcoal production for employment in Kenya, Malawi, and DRC, respectively. The economic implications of the charcoal sector have been rising through the direct engagement of millions of people as producers, transporters, and traders in developing countries [13]. Aside from charcoal production, focusing on fattening, beekeeping, tourism, peat trade, and other activities would provide communities with more diverse livelihood options.

3.3. Forest Degradation Associated with Charcoal Production. As observed in Table 3 and Supplementary table 3, following agricultural expansion (39.8%), charcoal production (32.7%) is the second in its negative contribution to forest degradation. It means that felling trees for charcoal has a negative impact on ecosystem functioning and patterns over large areas and long periods of time [8, 57, 58]. According to the literature, the charcoal production process is commonly linked to forest degradation [10, 59, 60]. The key information and focus group discussion also confirmed the lack of adequate agricultural land and the absence of sufficient agricultural production in the study area. The other drivers of forest degradation in the study area are livestock grazing (5.1%), bushfires (6.12%), and wood for construction and fire (16.3%) (Table 3; Supplementary table 3). The findings obtained from this study are in line with reports by Kibet [8], Handavu et al. [61], and Herold et al. [62] that charcoal production has largely been responsible for the degradation of woodlands and, together with agriculture, for the large-scale deforestation that has occurred in East and Southern Africa over time. Furthermore, charcoal producers in Ghana

Figure 5: Charcoal transportation and marketing system in Offa woodlands. source: survey data (field photos by author (2018/2019)).

Table 3: Charcoal production and its associated socioeconomic contribution and forest degradation according to the producer's answer in Offa Woreda ($n = 98$).

Factors	Charcoal welfares	Sign and rank Positively	Frequency	Percentage (%)
Socioeconomic contribution	Livelihood source	1st	55	56.10
	Money source for buying livestock	5th	5	5.10
	Business capital	2nd	18	18.4
	Clothing purpose	4th	6	6.12
	School fees	4th	6	6.12
	Generate money for farming	3rd	8	8.16
	Human employment rate	Positively		
	4 to 6	2nd	25	25.51
	1 to 3	1st	73	74.49
	Causes of forest degradation	Negatively		
Forest degradation	Bush fires	4th	6	6.12
	Agriculture expansion	1st	39	39.8
	Wood for construction and firewood	3rd	16	16.3
	Grazing	5th	5	5.10
	Charcoal activities	2nd	32	32.70

Source: survey result (2018/2019).

indicate that, depending on the nature of the woodland management plans, producing charcoal for a long time can have positive or negative effects on the state of the woodlands [63].

The majority of charcoal producers (67.3%) have limited knowledge of the impact of their activities on forest status (Table 3; Supplementary table 3). Only 32.7% thought charcoal production was the main factor responsible for forest degradation in the study area. However, the relationship between charcoal production and environmental sustainability is not as direct (i.e., increased charcoal production causes severe environmental degradation) as has been suggested (e.g., [64]). The communities attributed the change in forest status to other causes (67.3%), such as grazing, agriculture, construction, firewood, and bushfires (Table 3; Supplementary table 3). In a focused group discussion, further interrogation of participants about the past status of forest in the area in the past 5 to 10 years indicated that the area was largely covered by a natural forest with large trees such as *Acacia* and *Podocarpus* and large wild animals, including elephants. Venturing into the forest was a risky affair due to a wide range of predators, and even crossing over to the nearby village was discouraged amongst young children, as it was dangerous.

Charcoal producers have acknowledged deforestation and the associated harmful impacts on their day-to-day livelihood activities. The study area is heavily reliant on rainfed agriculture as the majority (36%) of the respondents talked about ever-declining rainfall amounts as compared to the past when a relatively high amount of rainfall was experienced before forest clearance (Figure 6; Supplementary table 4). They also indicated the impacts that they experienced directly or indirectly due to deforestation comprising loss of pastures for livestock feeding (22.1%), soil erosion (14%), loss of biodiversity (8.1%), loss of wild food/fruits (4.7%), loss of medicinal plants (3.5%), and flash floods (11.6%) (Figure 6; Supplementary table 4). Similarly, other authors [8, 13, 52, 65] stated that increased use of fuelwood and charcoal leads to deforestation and forest degradation, erosion, loss of biodiversity, and other environmental problems.

