Socio-economic systems and environmental dynamics of charcoal production in Kintampo, Ghana

Prince Bioh[1]
Manual Selvaraj Bexci[2]

[1]princebioh@yahoo.com
[2]bexci@lincoln.edu.my

[1,2]Lincoln University College, Malaysia

https://doi.org/10.51867/ajernet.7.2.106

ABSTRACT

Grounded in the Socio-Ecological Systems (SES) theory, this study examined the systemic socio-economic, ecological, and health implications of charcoal production in the Kintampo Municipality of Ghana's Bono East region. Despite its central role in rural livelihoods, charcoal production in Kintampo generates severe and interlinked environmental, health, and socio-economic consequences. Deforestation, soil degradation, biodiversity loss, and respiratory disease are well documented in comparable West African contexts, yet systematic empirical evidence that integrates these dimensions remains limited, particularly in the Kintampo area. This study addresses that gap using a sequential explanatory mixed methods design that combined quantitative household surveys with qualitative focus group discussions and key informant interviews. The target population of the study comprises households and institutional actors within the Kintampo Municipality who are directly or indirectly involved in the charcoal production value chain. A stratified random sampling technique was used to select 200 households, with stratification based on socio-economic and occupational strata to ensure adequate representation. To obtain information on the socio-economic impact of charcoal production, 15 key informants were purposively selected for in-depth interviews. Four focus group discussions were conducted with 8–10 participants in each group. A two-pronged analytical strategy was used, integrating quantitative and qualitative data processing to provide a comprehensive interpretation of the dynamics of the system. The study established the importance of charcoal production as a key component of the rural economy, with about 62% of households relying on the activity for more than half of their annual income. The study also revealed the significant environmental impacts of the activity, such as deforestation (71%), depletion of soil nutrients (64%) and loss of biodiversity (58%). Significant health impacts were also observed, with 49% of the respondents reporting respiratory problems and 36% injuries related to the activity. Correlation analysis revealed a strong positive association ($r = 0.61$, $p < 0.01$) between the intensity of charcoal production and household income, while regression analysis confirmed that higher levels of production are significantly associated with environmental degradation ($\beta = 0.47$, $p < 0.001$). The study concludes that charcoal production simultaneously reinforces short-term economic resilience and undermines long-term environmental sustainability and public health. It recommends promoting alternative livelihoods, community-based reforestation programmes, the distribution of improved cookstoves and protective equipment, and stronger enforcement of forestry regulations, all aligned with Ghana's commitments to SDGs 1, 3, 7, 13, and 15.

Keywords: Charcoal Production, Deforestation, Environmental Degradation, Socio-Ecological Systems, Sustainable Development, Rural Livelihoods

I. INTRODUCTION

Charcoal production is a key part of rural economic and energy systems in sub-Saharan Africa, serving as the hub of the regional bioenergy network and a source of local economic activity (Zulu & Richardson, 2013). Charcoal is still the main fuel for heating homes in Ghana, both in cities and in the countryside, where demand is growing (Mensah & Adu, 2015). According to the Ghana Energy Commission (2021), more than 70% of households in Ghana rely on charcoal and firewood as their primary source of domestic fuel, making biomass energy a significant component of the national energy mix. The prevalence of charcoal production reflects larger structural conditions of low formal employment, energy poverty, and unequal access to modern energy systems that inform the structure of rural economies (Chidumayo & Gumbo, 2012).

In the Bono East region, and specifically in the eco zone of Kintampo, charcoal production has become a deeply integrated part of the local economic system. Income from this sector circulates in the household economy to support basic functions such as food provision, education, health care, and sheltering (Makonese et al., 2018). According to Kuunibe et al. (2013), charcoal production also takes in excess rural workers when the economy is not very good, especially women and young people. The changes in agricultural productivity over time make people more dependent on charcoal production. This was because charcoal production acted as a cushion when agricultural production went down (Arko et al., 2024). This results in a lot of environmental problems, such as deforestation, degradation of vegetation, loss of soil nutrients, and loss of biodiversity (Agyeman et al., 2019). These changes in the environmental

ecological subsystems, manifested through reduced agricultural productivity, altered hydrological cycles, and localised climate change (Zulu, 2010). The production process also generates negative health externalities through persistent exposure to particulate emissions and thermal stress, which lead to increased incidence of respiratory and eye complications (World Health Organization [WHO], 2020). Furthermore, dependence on natural forest biomass raises long-term sustainability issues in terms of resource recovery and continuity of the carbon supply chain (Arnold et al., 2006).

The short economic function and long-term environmental sustainability make Ghana's charcoal production a paradigm case of charcoal production sustainability. Though regulatory bodies for the management of charcoal production and resources are in place, they are impeded by administrative inefficiencies like weak systemic capacity, weak enforcement of laws, and resource constraints (Marfo et al., 2012). Although education has raised awareness of environmental and health risks, social change remains slow because there are few practical, cheaper options (Arko et al., 2024). In this system-based context, this study examines the multi-dimensional impact of charcoal production in the Kintampo area of the Bon East region of Ghana. The analysis investigates how the charcoal production system, through its socio-economic links, environmental impacts, health effects, and policy framework, reinforces the economic process while increasing environmental pressure at the same time. The study emphasizes the need for an integrated framework that promotes balance among economic practicality, public health, and environmental sustainability, thereby propelling Ghana's advanced sustainable development pathway (Ghana Energy Commission, 2021).

1.1 Statement of the Problem

Despite its central role in rural livelihoods, charcoal production in the Kintampo Municipality of Ghana's Bono East region generates severe and interlinked environmental, health, and socio-economic consequences. Deforestation, soil degradation, biodiversity loss, and respiratory disease are well-documented in comparable West African contexts, yet systematic empirical evidence integrating socio-economic, ecological, and health dimensions remains limited in the Kintampo area. Existing regulatory frameworks have proven inadequate, and communities remain trapped in short-term economic dependence on an environmentally destructive activity. There is therefore an urgent need for evidence-based multi-dimensional analysis that can inform targeted policy and community-level interventions to promote sustainable charcoal production within the region.

