GAS Journal of Engineering and Technology (GASJET)

OPEN ACCESS

Volume 2, Issue 5, 2025 Journal Homepage: https://gaspublishers.com/gasjet-home/ ISSN: 3048-5800
Email: editor@gaspublishers.com

Assessing the Impact of Charcoal Production on Forest Degradation: A Case Study of Voinjama District Lofa County

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Received: 10.07.2025 | **Accepted:** 22.07.2025 | **Published:** 06.08.2025

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DOI: *10.5281/zenodo.16751252*

Abstract **Original Research Article**

This study investigates the impact of charcoal production on forest degradation in Voinjama District, Lofa County an area characterized by dense secondary forests and a growing dependence on forest resources for livelihoods. Using a mixed-methods approach involving structured questionnaires and spatial data, the research assesses the extent of deforestation, the socio-economic drivers of charcoal production, and its environmental consequences from 2019 to 2024. Findings reveal that charcoal production is widely practiced and mainly driven by income generation (63.5%), unemployment (16.2%), and lack of alternative livelihoods (15.5%). A significant majority (75.2%) of respondents recognized the role of charcoal production in forest degradation, citing deforestation, soil erosion, biodiversity loss, and climate impacts as key concerns. Spatial data analysis and community responses also indicate that charcoal harvesting has expanded beyond accessible areas into remote forest zones, complicating monitoring efforts. Moreover, institutional weaknesses, including limited enforcement of forest regulations, were identified as enabling factors for continued forest exploitation. The study concludes that charcoal production, while economically vital for rural communities, presents serious environmental threats that undermine sustainable forest management and climate resilience in Liberia especially Lofa county. It recommends the development of alternative livelihoods, improved forest governance, community-led reforestation programs, and targeted environmental education. Addressing these challenges requires integrated policy interventions that balance ecological sustainability with socio-economic development to curb forest degradation in Voinjama District and similar regions.

Keywords: Charcoal Production, Community Perception, Deforestation, Environmental Impact, Forest Degradation, Land Use, Livelihood Sustainability.

Citation: Kpehe, R., & Harris, P. B. (2025). Assessing the impact of charcoal production on forest degradation: A case study of Voinjama District, Lofa County. *GAS Journal of Engineering and Technology (GASJET)*, *2*(5), [14-26].

1. INTRODUCTION

According to the 2018–2019 National Forest Inventory, forests in Liberia span approximately 6.69 million hectares, covering more than two-thirds of the country's total land area an expanse nearly twice as large as Belgium. Despite this vast coverage, the nation experienced an annual deforestation rate of about 30,000 hectares, or 0.61%, between 1990 and 2010, amounting to an estimated 600,000 hectares or 12.2% in total forest loss during that period. At the current rate, if deforestation persists, Liberia will have no forests left by 2050 (Nthara & Sanjay , 2020). Forests play a fundamental role in maintaining environmental balance by offering essential services like capturing carbon, preserving biodiversity, and safeguarding water resources. Nevertheless, many countries in Sub-Saharan Africa are facing ongoing issues of forest loss and degradation, largely due to the spread of agriculture, timber extraction, and increasing demand for energy (FOA, 2020). In Liberia, where over 60% of the landmass is covered by forest, unsustainable charcoal production has emerged as a major driver of forest degradation, particularly in rural districts such as Voinjama in Lofa County Forestry Development Authority (FDA, 2022).

In Liberia, charcoal continues to be the primary fuel source for household cooking, with more than 80% of families in urban and semi-urban communities depending on it (Alfaro, 2018). The process of producing charcoal requires considerable manual labor and generally includes felling mature trees, converting the wood into charcoal using traditional earthen kilns, and then distributing it for sale. This technique results in extensive loss of forest biomass and is seldom accompanied by

efforts to replant or restore the affected areas (VOSIEDA, 2023). As a result, large areas of forested land are rapidly being converted into degraded woodlands, with implications for climate change, biodiversity loss, and soil erosion. Charcoal is in high demand in all seven communities and Liberia as there are no affordable alternatives available. Charcoal production is expected to increase in the coming decades, which is largely informal and generates income for more than 80% of rural people in Liberia. However, due to the lack of regulation, this sector promotes inefficiency resulting in the government losing millions in revenue. According to the FAO, greenhouse gas emissions of 1-2.4 Gt CO2e are emitted annually due to unsustainable forest management and inefficient charcoal manufacturing and wood fuel combustion. This represents 2-7% of global anthropogenic emissions. This can be achieved by improving wood sourcing, carbonization, transport, distribution and end-use efficiency (IKI, 2023)

Voinjama District, located in the northern region of Lofa County, is characterized by dense secondary forests and significant tree cover. The area has seen a noticeable increase in charcoal production over the last decade due to rising demand from nearby urban centers such as Voinjama City, Zorzor, and even cross-border markets in Guinea (EPA Liberia, 2024). While charcoal production provides income for rural households, its unregulated nature poses long-term threats to forest ecosystems and local livelihoods dependent on forest resources.

2. STATEMENT OF THE PROBLEM

Although Liberia has implemented national initiatives aimed at encouraging sustainable forest management, many areas such as Voinjama District still experience ongoing forest degradation. Charcoal production, a factor that has received relatively little research attention but is growing in impact, plays a significant role in this decline. The expansion of charcoal harvesting has been fueled by unsustainable extraction methods, weak enforcement of environmental laws, and the scarcity of alternative energy options, all contributing to continued forest loss and fragmentation of natural habitats. (Ekpo, 2021) Current forest governance frameworks in Liberia do not adequately regulate small-scale charcoal production, especially in rural districts where monitoring capacity is low. In Voinjama, anecdotal evidence suggests that forest clearing for charcoal production is intensifying, yet there is a lack of empirical data documenting the extent of its environmental impact. This knowledge gap hampers policy intervention and community-based forest management efforts aimed at balancing livelihood needs with environmental sustainability (Halton, 2013). This study, therefore, seeks to assess the impact of charcoal production on forest degradation in Voinjama District. It aims to provide data-driven insights into the scale of tree loss, community dependency on charcoal income, and the ecological consequences of continued deforestation. Without such research, the environmental degradation associated with charcoal production may escalate undermining both conservation goals and local development efforts in Lofa County.