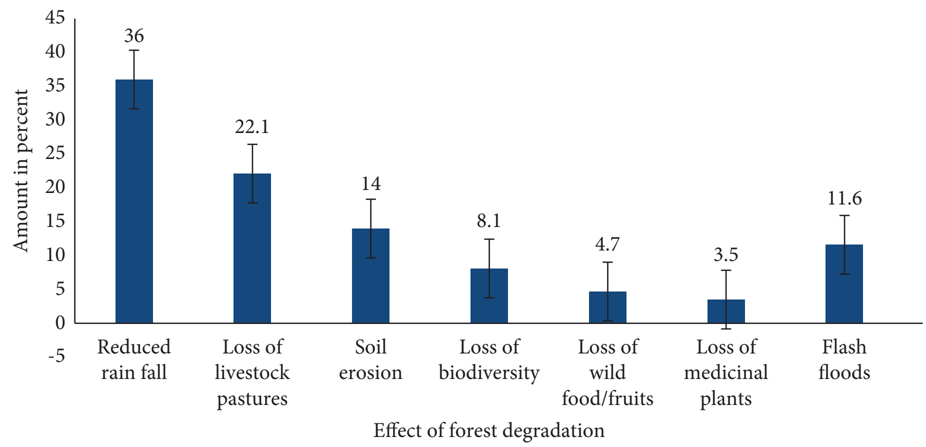

Figure 6: Negative impacts of deforestation in Offa Woreda. source: field survey result (2018/2019).

3.4. Preferred Tree Species Used for Charcoal Production in the Study Area. In the study area, indigenous local trees are used for charcoal production. As observed in Figure 2 and Supplementary table 5, charcoal producers prefer to use trees like *Acacia* species, *Combretum mole* locally named as Sobbuwaa in the Wolaita language, *Cuspidate cif* (Wogera), *Terminalia schimperiana* (Ambiyaa), *Syzygium guineense* (Ochaa), and *Olea capensis* (Meegaaraa). As a result of the sole features of these tree species, they produce good-quality charcoal. According to the findings of the Netherlands Programme of Sustainable Biomass study [66], producers prefer tree species with slow-burning characteristics for charcoal, despite the fact that these species are the most economically important trees that grow slowly.

Moreover, these species are endemic or endangered, and their exploitation will negatively affect biodiversity. These tree species are very imperative in the production of charcoal due to the thick and hard charcoal they produce with a higher calorific value [67]. They have strong wood and a high economic value, such as timber, poles, pulp and paper, food and fruits, etc.; some are protected but feel illegal. This study agreed with the report of [39] that *Terminalia* species were collected in Oyo State, Nigeria. In addition, *Acacia tortilis* (Oddoruwaa) (33.7%) has a strong preference for charcoal production (Supplementary table 5; Figure 2). *A. tortilis*, which is crucial for the sustenance of the vegetation and livelihoods in the area, is mostly destroyed. With this prevailing situation, it is faced with exhaustion in the study area. In line with this [8, 40, 43, 68], the authors indicate the preferences of *Olea* and *Acacia* species because of their availability and high-quality characteristics. *Combretum mole* is another important tree, mostly used in the housing industry and also used for charcoal production. About 22.1% of charcoal producers showed a strong preference for the species *C. mole* (Figure 2; Supplementary table 5). This indicated that charcoal was produced from the indigenous tree species by a considerable number of households, and this causes the indigenous tree species to be more severely degraded. This finding agreed with the report [69] that indigenous tree species are obtained from natural forests and were planted as woodlands on several occasions but were poorly managed and suffered from unsustainable harvesting practices.

3.5. What Technology Are Producers Using to Produce Charcoal? As seen in Figures 3(a)–3(e), the technologies used for charcoal production in the study area are traditional, namely earth mound kilns. There were not any training or capacity-building programs carried out in the area by government or nongovernmental organizations on efficient charcoal production techniques and best practices to ensure sustainable charcoal production.

All of the charcoal producers surveyed used traditional earth kiln technology in charcoal production, which is a highly destructive forest resource. Similarly, [8, 59] indicate that the high efficiency of the traditional kiln, if properly tended, appears comparable to that of improved kilns. In addition, the quantity of charcoal produced from an earth mound kiln depends on several factors associated with the carbonization efficiency and the types of kilns used to burn charcoal in Brazil [70, 71].