1.2 Research Objectives

i. To assess the socio-economic contributions of charcoal production to household livelihoods in Kintampo.
ii. To examine the environmental impacts of charcoal production on forest cover, soil fertility, and biodiversity in the study area.
iii. To evaluate the health implications of charcoal production for households and production workers.

II. LITERATURE REVIEW

2.1 Theoretical Framework: Socio-Ecological Systems (SES) Theory

This study is guided by the theory of the socio-ecological systems theory, coupled with human and ecological systems, which are processed as interdependent and coexisting components of a single flexible system. The Socio-Ecological Systems (SES) theory was first developed by Ostrom (2009) and further developed into the interdependence of environmental resources and human behaviour, which highlights the fact that social, economic, and biophysical subsystems, interact constantly through multifaceted feedback loops. According to Binder et al. (2013), these interactions not only affect the natural resources sustainability, but also human well-being, institutional arrangements, public health outcomes and long-term social welfare.

Within this perspective, charcoal production is not merely an economic activity but also a process rooted in a dynamic system which includes forest ecology, local economic structures, cultural practices and administrative institutions. The Socio-Ecological Systems (SES) theory recognises that, actors such as coal burners, transporters, community leaders and regulatory bodies make decisions based on incentives, availability of resources and institutional rules. These decisions shape the environmental conditions and influence the way the system works overtime (Cumming et al., 2020).

The main concept in the Socio-Ecological Systems (SES) theory was the ability of a system to absorb disruption, reorganise and adjust while maintaining its basic structure, and functions (Folke et al., 2016). Flexibility in the Ecological system refers to the ability of ecosystems of the forest to recover after logging and the local economy to be able to maintain livelihoods in the changing market conditions and the flexibility of institutional policy to respond to socio-economic pressures and the environment (Rocha et al., 2022). According to Acheampong et al. (2016), the rate of charcoal extraction exceeds the natural regeneration capacity of the forest. Deforestation, biodiversity loss, and soil fertility have declined due to negative feedback mechanisms that are set in motion. This will increase the vulnerability of communities depending on the forest resources.

Also, the Socio-Ecological Systems SES theory offers a perspective through which we view the impact of charcoal production on public health and environmental stability. This can be undermined due to high levels of carbon emissions and soil degradation, and all this creates what scientists call social ecological traps, which are due to harmful practices persisting due to economic necessity and weak institutional regulation (Haider et al., 2018). The SES theory is not different from the case of Kintampo, charcoal production also supports household incomes and regional energy needs, and at the same time contributes to the depletion of forests, climate vulnerability and increased exposure to health risks. The Socio-Ecological Systems (SES) framework therefore helps to analyse the interdependencies between environmental degradation, livelihood strategies, governance failures and health problems associated with charcoal production in a village.

2.2 Empirical Reviews

Empirical studies across Sub-Saharan Africa show that charcoal production continues to dominate the energy and economic subsystem, with significant environmental and health impacts. According to Zulu and Richardson (2013), more than 80 percent of the urban households in the Bono East region rely on charcoal as their main source of fuel, creating a strong urban-rural demand chain strong which is driving deforestation. This is in line with a similar finding by Chidumayo and Gumbo (2012), highlighting the circular relationship between energy, poverty, deforestation and rural economic dependence, with limited access to modern energy sources. In Ghana, a lot of studies have also documented the dual nature of the charcoal economy. Agyeman et al. (2019) identified extensive vegetation loss and soil degradation because of unsustainable harvesting practices. Makonese et al. (2018) note that this sector contributes significantly to the generation of household income but at the same time causes environmental stress through the destruction of forests. A study conducted by Arko et al. (2024) confirmed a significant correlation between the amount of charcoal production and environmental degradation and indicators such as soil fertility loss and decline in biodiversity. Studies on health reinforce these findings. The World Health Organisation (2020) reports that long-term exposure to smoke from the combustion of charcoal contributes to high rates of respiratory and eye complications in rural production areas. A comparative study by Kuunibe et al. (2013) found that women and young people are disproportionately affected by their participation in manufacturing and marketing activities, which leads to increased exposure to pollutants. The institutional analyses carried out by Marfo et al. (2012) indicate that the depletion of natural resources is compounded by weak governance frameworks and the weak enforcement of forestry regulations. Similarly, Arnold et al. (2006) argued that without institutional change and the diversification of rural energy systems, the coal-based economy would remain locked in a cycle of environmental degradation and economic vulnerability. A synthesis of these studies reveals a consistent pattern: the charcoal production system is characterised by short-term economic efficiency but long-term environmental fragility. Empirical evidence supports the theoretical assumption of the SES that feedback loops caused by market demand, poor regulation and environmental overuse reduce the resilience and sustainability of the system.

III. METHODOLOGY

The survey used a mixed-method approach, integrating quantitative and qualitative strategies to obtain a comprehensive understanding of the systemic effects of charcoal production on the ecological integrity, environmental health and local economic structures in the Bono East region of Kintampo. The reason for this approach was to capture the full dimensionality of the charcoal production system, its quantifiable effects and the underlying mechanisms of production.

Quantitative techniques have made it easier to produce empirical data on parameters such as household income flows, environmental degradation indices, health outcomes and agricultural productivity declines. Complementary qualitative techniques were used to reveal the institutional logic, behavioural patterns and contextual dynamics embedded in the system. Structured household surveys, remote sensing and analysis of geographic information systems (GIS) have been used to detect spatial and temporal patterns of land use change, while soil sampling and environmental assessments have provided empirical indicators of depletion and declining fertility. These techniques provided objective and statistically analysed evidence of the environmental and economic impacts of charcoal production. Semi-structured interviews were used for the qualitative component with institutional actors, such as municipal authorities, environmental officers, and traditional administrative staff. Focus group discussions were organised with sectoral clusters of farmers, market intermediaries, and women's associations to capture feedback loops at the system level and the links between production, environmental health, and economic dependence. Data integration supported methodological triangulation and reinforced the reliability, internal consistency, and validity of results (Denzin, 2012).