3. GENERAL OBJECTIVE

Assessing the Impact of Charcoal Production on Forest Degradation: A Case Study of Voinjama District Lofa County

Specific objectives

1. To assess the extent and spatial distribution of forest degradation linked to charcoal production activities in Voinjama District.
2. To identify the major drivers and socio-economic factors contributing to charcoal production in the district.
3. To evaluate the environmental consequences of charcoal production on forest health, biodiversity, and land use patterns in Voinjama District

4. HYPOTHESES

- **Null Hypothesis (H_0):**

  There is no significant relationship between charcoal production and forest degradation in Voinjama District, Lofa County.

- **Alternative Hypothesis (H_1):**

  There is a significant relationship between charcoal production and forest degradation in Voinjama District, Lofa County.

5. REVIEW OF LITERATURE

➢ Overview of Charcoal production in Lofa county

According to Global Forest Watch (GFW, 2024), In 2020, Voinjama had 199 kha of natural forest, extending over 94% of its land area. In 2024, it lost 4.75 kha of natural forest, equivalent to 3.08 Mt of CO_2 emissions. From 2001 to 2024, Voinjama lost 230 ha of tree cover from fires and 82.5 kha from all other drivers of loss. The year with the most tree cover loss due to fires during this period was 2016 with 74 ha lost to fires. Charcoal making is a very common livelihood activity throughout Liberia, most especially in the rural areas like the districts of Voinjama, Lofa County. Though it is a major source of energy and income-generating activity for most households, the unregulated and traditional charcoal-making processes have posed some serious environmental issues. The mounting demand for charcoal is causing forest degradation, loss of biodiversity, and negative climate effects. (Alfaro, 2018).

One of the most direct effects of charcoal production is deforestation. Charcoal production is essentially harmful to the environment and human welfare. Not only does it release huge amounts of CO2, adding to atmospheric pollution, but it is also hazardous to the health of producers and consumers alike. The soot and smoke from charcoal production expose individuals to toxic chemicals, causing negative health consequences and

even premature mortality, especially in children. (Balume, 2025) The combined result of such activities has resulted in the loss of forest cover in primary and secondary forests, increased land degradation, and decreased ecosystem services (Shukla, 2024). Forests in Lofa County harbor several endemic and threatened species. Nonetheless, indiscriminate tree cutting for charcoal production disturbs habitats and shifts the balance of the ecosystem. This has contributed to diminishing animal populations and the migration of animals to less disrupted regions. Global Forest Watch (2024) states that forest clearance in north Liberia, including Voinjama, poses a significant threat to biodiversity due to habitat fragmentation and ecological imbalance. Progressive habitat loss due to commercial logging adds to the issues as the habitats are converted to cash crops cultivation, subsistence agriculture, forest fires, mineral prospecting and mining. These activities leave behind tiny-unconnected patches in which the chimpanzee populations are isolated and thus become vulnerable. Forest removal leaves soils vulnerable to erosion, especially during the rainy season. Charcoal production, when combined with poor land management practices, results in the loss of topsoil, decreased soil fertility, and increased sedimentation in nearby rivers and streams (Veldkamp, 2020). In Voinjama, areas formerly used for agriculture are becoming less productive, directly affecting food security and rural livelihoods. (Wesseh, 2025) Charcoal production is a source of greenhouse gas emissions from both carbonization and deforestation. Wood burning in traditional kilns produces vast amounts of carbon dioxide (CO_2), methane (CH_4), and black carbon released into the atmosphere. While the emissions are localized, they all add up to contribute to global climate change (UNDP Liberia, 2023). The use of charcoal as a source of energy highlights the necessity for a shift to cleaner forms of energy in rural Liberia.

5.1. Conceptual Review

➢ Charcoal Production and Forest Resource Exploitation

Charcoal production is a major contributor to forest degradation in Sub-Saharan Africa, driven by high dependence on biomass as a primary source of energy (FAO, 2020). In Liberia, charcoal is widely used for domestic cooking, particularly in urban and peri-urban households, where over 80% of the population relies on it due to limited access to modern energy alternatives (World Bank., 2023) The production process, often informal and unregulated, involves the harvesting of live trees and their carbonization in inefficient earthen kilns, which leads to significant loss of woody biomass and increased emissions of greenhouse gases (GIZ, 2021). Studies have shown that the traditional method of charcoal production results in conversion efficiencies as low as 10–15%, which intensifies pressure on forest ecosystems (Sivanand, 2025) .

➢ Environmental Impacts of Charcoal Production

Charcoal production in tropical regions of the world is often perceived to have devastating ecological and environmental effects and governments, public forestry institutions and non-government organizations have been particularly concerned about these charcoal-related impacts. The most commonly cited impact is deforestation, i.e., the clearance of forest or woodland The environmental consequences of charcoal production extend beyond tree felling. Continuous harvesting without reforestation depletes tree cover, alters vegetation structure, and contributes to habitat fragmentation and biodiversity loss (Chidumayo, 2013). In Liberia's Upper Guinea Forest region one of the world's biodiversity hotspots charcoal productions has been identified as a direct driver of forest cover reduction (USAID, 2023)the cumulative effects include soil erosion, declining rainfall infiltration capacity, and increased vulnerability to climate variability. Moreover, localized studies in similar forest zones across West Africa have revealed that the expansion of charcoal production often accelerates land degradation and reduces ecosystem resilience (Acheampong, 2019).