3.6. Existing Policies and Regulations for Charcoal Production. As reported by Melaku and Girmay [19], the major shortfall in the charcoal industry in Ethiopia is the institutional deficits it has been suffering from for a long time. There is no public agency or any kind of regulatory intervention on the part of the government to regulate the production, marketing, and consumption of charcoal, as well as the impact of charcoal production in the country generally and at the district or regional level particularly. But today, the country is planning to ensure sustainable charcoal production and marketing under the umbrella of forest (charcoal) regulations (2009). The Forest Act of 2005 embeds participatory forest management that boosts partnerships and livelihoods. Section 7 (1) of the charcoal regulations (2009) states that "No person shall undertake or engage in any activity relating to commercial charcoal production and transportation without a valid license, issued by the service under these regulations." The regulation in Section 5 requires commercial charcoal producers to form certified public

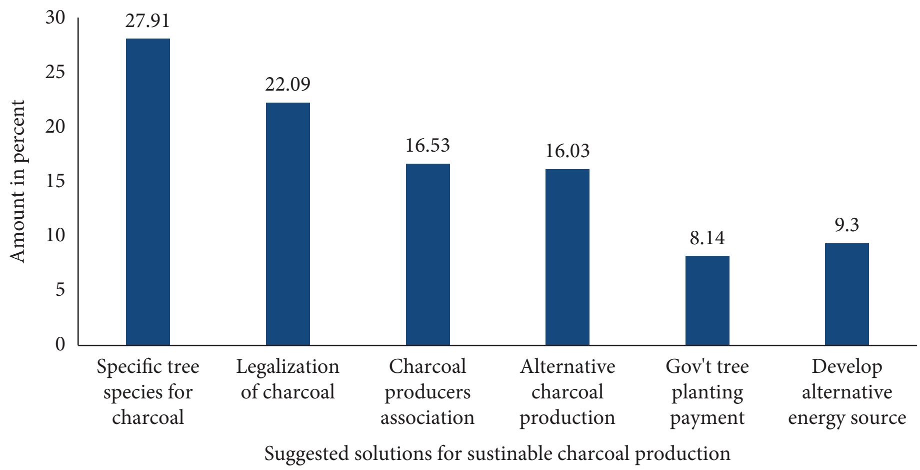

Figure 7: Suggestion for sustainable charcoal production. source: survey result (2018/2019).

accountants (CPAs), which are then registered by Ethiopian Forest Sectors (EFS). Under the regulation, any person or group wishing to produce charcoal for a commercial purpose shall be required to have a license from EFS. Charcoal regulations, 2009 Section 5 (3), an association registered under this regulation shall (a) facilitate sustainable production of charcoal by its members; (b) ensure that its members implement the reforestation conservation plans; (c) develop and implement a code of practice for self-regulation; (d) assist the service in enforcing the provisions of the act relating to sustainable charcoal production, transportation, and marketing; (e) do any other thing that is necessary for sustainable charcoal production and transportation. Despite the presence of this regulation at the national level, implementation at regional and lower levels is missing. It is mainly because of the lack of organizational structures at the regional and local levels. For instance, Offa Woreda does not have CPAs at the Woreda level. This indicates that the Woreda does not meet the requirements provided under regulations in 2009. If the regulation cannot be properly implemented and resources are not used sustainably, it will cause huge social, economic, and environmental crises.

3.7. Suggested Solution for the Sustainable Production of Charcoal from Offa Dry Woodlands. Charcoal production and its effects on deforestation, land degradation, climate change, as well as negative health require due attention from policymakers. The forest and/or woodland often selected for charcoal production are communal lands and often harvested without acquiring a permit (Figure 4). This study confirmed what has been reported [8, 25], stating that the majority of the charcoal market is informal.

The majority of charcoal producers (27.91%) have a strong feeling that the establishment of specific tree species plantations for charcoal production would improve and make the charcoal industry sustainable (Figure 7; Supplementary table 6). Similarly, [8, 72] indicated the need for the establishment of species-specific tree planting for sustainable fuelwood and charcoal production systems in Nepal. Legalization (22.09%) of charcoal production will be an improvement for the industry and put an end to illegal and unsustainable charcoal production practices (Figure 7; Supplementary table 6).