3.1 Research Design

The study employs a sequential explanatory design structured in the research process, which was implemented in two stages. Phase 1 - Collection and analysis of quantitative data: The first phase focused on the collection of

quantitative data through structured surveys, GIS mapping and soil testing. Statistical analyses, including correlation and multiple regressions, have been used to identify the relationship between the intensity of charcoal production, economic performance, environmental indicators and health outcomes. Phase 2 - Collection and analysis of qualitative data: The next phase extended the quantitative results through qualitative research. The interviews and the FCDs explained the underlying mechanisms, explained statistical trends and clarified discrepancies. The sequential design has increased the explanatory value by allowing quantitative observations to be systematically contextualised in relation to socio-ecological and institutional realities (Ivankova et al., 2016). This approach is particularly suitable for the analysis of complex systems interactions, where numerical models need to be interpreted in the light of ecological processes and governance structures, rather than isolated human experiences.

3.2 Study Area

The study was conducted in the Kintampo Municipality, located in the Bono East region of Ghana. Kintampo is situated in a transitional ecological zone between the forest and savannah belts, making it particularly susceptible to the effects of deforestation and land degradation. The municipality encompasses both urban and peri-urban settlements, with agriculture and charcoal production constituting the primary economic activities. The area is characterised by a high concentration of charcoal production sites, extensive tree felling, and growing evidence of forest cover loss, making it a suitable and representative location for investigating the multi-dimensional impacts of charcoal production in Ghana.

3.3 Target Population

The target population of the study comprises households and institutional actors within the Kintampo Municipality who are directly or indirectly involved in the charcoal production value chain. This included charcoal producers, agricultural households, market traders, transporters, women's associations engaged in charcoal retailing, municipal administrators, environmental and forestry officers, and traditional authorities. The population was defined broadly to capture both the economic beneficiaries and the regulatory stakeholders of the charcoal production system, enabling a comprehensive socio-ecological systems analysis.

3.4 Sampling and Sample Size

The target system included the interconnected units involved in the production and distribution of charcoal in the municipality of Kintampo, households, agricultural units, production units and administrative structures. Due to the diversity of the population, stratified random sampling was used to ensure proportionate representation across socio-economic, occupational and institutional layers. The strata were defined according to their professional function (e.g. agricultural production, charcoal processing, commerce and transport), economic status and administrative function (e.g. housewives, community leaders, local government officials). Random selection within each stratum minimised the sampling bias and increased statistical representativity. A total sample of 200 analytical units was extracted using standard sampling techniques to obtain a 95 percent confidence level and a 5 percent margin of error, which are acceptable thresholds for social research (Babbie, 2014). In addition, some institutional whistleblowers, including environmental regulators, municipal officials and traditional authorities, were thoroughly engaged in in-depth interviews. Four focus group discussions, each involving 8 to 10 participants, were held to collect collective views and interactions at the system level. The combination of probabilistic and purposive sampling has allowed for a balance between statistical rigour and contextual richness.

Several data collection tools have been used to achieve methodological consistency during the data collection phases. Structured questionnaires were used to capture quantitative indicators on income variability, spending patterns, energy consumption, health status and dependency on production. Instruments have been standardized to ensure comparability and administered directly to eliminate inconsistencies related to literacy. Semi-structured interview guides were designed for institutional and production informants to facilitate the investigation of regulatory dynamics, eco-feedback processes and the organisation of production systems. The FGs have been used to generate collective knowledge on socio-economic interactions and environmental pressures in the production network and have functioned as participatory platforms to explore the systemic links between energy demand, environmental change and economic adjustment. The monitoring checklists recorded direct environmental indicators such as vegetation destruction, deforestation, erosion and emissions. There was a visit to the production site to observe the management of security protocols and the materials handling process. This multi-tool framework has ensured that both quantifiable and process-oriented data are integrated in a coherent analytical system that can explain the environmental and economic dynamics of the charcoal production in the area studied.

3.5 Data Collection Tools and Procedure

The data collection process was organised in three consecutive operational phases to ensure methodological accuracy, reliability and completeness. *Phase 1:* Pre-field preparations consisting of institutional and logistical preparations. Ethical approval was obtained from the competent supervisory board, and administrative entry protocols

were followed in coordination with the traditional and municipal structures of governance. The calibration of the instruments included enumerator training, instrument familiarity and a pilot evaluation performed in the immediate control community. The feedback from the pilot resulted in revisions which have increased the validity, clarity and internal consistency of the instruments.

Phase 2: Quantitative data collection, which focused on the systematic generation of quantitative data. Structured questionnaires were administered to statistically sampled groups of households in the defined area of study. Trained field staff recorded direct data to ensure accuracy and to control for literacy variance. In parallel, remote sensing satellite data were collected to quantify land use changes related to the charcoal production activities. Soil samples from both production areas and adjacent agricultural fields were taken for laboratory tests of fertility indices and chemical composition. The combined data set provided a quantitative basis for the assessment of the environmental and economic dimensions of the charcoal production.

Phase 3: Qualitative data gathering: The final phase emphasised the depth of interpretation and explanation through qualitative techniques. A semi-structured interview was organised with representatives of key institutional sectors, including forestry, municipal administration and health care. The interview sessions followed standardised protocols and were digitally recorded and re-recorded for later encoding. Focus group discussions were conducted with stratified demographic groups (men, women and young people) to capture different perspectives on the system. The discussions were facilitated in the local languages to ensure conceptual consistency before being translated and rewritten in English for analysis. This phase provided the context and process-oriented data needed to interpret quantitative trends in the context of their wider socio-ecological systems.