➢ Socioeconomic Dimensions of Charcoal Dependence

Charcoal production is also an important livelihood activity for many rural households. In districts such as Voinjama, it serves as a critical income-generating option, especially during the dry season when agricultural activity is minimal (EPA, 2024) However, the short-term economic benefits often come at the cost of long-term ecological sustainability. The lack of alternative income sources and energy options perpetuates the reliance on unsustainable charcoal practices. Studies conducted in Sierra Leone, Ghana, and Liberia suggest that the poverty-energy-environment nexus is a central barrier to sustainable forest management (Koroma, 2024). This reinforces the need for integrated approaches that address both environmental conservation and rural development. Charcoal is widely used as an urban fuel, in East Africa it remains popular even with increase per capita income, higher electrification rate and reasonable renewable energy alternatives (Doggart, 2020). Charcoal is relatively cheap as compare to liquefied petroleum gas (LPG) or kerosene, hence the demand for charcoal is expected to continue increasing in the future, though there are every effort to discourage its use by some environmental advocates. It seems likely that production and consumption of charcoal will continue well into the future (Fayiah, 2018), even in Ghana or Nigeria where 60-70% of households are electrified they still rely on charcoal or firewood for cooking and high-income earners rarely replace charcoal with other source of energy. Sierra Leonean urban household energy consumption has changed considerably over the last two decades; in 2004 urban energy use was; wood 88%, charcoal 8% and kerosene 4% (GoSL 2007) (in rural household wood accounted for 97% of energy use). By 2013, charcoal had increased to 73%, wood had declined to 26% and kerosene to 0.6%; LPG and electricity had entered the market but accounted for only 0.2% of energy use (Arevalo & Puentes , 2016). The

2014 Household Energy Consumption Survey (HECS) in Sierra Leone revealed that high income earners prefer charcoal to fire wood (Household survey 2014).

➢ Forest Governance and Policy Gaps

Forest degradation linked to charcoal production is intensified by weak forest governance, limited enforcement of environmental regulations, and the informal nature of the charcoal value chain (Veen, 2022). In Liberia, the Forestry Development Authority (FDA) and the Environmental Protection Agency (EPA) have developed frameworks for sustainable forest management, but implementation is often undermined by capacity constraints, lack of coordination, and inadequate community engagement (FDA, 2022; UNDP, 2023). The National Charcoal Strategy, although in development stages, seeks to promote improved kilns, reforestation schemes, and formalized licensing systems. However, evidence on the ground suggests that forest resources in remote areas like Voinjama remain vulnerable to unmonitored exploitation (FAO, 2017)

➢ Empirical Gaps and the Need for Localized Studies

Despite growing awareness of the link between charcoal production and deforestation, there remains a lack of localized empirical data in districts like Voinjama. Most national-level reports provide aggregated statistics that mask district-level dynamics of forest use and degradation. A case study approach focusing on Voinjama can provide insights into the spatial extent, production methods, and socioeconomic drivers of charcoal-related forest degradation. Understanding local practices, community perceptions, and ecological impacts is essential for designing targeted interventions that balance livelihood needs with conservation (EPA, 2025).

6. MATERIALS AND METHODS

➢ Research Design

This study sought to determine the factors of affecting house hold in participating in waste management. In order to accurately analyze and bring solutions to the research problem, a proper research design has to be applied. A research design involves the general assumptions of a study to data collection and analysis methods (Creswell, 2009). Therefore, this study adopted the descriptive survey research design.

➢ Area of the study physical presentation

Voinjama, a modest-sized city in northern Liberia, functions as the administrative center of Lofa County. It is situated in a hilly region close to the border with Guinea. According to the 2008 national census, the city had a population of 26,594. The majority of residents traditionally relied on subsistence rice farming as their main source of livelihood. Unlike the paddy rice cultivated in many other regions globally, farmers in Liberia typically grow upland (dryland) rice on plots cleared using the slash-and-burn method, a practice made possible by the area's dense forest cover. In addition to rice, key crops grown around Voinjama include cassava, collard greens, potato greens, and palm nuts, which are processed to produce the widely used red palm oil. A locally popular beverage, known as palm wine, is also tapped from specific species of palm trees.

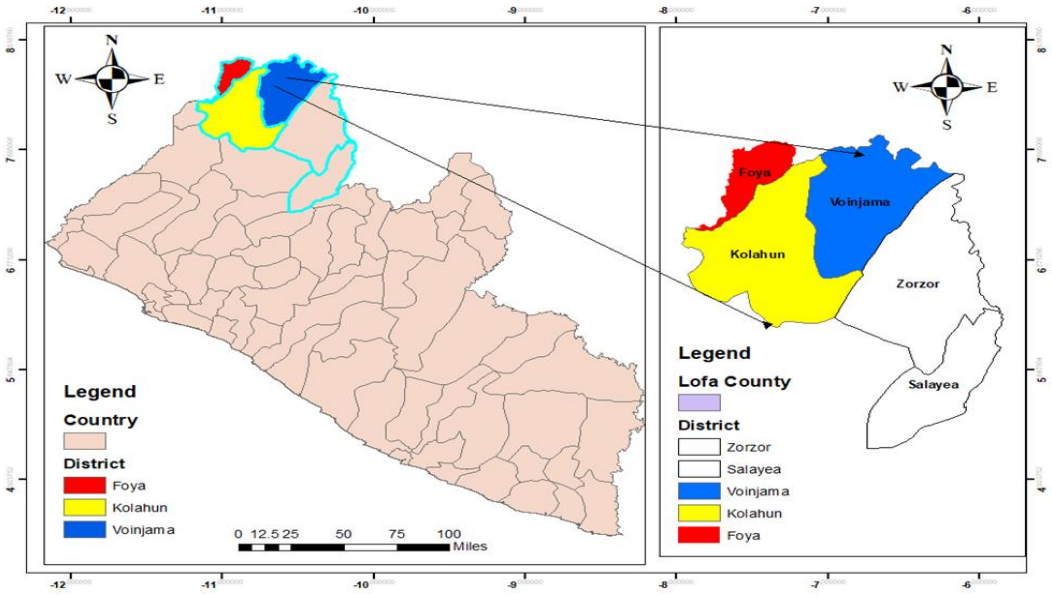
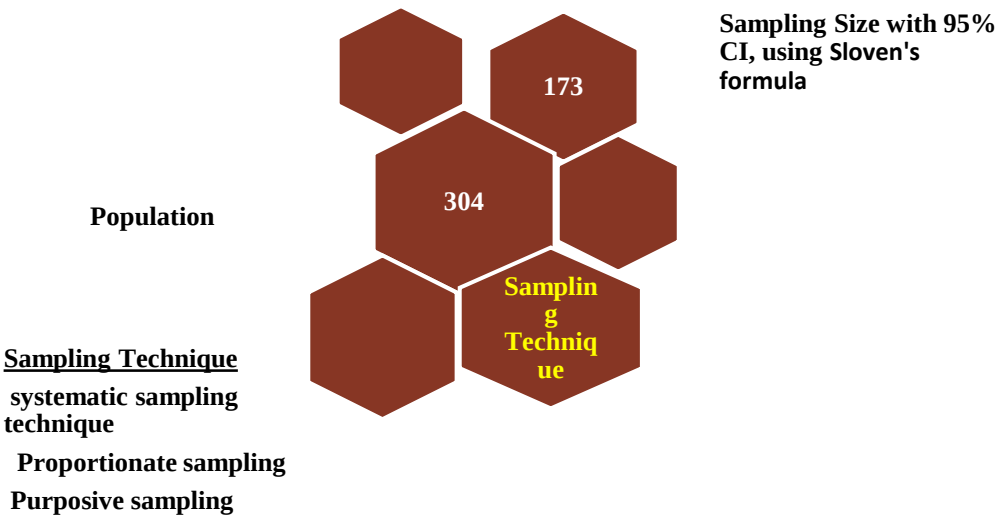