Strengthening and formation of more charcoal producers' associations (16.53%) in the study area will also help to ensure sustainable charcoal production as members are trained and equipped with the necessary knowledge to ensure sustainability in the charcoal industry (Figure 7; Supplementary table 6). Similarly, [4, 8] reported that building formal organizations is considered the best way to improve the sector sustainably. Furthermore, putting the charcoal industry on the policy agenda helps to create job opportunities, improves its economic significance, and emphasizes the need to end the open access situation in the woodlands and establish proper resource management. The introduction of a management system in which exploitation can be based on the capacity of the resource to recover itself, giving charcoal its source by establishing forest plantations of appropriate species, and creating a charcoal agency to regulate the industry is crucial. Additionally, work towards improving charcoal technology and diversifying its sources, decriminalizing charcoal production, and including charcoal in the extension packages should be the concern of the government to create a win-win situation. That means, getting benefits from the resource and conserving it. The government can also discourage charcoal production (a) by providing alternative livelihood options just as beekeeping, fatting, carbon trade, and others, (b) by providing training on the negative effects of charcoal on forests, health, and the ecosystem, (c) by implementing and enforcing the existing rules and regulations, and (d) by levying tax on those who are highly dependent on charcoal production.

4. Conclusions and Recommendations

Charcoal production is one of the main livelihood options for the community in the dry Afromontane woodlands of Offa Woreda of Wolaita. Despite its vital socioeconomic significance, charcoal production for energy demand is the basic driver of forest degradation. The findings of this study indicated more engagement among males than females, and charcoal production seems to be driven by large family sizes against low farmers' monthly income and low educational status. The majority of charcoal producers are farmers, followed by civil servants. Concerning the level of education, the majority of charcoal producers attend nonformal education, followed by primary school and tertiary. Except for the chi-square result of age, level of association, and ancestry, all socioeconomic variables of the chi-square result were significant at $P < 0.05$ and are highly associated with charcoal production and, thereby, forest degradation.

All of the charcoal producers have realized the high-income contribution of charcoal production, among others, for livelihood sustenance. Also, the welfare from charcoal production enables them to get basic items that are necessary for their sustenance. The charcoal business offered job opportunities for the majority of the youth. Following agricultural expansion, charcoal production by the community is the second in its negative contribution to forest degradation. In addition to this, livestock grazing, bushfires, and wood for construction and fire were other drivers of forest degradation in the study area. Producers acknowledge deforestation and the associated harmful impacts on their day-to-day livelihood activities. They also indicated the impacts that they experience directly or indirectly due to deforestation, including loss of pastures for livestock feeding, soil erosion, loss of biodiversity, loss of wild food and fruits, loss of medicinal plants, and flash floods.

In the study area, charcoal producers prefer to use indigenous local trees including *Acacia* species *Combretum mole*, *Cuspidate cif*, *Terminalia schimperiana*, *Syzygium guineense*, and *Olea capensis*. They have strong wood and high economic value, such as timber, poles, pulp and paper, and food and fruits; some are protected but feel illegal. However, producers often harvest these species without acquiring a permit. Due to this, the majority of the charcoal market is informal. They had a strong feeling that the establishment of specific tree species plantations in the study area would improve and make the charcoal industry sustainable. Therefore, building formal organizations through policies and rules for charcoal production is so considered the best way to improve the sector sustainably. Moreover, all of the charcoal producers in the study area use traditional earth mound kiln technology, which is a highly destructive forest resource. Thus, we recommend the use of the suggested solution and alternative livelihood options (beekeeping fatting, petty trade, etc.) for sustainable charcoal production and resource management and thereby livelihood improvement. In addition, the creation of sustainable rehabilitation programs and sustainable forest management to control the undiscerning felling of trees and the legal use of forest products is needed. The existing policies and regulations should also be implemented to foster sustainable management and improve the community's livelihood.

Data Availability

The data used to support the findings of this study are available in the figure files (Figures and Tables) and/or main text of this manuscript as well as in supplementary materials. The whole analysis and write-up were undertaken from the data collected and the data are secured to our reach.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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Supplementary Materials

Summary data on the determination of sample size of the study Kebeles (Supplementary table 1), and charcoal producer's background data and the level of association, occupation, ancestry, and monthly income depending on the producer's answer based on sample size ($n = 98$) (Supplementary table 2). Also, the summary data on the charcoal welfare from charcoal activity, rate of human employment in the charcoal business, and causes of forest degradation according to the producer's answer ($n = 98$) (Supplementary table 3), the impact of forest degradation (Supplementary table 4), and the preferred tree species for charcoal production (Supplementary table 5) according to the producer's answer ($n = 98$). Moreover, the summary data on suggestions for sustainable charcoal production according to the producer's answer ($n = 98$) (Supplementary table 6) used to support the findings of this study are available in editable version table files (*Supplementary materials*). Social, field survey data and semistructured and structured questionnaires (2018/2019). (*Supplementary Materials*)

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