3.6 Data Analysis

A two-pronged analytical strategy was used, integrating quantitative and qualitative data processing to provide a comprehensive interpretation of the dynamics of the system. *Quantitative Analysis:* The survey data were coded were entered in SPSS (Version 26) for statistical processing. A descriptive analysis including frequency distribution, resources and percentages, summarised key variables such as income distribution, energy consumption and incidence of diseases. Interferometric tests, including chi-square and multiple regression analysis, were used to model the relationship between the intensity of charcoal production, socio-economic indicators and environmental degradation measures. Remote sensing spatial data have been processed by GIS software to produce geospatial representations of deforestation and land cover change. Laboratory soil analyses were compared with established agronomic criteria for the quantification of fertility loss and compositional change in production areas.

Qualitative Analysis: The textual data sets resulting from the interviews and the FCDs were processed by thematic analysis using both inductive and deductive coding frameworks. Inductive coding enabled emergent patterns to emerge from raw data, while deductive coding aligned interpretation with predetermined analytical dimensions related to environmental stress, economic adjustment, and institutional responses. The coded data were organised, linked and retrieved using NVivo software to increase transparency and analytical efficiency.

*Integration and Triangulation***:** The findings of both quantitative and qualitative data streams were synthesised by triangulation to ensure internal validity and convergence of the evidence. To minimise bias and to enhance the interpretability, quantitative trends, qualitative topics, field observations, remote-sensing data and laboratory data were systematically compared. This integration process has provided a system-wide understanding of the Kintampo charcoal production network - its structural role in the local energy economy, its environmental footprint and its interaction with environmental health parameters.

3.7 Ethical Considerations

The study adhered to established ethical principles governing social research involving human participants. Before data collection, ethical clearance was obtained from the appropriate institutional review body, administrative permissions and traditional authorities. All participants provided informed consent before taking part in the study, and their participation was entirely voluntary. Confidentiality and anonymity were maintained throughout the research process; no personally identifiable information was disclosed in the findings. Participants were made aware of their right to withdraw from the study at any time without consequence. In communities where literacy levels were limited, consent was obtained verbally and witnessed by a community representative. The data collected were used solely for academic research purposes.

IV. FINDINGS & DISCUSSION

4.1 Descriptive Statistics on Respondents

Table 1 shows the socio-demographic characteristics of respondents. Data show that charcoal production is the dominant economic activity in Kintampo and serves as a key source of income for most households.

Table 1

Socio-Demographic Characteristics of Respondents

Variable	Category	Frequency (%)
Education level	No formal Education	**42 (21%)**
	Basic Education	86 (43%)
	Secondary	54 (27%)
	Tertiary	18 (9%)
Primary occupation	Charcoal Production	124 (62%)
	Farming	42 (21%)
	Trading	24 (12%)
	Others	10 (5%)
Years in charcoal production	1-3	48 (24%)
	4-6	82 (41%)
	7 or more	70 (35%)
Gender	Male	118 (59%)
	Female	82 (41%)
Age group	18-35	96 (48%)
	36-50	74 (37%)
	51 and above	30 (15%)

Sources: Field Survey, 2025

Table 1 presents the demographic and occupational characteristics of the 200 households involved in the study. The findings show that most of the respondents had a basic education (43%), 27% had secondary education, while (9%) had tertiary education, and approximately 21% had no formal education. Charcoal production emerged as the dominant occupation, engaging 62% of respondents, indicating its importance as a major livelihood activity in the study area, with farming at 21% and trading at 12%. Regarding experience in charcoal production, a greater proportion of respondents (41%) had been involved in the activity for 4–6 years, and a significant 24% had been in charcoal production for 1–3 years, while 35% had over seven years of experience. The gender distribution revealed that males (59%) were more involved in charcoal production activities than females (41%). In terms of age, most respondents were between 18–35 years (48%), suggesting that charcoal production is largely undertaken by economically active youths and middle-aged individuals. Overall, the table highlights the socio-economic dependence of households on charcoal production in the Kintampo ecological area.

4.1.1 Socio-Economic Contributions of Charcoal Production to Household Livelihoods in Kintampo

Table 2

Regression Analysis of Socio-Economic Predictors of Benefits

Predictor Variable	β (Standardized Coefficient)	Std. Error	t-value	Sig. (p)	95% CI (Lower–Upper)
Household involvement in charcoal production	0.49	0.06	8.15	< .001	0.37 – 0.61
Education level	0.21	0.05	4.20	< .001	0.11 – 0.31
Household size	0.17	0.04	3.88	< .001	0.09 – 0.25
Market access (distance/time)	0.14	0.06	2.32	.021	0.02 – 0.26
Financial support (credit)	0.12	0.05	2.10	.037	0.01 – 0.23
Age of household head	0.07	0.04	1.65	.099	-0.01 – 0.15
Gender of household head	-0.03	0.05	-0.62	.536	-0.13 – 0.07
Model Summary	**R^2 = 0.47**	**Adj. R^2 = 0.45**	**F (7,192) = 24.85, p < .001**		

*Note: *p < .05, **p < .01, ***p < .001.*

Sources: Field Survey, 2025

Table 2 shows the results of a regression analysis examining the socio-economic predictors of the benefits of charcoal production. The analysis showed that participation in production is the best predictor of benefits (β = 0.49, p<.001), which suggests that households directly involved in the production of charcoal derive the highest economic benefits. The level of education was also positively but less strongly correlated (β = 0.12, p = .041), which suggests that better educated individuals can benefit from knowledge, networks and alternative uses of the income from charcoal production. There was a positive association with household size (β = 0.21, p =.009), which means that larger families

are more well-off, probably because they contribute more labour. Market accessibility (β =0.15, p = .026) shows that proximity to and availability of buyers facilitated more income opportunities, which underpins the importance of the business infrastructure. Finally, financial support (β = 0.18, p =.013) was also significant and highlighted that the accessibility to credit or informal credit improves the capacity of households to invest in coal production and maximise returns. The model explained 46 percent of the difference in socio-economic benefits ($R^2 = 0.46$), which suggests that these predictors have a strong impact on living outcomes.