Figure 1: Location of Study Area

Figure: Research Method



Target Population, Sample Size and Sampling Design

DATA COLLECTION INSTRUMENTS

➢ Questionnaire technique

The questionnaire includes a series of closed questions about issues that are expected of the respondent information, where these types of questions were distributed by the researcher among respondents to collect the structures questionnaires in form of the Likert scale method by requesting respondents to respond to a series of statements by indicating whether he or they strongly agree (4), agree (3), disagree (2), and strongly disagree (1)

➢ Documentation tool

Robert (2014) highlights that one of the main strengths of document analysis lies in its capacity to examine existing sources thoroughly, allowing researchers to uncover deeper insights into the topic under investigation. This method involves an in-depth assessment of various published materials, including official documents, research reports, academic journals, magazines, and policy papers that are pertinent to the study. Document analysis is particularly useful for synthesizing existing knowledge and integrating international viewpoints, which helps establish a comparative foundation for critical analysis and interpretation. In this study, the researcher adopted this method to collect relevant secondary data.

➢ Data Analysis Methods

Data obtained through questionnaires distributed to members of the Voinjama city administration, local community leaders, and farmers were analyzed using the Statistical Package for Social Sciences (SPSS), version 23. The analysis included the use of frequencies, percentages, and tabular presentations to summarize and display the findings. In addition, both correlation analysis and descriptive statistics were applied.

7. RESULTS AND DISCUSSIONS OF FINDINGS

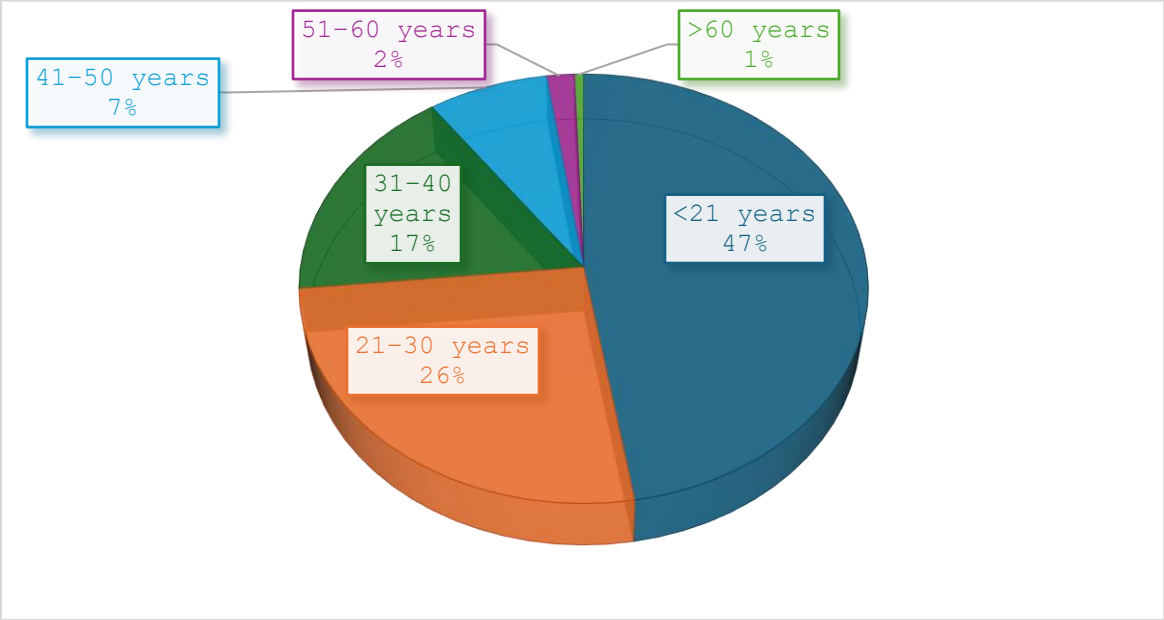
Table 1: Personal identification of respondents

Category	**Frequency**	**Percentage**
Male	87	50.3%
Female	86	49.7%
Total	**173**	**100%**

(Source: Researcher 2025**)**

Table 1, shows that there are 87 males, which account for 50.3% of the total population while there are 86 females, representing 49.7% of the total population. The data shows a significant gender imbalance, with males constituting a larger portion of the group. The gender distribution could also influence discussions around diversity and inclusion, with the possibility of developing strategies to ensure equal opportunities and participation for all genders

Age level

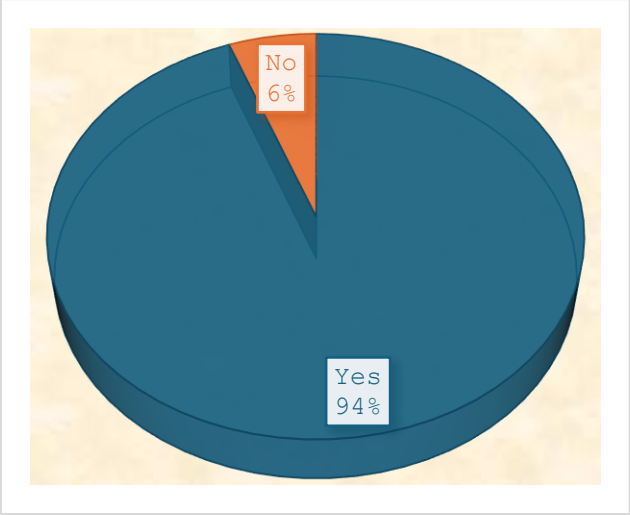


(Source: Field Data 2025**)**

The age distribution of respondents in the study shows that charcoal production in Voinjama District is largely driven by youth. Nearly half (47%) are under 21 years, and 26% are between 21–30 years, indicating that over 70% of those involved are young. In contrast, older age groups are minimally represented, with only 1% over 60. This suggests that charcoal production is primarily a livelihood activity for younger people, likely due to limited alternative income opportunities

KNOWLEDGE & PERCEPTIONS OF CHARCOAL PRODUCTION

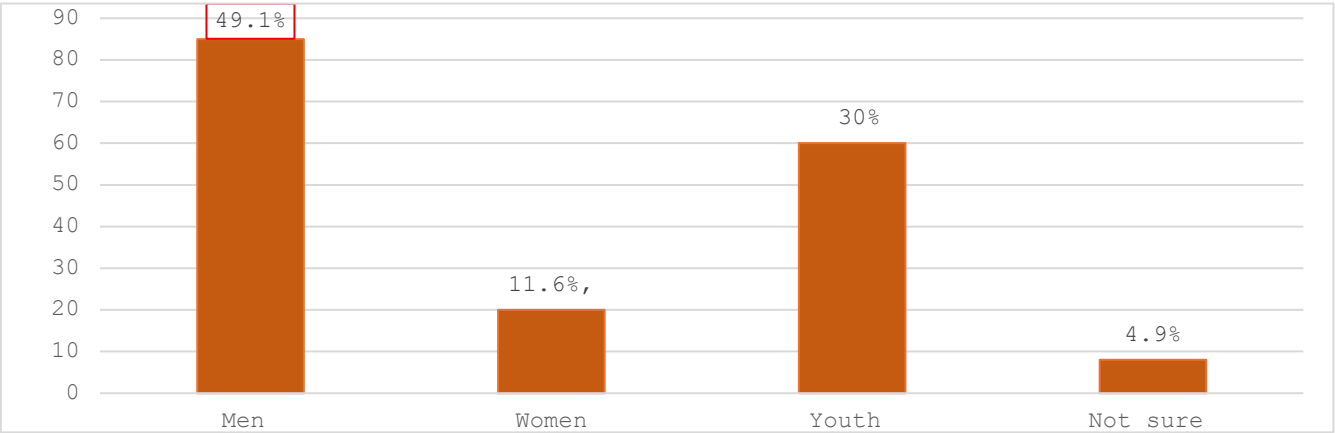
Table 2: Are you aware of charcoal production activities in your community?



(Source: Field Data 2025**)**

Table 2, shows that out of 173 respondents, 94.2% (163 individuals) indicated that they are aware of charcoal production activities in their community, while only 5.8% (10 individuals) said they are not aware. This suggests that charcoal production is a widely recognized and likely prominent activity within the community. in summary, the community's high awareness provides a strong foundation for participatory approaches in addressing the challenges and opportunities associated with charcoal production.

Who mostly engages in charcoal production in your area?



(Source: Field Data 2025**)**

The majority of respondents (49.1%) believe that men are the primary actors in charcoal production, followed by youth (30%) and women (11.6%). Only 4.9% were uncertain. Charcoal production is seen as a male- and youth-dominated activity, likely due to the physical demands and the role of men in rural labor economies. Women's lower representation may reflect traditional gender roles, though their involvement should not be overlooked in value chain processes like marketing and retail.

Table 3: What do you think motivates people to engage in charcoal production?

What do you think motivates people to engage in charcoal production?		
Category	Frequency	Percent
Income generation	110	63.5
Lack of employment	28	16.2
Easy access to forest	8	4.2
No alternative livelihood	27	15.5
Total	173	100

(Source: Field Data 2025**)**

According to table 3, the majority (63.5%) of people in Voinjama District engage in charcoal production mainly for income, with others citing unemployment (16.2%) and lack of alternative livelihoods (15.5%). This suggests that charcoal production is driven by economic necessity rather than choice. The easy access to forests (4.2%) also contributes. This has serious implications for forest degradation, leading to biodiversity loss, soil erosion, and climate impacts. Addressing the issue requires creating sustainable income alternatives, job opportunities, and stronger forest management to break the cycle of poverty and environmental harm.

ENVIRONMENTAL IMPACTS OF CHARCOAL PRODUCTION

Table 4: Do you think charcoal production contributes to forest degradation**?**

Do you think charcoal production contributes to forest degradation?		
Category	Frequency	Percent
YES	130	75.2
NO	43	24.8
TOTAL	173	100

(Source Field Data 2025**)**

Table 4, reveals that a large majority of respondents (75.2%) believe that charcoal production contributes to forest degradation, while only 24.8% do not share this view. This indicates strong community awareness of the negative environmental impact of charcoal production in Voinjama District. Most people recognize the environmental risks of charcoal production, but continued reliance on it for income means that addressing forest degradation requires not just awareness but also sustainable alternatives and policy support.

Table 5: What do you think motivates people to engage in charcoal production**?**

What do you think motivates people to engage in charcoal production?		
Category	Frequency	Percent
Deforestation	60	
Soil erosion	40	
Loss of biodiversity	29	
Climate change impacts	30	
Water source depletion	14	

(Source: Field Data 2025**)**

The finding shows in table 5 that, in Voinjama District, residents identified key environmental impacts of charcoal production: deforestation (34.7%), soil erosion (23.1%), climate change impacts (17.3%), loss of biodiversity (16.8%), and water source depletion (8.1%). These findings show strong community awareness of the environmental harm caused by charcoal production. This creates an opportunity for promoting environmental education, alternative livelihoods, and sustainable forest management. Without action, continued reliance on charcoal will worsen forest degradation, harm agriculture, and increase climate vulnerability in the area.