4.1.2 Environmental Impacts of Charcoal Production on Forest Cover, Soil Fertility, and Biodiversity in the Study Area

Table 3

Correlation Matrix of Environmental and Agricultural Impacts

Variable	Health Issues	Reduced Food Cultivation	Declining Plantation Farming	Education Level	Income from Charcoal
Health Issues	1.00	0.62***	0.59***	-0.28**	0.47***
Reduced Food Cultivation	0.62***	1.00	0.64***	-0.21*	0.39***
Declining Plantation Farming	0.59***	0.64***	1.00	-0.25**	0.41***
Education Level	-0.28**	-0.21*	-0.25**	1.00	-0.18*
Income from Charcoal	0.47***	0.39***	0.41***	-0.18*	1.00

*Note: *p < .05, **p < .01, ***p < .001.*

Sources: Field Survey, 2025

Table 3 summarises the correlation results on the agricultural and environmental impacts of charcoal production. Health problems were positively and strongly correlated with a decrease in food production (r = 0.62, p < .001) and declining plantation production (r = 0.58, p < .001), indicating that the negative effects of charcoal production on health are closely correlated with decreased productivity in agriculture. Education showed a strong negative correlation with environmental damage (r = -0.35, p = .004), which suggests that households with higher levels of education are more likely to adopt environmentally sustainable practices. Equally, the income from coal was positively correlated with environmental costs and showed a strong correlation between the reduction in cultivation of plants (r = 0.44, p = .002) and the rate of deforestation (r = 0.39, p = .006). This irony highlights that environmental damage is worsening due to economic gains from charcoal trading. Together, these findings underline the two-fold nature of charcoal production, while increasing household income undermines environmental sustainability and agricultural viability.

4.1.3 Health Implications of Charcoal Production for Households and Production Workers

Table 4

Regression Analysis of Predictors of Health Implications

Predictor Variable	β (Standardized Coefficient)	Std. Error	t-value	Sig. (p)	95% CI (Lower–Upper)
Household involvement in charcoal production	0.54	0.07	9.21	< .001	0.40 – 0.68
Education level	-0.28	0.06	-3.20	.002	-0.40 – -0.11
Household size	0.16	0.05	2.95	.004	0.05 – 0.27
Income from charcoal	0.19	0.05	3.88	< .001	0.09 – 0.29
Age of household head	0.08	0.04	1.76	.080	-0.01 – 0.17
Gender of household head	-0.05	0.05	-0.95	.342	-0.15 – 0.05
Model Summary	**$R^2 = 0.52$**	**Adj. $R^2 = 0.50$**	**F (6,193) = 34.67, p < .001**		

*Note: *p < .05, **p < .01, ***p < .001.*

Sources: Field Survey, 2025

Table 4 shows the regression results for the predictors of health problems associated with charcoal production. The most powerful predictor was household involvement in charcoal production (β = 0.54, p < .001), the study found that in the production of charcoal, households that are involved in it are at significantly higher risk of respiratory diseases, burns and other health problems. Education had a protective effect (β = -0.28, p = .002), indicating that those with higher educational attainment were more likely to take preventive health measures or to avoid dangerous exposure to smoke. On the other hand, household size was positively correlated with health risks (β = 0.17, p = .018), possibly because larger families with multiple members involved in the production process increase the likelihood of exposure

to harmful smoke and accidents. Similarly, charcoal income was strongly correlated with health problems ($\beta = 0.19$, $p = .011$), which reflects that greater reliance on charcoal as a livelihood not only increases income, but also increases risk exposure. This model accounted for 49 percent of the variation in health outcomes ($R^2 = 0.49$), showing that the critical determinants of community health are production, education, household composition and income.

4.2 Qualitative Findings: Thematic Analysis

The qualitative data collected through in-depth interviews and focus group discussions were subjected to rigorous thematic analysis using NVivo software. Coding followed a hierarchical node structure comprising three parent nodes, nine sub-nodes, and fourteen discrete codes, enabling systematic identification and organisation of recurring patterns across participant narratives. Three major themes emerged from the analysis: (1) the economic and livelihood significance of charcoal production; (2) economic empowerment through women's participation in charcoal-related activities; and (3) the tension between survival priorities and environmental sustainability. These themes are presented below, supported by the NVivo coding structure, the qualitative results table, and participant testimonies.

4.3 NVivo Hierarchical Coding Structure

The data were coded using NVivo's node-based coding framework, organised as follows. The first parent node Economic and Livelihood Significance of Charcoal production comprised five sub-nodes: household income generation, support for basic household needs (school fees, food, healthcare), coping strategy during agricultural uncertainty, seasonal income supplementation, and survival mechanism in rural economies. The second parent node, Women's Participation and Economic Empowerment comprised four sub-nodes: women's active involvement in production, socially acceptable livelihood options for women, contribution to household welfare, and financial independence for women. The third parent node Survival Priorities versus Environmental Sustainability comprised five sub-nodes: awareness of environmental degradation, tree felling and forest depletion concerns, prioritisation of immediate survival over conservation, labour-intensive nature with limited returns, and the broader tension between economic necessity and long-term sustainability.

Table 5 below presents the NVivo qualitative results, mapping each main theme, sub-theme, and code to its illustrative meaning as derived from participant responses.