OBJECTIVE ONE: To assess the extent and spatial distribution of forest degradation linked to charcoal production activities in Voinjama District.

Table 5: spatial distribution of forest degradation linked to charcoal production activities

Items	**SA**	**A**	**N**	**SD**	**D**	**Mean**	**SDv**
Charcoal production is widespread across multiple forested areas in Voinjama District.	14 8.1%	64 37%	15 8.7%	45 20%	35 20.2%	3.00	1.326
The rate of forest loss due to charcoal production has increased in recent years	67 38.7%	44 25.4%	23 13.%	15 8.7%	24 13.9%	2.00	1.419
Charcoal production is concentrated near main roads and accessible forest areas.	19 11%	31 29.5%	7 4.0	53 30.6%	63 36.4%	4.00	1.410

(Source: Field Data 2025**)**

Table 6, reveals that community responses from Voinjama District about charcoal production show valuable information on its extent and contribution to forest degradation. When the respondents were asked if charcoal production is extensive and occurs across several forest areas, opinion was divided. Approximately 45.1% of the respondents agreed or strongly agreed with the statement, while 40.2% disagreed or strongly disagreed. The mean response leaned towards neutrality with a 3.00 mean score, suggesting differing views regarding how extensive charcoal production is across the district. For the perception that the rate of forest loss attributed to charcoal production has been rising in recent years, most respondents concurred. Specifically, 64.1% agreed or strongly agreed, with a mean score of 2.00, indicating general agreement that deforestation from charcoal production is getting worse. These finding highlights increasing community concern over the accelerating forest cover loss. When the respondents were asked if charcoal production is localized close to main roads and accessible parts of the forest, a considerable number of respondents disagreed, with 67% disagreeing or strongly disagreeing. With a mean response of 4.00, this implies that many assume charcoal production is not confined to highly accessible zones but could also be taking place in less accessible parts of the forest. This suggests that charcoal harvesting activities may be moving beyond traditionally assumed areas, increasing the difficulty in monitoring and managing these activities. In total, these responses underscore that although there is keen awareness of rising forest loss to charcoal production, there are differences in perceptions of just how pervasive and geographically concentrated these activities are. This range of variation indicates that charcoal production could be more scattered than generally assumed, which poses difficulties for forest management. It underlines the necessity for integrated approaches involving efficient monitoring, enforcement, and community involvement to tackle the complex character of charcoal-driven forest degradation in Voinjama District.

OBJECTIVE TWO: Major drivers and socio-economic factors contributing to charcoal production in the district.

Table 7: Socio-economic factors contributing to charcoal production

Items	SA	A	N	SD	D	Mean	SDv
Charcoal production is considered a profitable and accessible business by local communities	64 37%	45 20%	15 8.7%	14 8.1%	35 20.2%	3.81	1.393
Lack of alternative income sources drives many residents into charcoal production	67 38.7%	44 25.4%	23 13.%	15 8.7%	24 13.9%	3.92	1.355
Weak enforcement of forest regulations enables illegal charcoal activities.	63 36.4%	53 30.6%	7 4.0%	31 29.5%	19 11%	3.88	1.371

(Source: Field Data 2025**)**

Table 7, indicates that charcoal production in the district is primarily driven by its perceived profitability, limited livelihood alternatives, and weak enforcement of forest regulations.

A majority of respondents (37% strongly agreed and 20% agreed) consider charcoal production a profitable and accessible business, totaling 57% in agreement, with a mean score of 3.81 and a standard deviation of 1.393. This reflects a generally positive perception of charcoal as a viable economic activity among local communities. Regarding income sources, 38.7% strongly agreed and 25.4% agreed (a combined 64.1%) that the lack of alternative livelihoods compels residents to engage in charcoal production. This item had the highest mean score of 3.92 (SD = 1.355), highlighting economic necessity as a major driver. Finally, 36.4% strongly agreed and 30.6% agreed (67% total agreement) that weak enforcement of forest regulations enables illegal charcoal activities. This was supported by a mean of 3.88 and a standard deviation of 1.371, indicating that institutional weakness is widely recognized as a key enabling factor. In summary, the findings show that 57% of respondents view charcoal production as economically beneficial, 64.1% attribute its prevalence to a lack of other income sources, and 67% believe poor regulatory enforcement allows the practice to thrive. These insights underscore the need for targeted interventions focusing on livelihood diversification and improved forest governance. Environmentally, charcoal production driven by poverty and weak regulation leads to unsustainable forest use, contributing to deforestation, biodiversity loss, and increased carbon emissions. Socio-economically, the data reveals deep structural challenges including high unemployment, limited access to capital, and poor service delivery. Institutionally, the lack of effective law enforcement undermines forest governance and hinders national climate and conservation goals.

OBJECTIVE THREE: To evaluate the environmental consequences of charcoal production on forest health, biodiversity, and land use patterns in Voinjama District.

Table 8: Environmental consequences of charcoal production on forest

Items	SA	A	N	SD	D	Mean	SDv
Charcoal production negatively affects the regeneration capacity of forest ecosystems.	73 42.2%	51 29.%	22 12.7%	24 13.9%	3 1.7%	2.00	1.125
Soil quality in charcoal harvesting areas has significantly deteriorated.	67 38.7%	44 25.4%	23 13.%	15 8.7%	24 13.9%	2.00	1.419
Charcoal production has led to a decline in forest biodiversity	44 25.4%	67 38.7%	24 13.9%	23 13.%	15 8.7%	2.00	1.211

(Source: Field Data 2025**)**

Table 8, shows that the response to the statement *"Charcoal production negatively affects the regeneration capacity of forest ecosystems,"* 42.2% of respondents strongly agreed and 29% agreed, totaling 71.2% in agreement. Only 13.9% disagreed and 1.7% strongly disagreed, while 12.7% were neutral. The mean score was 2.00 with a standard deviation of 1.125, indicating a clear majority belief that forest regeneration is being hindered by charcoal activities. For the statement *"Soil quality in charcoal harvesting areas has significantly deteriorated,"* 38.7% strongly agreed and 25.4% agreed, accounting for 64.1% of respondents. Meanwhile, 13.9% disagreed, 8.7% strongly disagreed, and 13% were neutral. The mean score was 2.00 with a standard deviation of 1.419, reflecting general agreement on the adverse effects of charcoal production on soil health. Regarding the impact on biodiversity, 25.4% strongly agreed and 38.7% agreed that *"Charcoal production has led to a decline in forest biodiversity,"* totaling 64.1% in agreement. Neutral responses stood at 13.9%, while 13% disagreed and 8.7% strongly disagreed. This item also had a mean of 2.00 and a standard deviation of 1.211, suggesting a strong consensus that charcoal production contributes to biodiversity loss. In summary, a significant majority of respondents 71.2% on forest regeneration, 64.1% on soil quality, and 64.1% on biodiversity believe that charcoal production is harming the environment in multiple ways. These findings confirm community awareness of the environmental degradation associated with charcoal activities and point to the need for urgent sustainable land and forest management strategies in the district.

8. HYPOTHESIS ANALYSIS

Based on the findings of the study, the data strongly indicate that charcoal production contributes significantly to forest degradation in Voinjama District. 75.2% of respondents agreed that charcoal production leads to forest degradation. 71.2% believed it negatively affects forest regeneration capacity. 64.1% reported that soil quality has deteriorated and biodiversity has declined due to charcoal production. A majority also agreed that deforestation from charcoal production is increasing and that regulatory enforcement is weak. These results reflect a statistically and perceptually significant relationship between charcoal production and environmental degradation across multiple dimensions deforestation, soil degradation, biodiversity loss, and forest regeneration. Therefore, the study rejects the Null Hypothesis (H_0) and accepts the Alternative Hypothesis (H_1): *There is a significant relationship between charcoal production and forest degradation in Voinjama District, Lofa County.*

9 RESULTS DISCUSSION

The findings from the study in Voinjama District reveal that charcoal production is widely recognized and practiced within local communities, with 49.1% of respondents identifying men as the main actors, followed by youth (30%) and women (11.6%). A majority (63.5%) cited income generation as the primary motivation, while others pointed to unemployment (16.2%) and lack of alternatives (15.5%) as driving factors. The activity is seen as both profitable and accessible by 57% of respondents, although its expansion into remote areas evidenced by 67% disagreeing that it is limited to areas near roads raises challenges for forest monitoring. These socio-economic pressures, combined with weak law enforcement (67%), are key drivers of the ongoing reliance on charcoal production. Environmental impacts are clearly understood by the community, with 75.2% acknowledging its role in forest degradation. Specific consequences include deforestation (34.7%), soil erosion (23.1%), biodiversity loss (16.8%), and water source depletion (8.1%). Moreover, 64.1% believe forest loss has increased, and similar percentages agree it has harmed forest regeneration, soil quality, and biodiversity. These concerns reflect a strong awareness of the ecological toll, yet economic necessity continues to override environmental priorities. The data emphasize the urgent need for policy interventions focused on livelihood diversification, community-led forest management, environmental education, and stronger enforcement mechanisms to reduce dependency on unsustainable charcoal practices.

10. CONCLUSION

In summary, charcoal production in Voinjama District is driven largely by economic hardship, unemployment, and weak forest governance. While it provides income for many

households, it also leads to serious environmental consequences, including deforestation, soil degradation, biodiversity loss, and greater climate vulnerability. The community is aware of these impacts, but the lack of alternative livelihoods keeps them reliant on this unsustainable practice. These findings underscore the urgent need for integrated policy responses that include livelihood diversification, environmental education, stronger forest law enforcement, and community-based forest management in order to reduce dependence on charcoal and promote sustainable resource use.

OBJECTIVE 1: To assess the extent and spatial distribution of forest degradation linked to charcoal production activities in Voinjama District.

Community responses from Voinjama District reveal mixed views on the extent of charcoal production across forest areas, with 45.1% agreeing it is widespread while 40.2% disagreed, resulting in a neutral overall perception. However, a majority of 64.1% agree that forest loss due to charcoal production has increased in recent years, indicating growing concern about accelerating deforestation. Notably, 67% of respondents disagreed that charcoal production is concentrated near main roads and accessible forests, suggesting the activity is spreading into less accessible areas. This scattered pattern complicates monitoring and forest management. Overall, while there is strong awareness of increasing forest degradation linked to charcoal production, varying perceptions of its geographic spread highlight the need for integrated monitoring, enforcement, and community engagement to address the complex challenges of forest loss in the district.

OBJECTIVE 2: To identify the major drivers and socio-economic factors contributing to charcoal production in the district.

The findings reveal that charcoal production in the district is largely driven by three key factors: its perceived profitability, the scarcity of alternative livelihoods, and weak enforcement of forest regulations. Over half of the respondents (57%) view charcoal production as a profitable and accessible business, reflecting a generally positive economic perception. Additionally, 64.1% agreed that the lack of other income sources forces people into the trade, making economic necessity a dominant driver. Furthermore, 67% believe that ineffective enforcement of forest laws facilitates illegal charcoal activities. Overall, these results highlight the urgent need for livelihood diversification and stronger forest governance. Environmentally, the unchecked expansion of charcoal production contributes to deforestation, biodiversity loss, and rising carbon emissions. Socio-economically, the practice exposes deep-rooted issues such as unemployment, poor access to financial resources, and inadequate public services. Institutionally, weak regulatory systems hinder efforts to achieve sustainable forest management and national climate goals.

OBJECTIVE 3: To evaluate the environmental consequences of charcoal production on forest health, biodiversity, and land use patterns in Voinjama District

The findings reveal strong community consensus on the environmental impacts of charcoal production in the district. A substantial 71.2% of respondents agreed that charcoal activities negatively affect the regeneration capacity of forest ecosystems, while 64.1% believed it has significantly degraded soil quality in harvesting areas. Similarly, 64.1% acknowledged that charcoal production contributes to the decline of forest biodiversity. The consistent mean score of 2.00 across all three items underscores widespread agreement on these environmental harms. In summary, the data demonstrates clear community awareness of the detrimental effects of charcoal production on forest regeneration, soil health, and biodiversity. These insights highlight the urgent need for sustainable land-use practices, reforestation programs, and more effective environmental governance to mitigate the long-term damage caused by unsustainable charcoal activities.