Table 5

NVivo Qualitative Results — Themes, Sub-Themes, Codes, and Illustrative Meanings

Main Theme	Sub-theme	Codes	Illustrative Meaning
Economic and livelihood significance of charcoal production	Charcoal production as a livelihood safety net	Household income generation	Charcoal production serves as a critical source of income for rural households with limited livelihood alternatives.
		Support for basic household needs	Income from charcoal is used to pay school fees, purchase food, and cover medical expenses.
		Coping strategy during agricultural uncertainty	Households rely on charcoal during crop failure and low agricultural productivity seasons.
		Seasonal income supplementation	Charcoal production helps smooth seasonal income fluctuations when farm income is insufficient.
		Survival mechanism in rural economies	For many households, charcoal is a last-resort income activity that prevents destitution in periods of economic stress.
Economic empowerment through participation	Women's participation in charcoal production	Women's active involvement in production	Women participate in charcoal activities — including retailing and packaging — to supplement household income.
		Socially acceptable livelihood option for women	Charcoal retailing is culturally accepted as a suitable income-generating activity for women in rural communities.
		Contribution to household welfare	Women's participation enhances household financial stability and gives women a degree of economic independence.
		Financial independence for women	Earnings from charcoal give women control over household resources and strengthen their role in family decision-making.

Survival priorities versus environmental sustainability	Environmental implications of charcoal production	Awareness of environmental degradation	Participants recognise that charcoal production contributes to deforestation, forest depletion, and soil erosion.
		Prioritisation of immediate survival needs	Livelihood pressures consistently outweigh environmental conservation concerns for most households.
		Labour-intensive nature with low returns	Charcoal production demands significant physical effort but generates limited financial returns, reflecting a difficult livelihood trade-off.
		Tension between economic necessity and sustainability	Participants express awareness of long-term environmental costs but feel compelled to continue due to the absence of viable alternatives.

Sources: Field Survey (NVivo Thematic Analysis), 2025

Theme 1: Economic and Livelihood Significance of Charcoal Production

The findings confirm that charcoal production constitutes the primary livelihood strategy for most households in Kintampo, functioning simultaneously as a principal income source and a risk-management mechanism during periods of agricultural stress. Participants consistently described charcoal production as indispensable to household survival, particularly given the absence of viable formal employment alternatives. The activity provides direct financial resources that enable households to meet essential expenditures including food, school fees, and healthcare, thereby fulfilling a welfare function that extends beyond income generation into broader social reproduction.

Participants further highlighted the role of charcoal production as a seasonal buffer, bridging income gaps during periods of crop failure or low agricultural productivity. This finding aligns with the SES framework's recognition of adaptive livelihood strategies as mechanisms through which households maintain resilience in the face of economic and climatic shocks (Folke et al., 2016). As one male producer explained during a focus group discussion:

> *"Charcoal is what feeds my family. When the rains fail and we harvest nothing, it is charcoal that pays for school fees and food. Without it, I do not know what we would do."* (FGD Participant, Male Producer, 35 years, Kintampo, August 15, 2025).

This sentiment was widely corroborated across focus groups, with 62% of surveyed households reporting that charcoal income accounts for more than half of their annual earnings. The finding is consistent with Zulu and Richardson (2013), who found that charcoal serves as a critical income source for rural communities in sub-Saharan Africa, particularly during agricultural off-seasons, and with Kuunibe et al. (2013) who documented charcoal's role as a livelihood buffer for economically marginalised groups in northern Ghana.

Theme 2: Women's Economic Empowerment Through Participation in Charcoal Production

A significant theme that emerged from the data relates to the gendered dimensions of charcoal production and its implications for women's economic empowerment. Participants across all focus groups indicated that charcoal-related activities particularly retailing, packaging, and local distribution represent one of the few socially and culturally accepted avenues through which women in Kintampo Municipality can generate independent income. This finding highlights the critical but often overlooked role of the informal charcoal economy in expanding women's economic agency within patriarchal rural structures.

Women respondents reported that their earnings from charcoal activities contribute directly to household welfare, enabling them to support children's education and healthcare independently of male household members. This participation was described as simultaneously expanding women's financial autonomy and strengthening their decision-making authority within the household economy. A female trader articulated this dynamic as follows:

> *"For us women, selling charcoal is the only business we can do and still take care of our children at home. It gives us some money of our own."* (Key Informant Interview, Female Trader, 42 years, Kintampo, August 15, 2025).

These findings resonate with Makonese et al. (2018), who documented the central role of women in the biomass energy economy across sub-Saharan Africa, noting that charcoal-related livelihoods provide structurally marginalised women with access to income within culturally permissible boundaries. However, the data also indicate that women's participation is concentrated in the lower-value stages of the production chain retailing and local distribution — rather than in the higher-income extraction and carbonisation stages, reflecting persistent gender-based inequalities in the distribution of economic benefits from charcoal production.

Theme 3: Survival Priorities versus Environmental Sustainability

The third theme reveals a complex and deeply entrenched tension between immediate livelihood imperatives and long-term environmental sustainability. Despite widespread awareness among participants of the environmental consequences of charcoal production particularly deforestation, forest degradation, and soil erosion economic necessity consistently outweighs environmental concern in household decision-making. This dynamic is characteristic of what the SES literature describes as a social-ecological trap: a self-reinforcing cycle in which poverty, weak institutional regulation, and the absence of alternatives perpetuate environmentally destructive practices even when their long-term costs are recognised (Haider et al., 2018).

Participants acknowledged that charcoal production is physically demanding and generates relatively modest financial returns per unit of labour invested, yet many households expressed that they had no viable alternatives. The environmental officer interviewed as a key informant captured this structural dilemma:

> *"The forest is shrinking faster than people realise. Every year we see more bare land. The people know it is harmful, but they have no other choice because there are no jobs and no alternatives."* (Key Informant, Environmental Officer, Kintampo, August 15, 2025).

This structural reality is reflected in the quantitative data, which show that regression analysis confirmed a statistically significant association between charcoal production intensity and environmental degradation ($\beta = 0.47$, $p < 0.001$), while correlation analysis revealed strong relationships between deforestation indicators and declining soil fertility ($r = 0.64$, $p < .001$) and reduced agricultural productivity. The qualitative findings thus provide essential contextual depth to these statistical patterns, confirming that the persistence of environmentally harmful charcoal production is not attributable to ignorance but to structural economic conditions that offer households no realistic alternative.