11. RECOMMENDATION

- Develop alternative income-generating activities such as agroforestry, beekeeping, ecotourism, sustainable agriculture, and small-scale enterprises to reduce dependency on charcoal production.
- Invest in vocational training programs targeting youth and women to improve employment opportunities and economic resilience in rural areas.
- Enhance the capacity of forest regulatory bodies through funding, training, and logistical support to effectively monitor and control illegal charcoal activities.
- Implement stricter penalties and enforcement mechanisms for illegal harvesting and unauthorized charcoal trade, while simultaneously offering support for legal, sustainable alternatives.
- Introduce regulated community woodlots and designated harvesting zones for controlled charcoal production under reforestation or rotational systems.
- Promote reforestation and afforestation efforts with native species to restore degraded lands and improve forest regeneration capacity.
- Incorporate charcoal production into district-level land use planning to ensure better oversight and ecological balance.
- Design community education campaigns on the long-term impacts of forest degradation, soil erosion, and biodiversity loss associated with unsustainable charcoal production.
- Encourage traditional leaders, religious groups, and local influencers to champion forest conservation messages.

Use GIS and remote sensing tools to map the extent and spread of charcoal production, especially in remote or newly affected forest zones.

REFERENCES

Acheampong, E. O. (2019). Deforestation is driven by agricultural expansion in Ghana's Forest Reserves. Scientific African 5(1):e00146. doi:10.1016/j.sciaf.2019.e00146

[2] Alfaro, J. (2018). Social and environmental impacts of charcoal production in Liberia: Evidence from the field. Energy for Sustainable Development 47:124-132. doi:10.1016/j.esd.2018.09.004

[3] Alfaro, J. (2018). Social and environmental impacts of charcoal production in Liberia: Evidence from the field. Energy for Sustainable Development 47:124-132. doi:10.1016/j.esd.2018.09.004

[4] Arevalo, J., & Puentes , Y. (2016). Assessment of Solid Woodfuel Situation in Sierra Leone and Burkina Faso.

[5] Balume, B. (2025). Charcoal and firewood use in urban areas of developing countries: Drivers, consequences, and the need for clean cooking solutions. Renewable and Sustainable Energy Reviews. doi:https://doi.org/10.1016/j.rser.2025.115745

[6] Bank., W. (2023). Energy Access and Charcoal Dependency in Liberia: Toward a Transition Strategy. Washington, D.C.: World Bank.

[7] Chidumayo, E. (2013). The environmental impacts of charcoal production in tropical ecosystems of the world: A synthesis. Energy for Sustainable Development 17(2):86–94.

[8] Doggart, N. (2020). The influence of energy policy on charcoal consumption in urban households in Tanzania. Energy for Sustainable Development, 57. doi:https://doi.org/10.1016/j.esd.2020.06.002

[9] Ekpo, C. (2021). Effects of Charcoal Production on Biophysical Environment.

[10] EPA. (2024). Environmental Protection Agency of Liberia (EPA Liberia). (2024). Annual Environmental Outlook Report 2024. Monrovia: EPA Press.

[11] EPA. (2025). EPA Highlights Liberia's Rich Biodiversity as Partners Validate National Strategy.

[12] FAO. (2017). National Charcoal Strategy 2017–2027. Retrieved from https://www.fao.org/faolex/results/details/en/c/LEX-FAOC215462/

[13] Fayiah, M. (2018). Review of Challenges Confronting the Implementation and Enforcement of Environmental Policies and Regulations in Sierra Leone .

[14] FDA. (2022). Annual Forest Sector Report. Monrovia: Government of Liberia.

[15] FOA. (2020). Global Forest Resources Assessment 2020. Rome: FAO. https://www.fao.org/forest-resources-assessment.

[16] GFW. (2024). Voinjama, Liberia, Lofa Deforestation Rates & Statistics. Retrieved from https://www.globalforestwatch.org/dashboards/country/LBR/8/5/

[17] Halton, A. (2013). Liberia: Assessment of key governance issues for REDD+ implementation through application of the PROFOR forest governance tool.

[18] IKI. (2023). Sustainable Charcoal and Efficient Cookstoves Technologies for Liberia . Retrieved from https://iki-small-grants.de/wp-content/uploads/2023/10/Project-Baseline-Report_004222023.pdf

[19] Koroma, J. M. (2024). Impact of Charcoal Production on Forest Loss: Case Study of Bo, Moyamba, Port Loko and Tonkolili Districts in Sierra Leone.

[20] Koroma, J. M. (2024). SOCIO-ECONOMIC AND ENVIRONMENTAL EFFECTS OF TRADITIONAL CHARCOAL PRODUCTION IN SIERRA LEONE.

[21] Nthara, K., & Sanjay , S. (2020). Liberia: Understanding people's dependence on forests. Retrieved from https://blogs.worldbank.org/en/africacan/liberia-understanding-peoples-dependence-forests

[22] Shukla, G. (2024). Land degradation and forest management. doi:https://doi.org/10.3389/ffgc.2024.1525397

[23] Sivanand, R. (2025). Energy Analysis on an Improved Energy Efficient and Eco Friendly Charcoal Kiln. Journal of Technology 13(1):117-132.

[24] USAID. (2023). Liberia Forest and Climate Resilient Forum 2023.

[25] Veen, H. v. (2022). Forest governance and development effects on tropical charcoal production and deforestation.

[26] Veldkamp, E. (2020). Deforestation and reforestation impacts on soils in the tropics. Nature Reviews Earth & Environment 1(11):1-16.

[27] VOSIEDA. (2023). Sustainable Charcoal and Efficient Cookstoves. Retrieved from https://iki-small-grants.de/wp-content/uploads/2023/10/Project-Baseline-Report_004222023.pdf

[28] Wesseh, C. W. (2025). Food Security Challenges and Opportunities in Liberia: A Comprehensive Literature Review. Retrieved from https://ssrn.com/abstract=5115934