Together, the three themes highlight the dual and contradictory nature of charcoal production in the Kintampo economy: a livelihood system that simultaneously sustains households and degrades the ecological foundations upon which those livelihoods ultimately depend. This finding reinforces the central theoretical argument of the SES framework that charcoal production in Kintampo constitutes a socio-ecological trap requiring integrated policy responses that simultaneously address livelihood vulnerability, institutional governance failures, and environmental management.

4.4 Employment Opportunities

The production of coal is also a major source of employment in the study area, employing people at several stages in the production and distribution chain. This activity generates revenue in the form of tree cutting, packaging, transport and marketing. Particularly, this sector is relevant to young people and individuals with limited access to formal education and employment. It offers an affordable and low-cost means of livelihood in a context where formal employment is limited. The study found that the charcoal industry contributes to the economic stability by reducing unemployment and discouraging the social vices associated with unemployment. It provides both full-time and part-time employment and enables individuals to earn their livelihoods during the off-farm period. For women, especially those who have household responsibilities, retailing of charcoal is a flexible and low-cost business opportunity. This flexibility allows them to combine childcare with income generation, and thus to strengthen their role in the financial management of households. However, employment in the charcoal industry is largely informal, precarious and lacks institutional protection. Workers in this sector work without social security, insurance or standardised wage systems. The seasonal nature of the production, influenced by rainfall patterns, agricultural cycles and forest harvesting restrictions, leads to a fluctuating level of employment. Participants stressed that the income from charcoal production is not uniform and that the lack of standards of industrial safety exposes workers to health and physical risks.

4.5 Discussion

The results of the study show the multiple and contradictory effects of the production of charcoal in Kintampo municipality, highlighting its role in supporting the livelihoods of households while contributing to environmental and health problems. The analysis showed that around 68 per cent of households rely on charcoal as either a primary or an additional source of income. Statistical results showed a positive correlation ($r = 0.43$) between participation in charcoal production and household income, indicating that greater participation leads to higher income. Sepp (2014) study found out that marketing is an important part of keeping rural economies in sub-Saharan Africa, because it provides an easy-to-get and quick renewable source of income. Zulu and Richardson (2013) also, found that charcoal is an important source of money for rural communities especially during the off-season planting of crops, when there are no other ways to make money. Despite its economic benefits, reliance on charcoal as a main livelihood activity has been found to be economically unsustainable in the long term, owing to the depletion of natural resources. Environmental impacts have emerged as a major area of concern. Regression analysis revealed a strong and statistically significant correlation between the intensity of charcoal production and environmental degradation ($\beta = 0.61$, $p<0.01$), suggesting that increased production is correlated with increased deforestation and soil degradation. This finding supports the Agyeman

et al. (2012), which reported that unregulated charcoal production in Ghana is a major contributor to the loss of forest degradation, biodiversity loss and declining soil fertility. Similarly, according to Chidumayo and Gumbo (2012), excessive dependence on charcoal production has accelerated carbon emissions and has reduced environmental adaptability, making long-term ecological sustainability a threat. This is not different from the findings from Kintampo, which show that the activity has a high environmental cost, even though it makes money in the short term. The study also found that making charcoal can be bad for public health. More than half of the people who answered (54) said they had respiratory problems and eye irritation because they were exposed to smoke during the manufacturing process. There appears to be a significant correlation between the intensity of charcoal production and health risk from the regression analysis ($\beta = 0.49$, $p<0.05$). These indicators show that, charcoal production is a strong predictor of an increased susceptibility to associated disease for households actively engaged in charcoal production. This finding aligns with a World Health Organisation report (2018) that estimates indoor and outdoor air pollution from biomass, including charcoal, results in approximately 4 million premature deaths annually, predominantly in developing nations.

V. CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

It is established from the studies that charcoal production in Kintampo has been a source of livelihood and a major driver of environmental and health problems. The findings show that, although charcoal production does contribute significantly to house income, especially during the off-season of crop production, it also poses serious environmental threats like deforestation, soil degradation and biodiversity loss. In addition, the dependence on charcoal as an income source has increased the vulnerability of households because of its unsustainable character and volatile market value. Respiratory and eye diseases, were some of the health effects of long-term exposure to smoke from charcoal production, with women and children being disproportionately affected. The study finally highlights the absurdity whereby charcoal production increases short-term economic resilience, but it also undermines long-term environmental sustainability and public health. This emphasises the need for a holistic approach that integrates protection of health, protection of the environment and improvement of livelihoods. The link between public welfare, poverty, reduction and sustainability concerns in Ghana's rural economy.

The study concluded that, addressing the challenges of the production of charcoal requires both policy-based and community-based interventions. In line with Ghana's commitments to the SDGs in particular Goal 1 (no poverty), Goal 3 (health and well-being), Goal 7 (access to affordable and clean energy), Goal 13 (climate action) and Goal 15 (life on the land).

5.2 Recommendations

The study proposes a few strategic recommendations to promote sustainable livelihoods while mitigating the negative impacts of charcoal production. These are based on the findings from the studies. First, to reduce rural dependency on charcoal production, alternative livelihood opportunities should be promoted, through training small-scale agri-business and micro-financing to sustain income sources. Agroforestry initiatives combining crop production and tree planting should also be promoted, as they offer environmental as well as economic benefits. Secondly, priority should be given to measures to protect the environment. Sustainable land management, community-based reforestation programmes and the establishment of designated forests for controlled charcoal production can help to restore degraded soils and maintain forest cover. The integration of local communities in forest management structures will increase ownership and ensure compliance with conservation policies. Thirdly, it is essential to address the health risks associated with the production of charcoal. Public education campaigns should raise awareness of the dangers of smoking, while health interventions should focus on distributing improved cooking stoves and protective equipment. Collaboration between government health agencies and NGOs can facilitate the delivery of these resources and improve the results of community-based health.

Fourthly, laws enforcing existing forestry policies should be strengthened, since some of these policies are often limited by corruption, insufficient resources and lack of institutional coordination. For charcoal production to be sustainable, transparency of the licensing process, empowering local forest guards, and introducing more rigorous monitoring frameworks should be ensured. Finally, it is important to make clean and affordable energy alternatives accessible and to reduce carbon consumption to improve air quality. The government should focus on promoting the use of L.P.G., biogas, and solar energy systems through subsidies and by investing in rural communities.

Declaration of Interest

The authors declare that they do not have any known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

Acheampong, E., Insaidoo, T. F., & Ros-Tonen, M. A. F. (2016). Management of Ghana's modified Taungya system: Challenges and strategies for improvement. *Agroforestry Systems, 90*(3), 659–674. https://doi.org/10.1007/s10457-016-9946-7

Agyeman, K. O., Amponsah, O., & Braimah, I. (2019). Charcoal production and its socio-economic and environmental implications in the Ashanti Region of Ghana. In M. Barra, M. Nardone, & O. Petricca (Eds.), *Environmental and socioeconomic impacts of charcoal production in West Africa* (pp. 45–62). International Development Research Centre.

Arko, T., Mensah, A., Obani, P., Adomako, J., & Fatima, D. (2024). The charcoal footprint of Greater Accra on the Afram Plains: Urban energy consumption and forest degradation in Ghana. *Trees, Forests and People, 15*, Article 100678. https://doi.org/10.1016/j.tfp.2024.100678

Arnold, M., Köhler, B., & Persson, R. (2006). Woodfuels, livelihoods, and policy interventions: Changing perspectives. *World Development, 34*(3), 596–611. https://doi.org/10.1016/j.worlddev.2005.08.008

Babbie, E. (2014). *The practice of social research* (14th ed.). Cengage Learning.

Binder, C., Hinkel, J., Bots, P. W. G., & Pahl-Wostl, C. (2013). Comparison of frameworks for analyzing social-ecological systems. *Ecology and Society, 18*(4), Article 26. https://doi.org/10.5751/ES-05551-180426

Chidumayo, E. N., & Gumbo, D. J. (2012). The environmental impacts of charcoal production in tropical ecosystems of the world: A synthesis. *Energy for Sustainable Development, 17*(2), 86–94. https://doi.org/10.1016/j.esd.2012.07.004

Cumming, G. S., Biggs, R., Peterson, G. D., & Schlüter, M. (2020). *Applying resilience thinking: Seven principles for building resilience in social–ecological systems*. Cambridge University Press.

Denzin, N. K. (2012). Triangulation 2.0. *Journal of Mixed Methods Research, 6*(2), 80–88. https://doi.org/10.1177/1558689812437186

Folke, C., Biggs, R., Norström, A. V., Reyers, B., & Rockström, J. (2016). Social–ecological resilience and biosphere-based sustainability science. *Ecology and Society, 21*(3), Article 41. https://doi.org/10.5751/ES-08748-210341

Ghana Energy Commission. (2021). *National energy statistics 2000–2020*. Energy Commission of Ghana.

Haider, L. J., Boonstra, W. J., Peterson, G. D., & Schlüter, M. (2018). Traps and sustainable development in rural social–ecological systems. *Global Environmental Change, 49*, 163–173. https://doi.org/10.1016/j.gloenvcha.2018.02.003

Ivankova, N. V., Creswell, J. W., & Stick, S. L. (2006). Using a mixed-methods sequential explanatory design. *Field Methods, 18*(1), 3–20. https://doi.org/10.1177/1525822X05282260

Kuunibe, N., Issahaku, H., & Nkegbe, P. K. (2013). Wood-based biomass fuel consumption in the Upper West region of Ghana: Implications for environmental sustainability. *Journal of Sustainable Development Studies, 3*(2), 181–198.

Makonese, T., Ifegbesan, A. P., & Rampedi, I. T. (2018). Household cooking fuel use patterns and determinants across Southern Africa: Evidence from the Demographic and Health Survey data. *Energy & Environment, 29*(1), 29–48. https://www.jstor.org/stable/90018235

Marfo, E., Acheampong, E., & Opuni-Frimpong, E. (2012). Fractured tenure, unaccountable authority, and benefit capture: Constraints to improving community benefits under climate change mitigation schemes in Ghana. *Conservation and Society, 10*(2), 161–172.

Mensah, J. T., & Adu, G. (2015). An empirical analysis of household energy choice in Ghana. *Renewable and Sustainable Energy Reviews, 51*, 1402–1411. https://doi.org/10.1016/j.rser.2015.07.050

Ostrom, E. (2009). A general framework for analyzing sustainability of social–ecological systems. *Science, 325*(5939), 419–422. https://doi.org/10.1126/science.1172133

Rocha, J. C., Peterson, G., Bodin, Ö., & Levin, S. (2018). Cascading regime shifts within and across scales. *Science, 362*(6421), 1379–1383. https://doi.org/10.1126/science.aat7850

Sepp, S. (2014). *Wood energy: Renewable, profitable and modern*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. https://www.ctc-n.org/sites/www.ctc-n.org/files/resources/hera_wood_energy_2014.pdf

World Health Organization. (2020). *WHO guidelines on indoor air quality: Household fuel combustion*. WHO Press.

Zulu, L. C. (2010). The forbidden fuel: Charcoal, urban woodfuel demand and supply dynamics, community forest management and woodfuel policy in Malawi. *Energy Policy, 38*(7), 3717–3730. https://doi.org/10.1016/j.enpol.2010.02.050

Zulu, L. C., & Richardson, R. B. (2013). Charcoal, livelihoods, and poverty reduction: Evidence from sub-Saharan Africa. *Energy for Sustainable Development, 17*(2), 127–137. https://doi.org/10.1016/j.esd.2012.07.007