Sokoine University of Agriculture

MSc Dissertation

Households Charcoal Consumption, Sustainability and its Environmental Impact in Montserrado County, Liberia

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HOUSEHOLDS CHARCOAL CONSUMPTION, SUSTAINABILITY AND ITS ENVIRONMENTAL IMPACT IN MONTSERRADO COUNTY, LIBERIA

Dissertation Submitted to Sokoine University of Agriculture in Partial Fulfillment of the Requirements for the Degree of Master of Science In Environmental and Natural Resource Economics

By

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EXTENDED ABSTRACT

The consumption of charcoal is a prevalent practice for many households in Montserrado County, Liberia. Charcoal serves as a primary source of cooking fuel for many families. While charcoal may be a readily available and affordable energy source, its production and consumption have significant environmental and sustainability concerns. The aim of this study was geared towards analyzing the factors influencing household charcoal consumption and the associated negative environmental consequences in Montserrado County, Liberia. Its sole objective was to gather necessary information to aid policy formulation on sustainable charcoal production and consumption in Liberia. Specifically, the study intended to look at the factors influencing households' charcoal consumption, determine the challenges associated with charcoal consumption in the study area, identify the main sources of energy in the study area, and determine the environmental impacts associated with charcoal consumption. In this study, a Cross-sectional research design was adopted. The sample size was 386 respondents in Montserrado County. Quantitative data were collected and descriptive statistics and regression models were both used with the aid of SPSS (Version 20) in analyzing the data. Findings from the multiple linear regression model showed that household's education level, number of meals per day, price of charcoal and household size were statistically significant ($p < 0.05$) associated with household's charcoal consumption in Montserrado County. Furthermore, respondents identified high price (22.7%), low quality (21.6%) and dirtiness of homes (20%) as main challenges faced in the consumption of charcoal. Moreover, it was evident that increase in household's charcoal consumption influenced charcoal production. More than half of the respondents (65.5%) strongly agreed that the unsustainable production of charcoal is one of the drivers of deforestation and (25.13%) agreed that the unsustainable production of charcoal also disrupt the soil profile, thus devastating the environment. Based on the findings from this study, to address

the challenges posed by high charcoal consumption and its associated adverse environmental impacts, it is crucial to promote sustainable energy practices, increase hydro-electricity power supply, raise awareness about the environmental impact, subsidize the production of energy efficient technologies to reduce charcoal consumption and production, regulate the charcoal industry, and support research and development of alternative cleaner energy technologies such as solar, and briquettes as well as initiating education programs tailored to sustainable charcoal consumption and production in the study area. On the other hand, it is believed that the introduction of Low-cost retort-kiln or Improved Charcoal Production System (ICPS) will help minimize the adverse effects on the environment caused by charcoal production processes. In addition, engaging local communities, offering incentives, and fostering collaborations among stakeholders will further contribute to a more sustainable energy landscape and forest conservation in the region.

IKISIRI KUU

Matumizi ya mkaa ni mazoea ya kawaida kwa kaya nyingi katika Kaunti ya Montserrado, Liberia. Mkaa hutumika kama chanzo kikuu cha nishati ya kupikia kwa familia nyingi. Ingawa mkaa unaweza kuwa chanzo cha nishati kinachopatikana kirahisi na kwa bei nafuu, uzalishaji na matumizi yake yana wasiwasi mkubwa kuhusu mazingira na uendelevu. Lengo la utafiti huu lilikuwa ni kuchambua sababu zinazoathiri matumizi ya mkaa kwa kaya na madhara hasi ya kimazingira yanayohusiana na hayo katika Kaunti ya Montserrado, Liberia. Lengo lake pekee lilikuwa kukusanya taarifa muhimu zitakazosaidia kuunda sera kuhusu uzalishaji na matumizi endelevu ya mkaa nchini Liberia.

Mahsusi, utafiti huu ulikusudia kuchunguza sababu zinazoathiri matumizi ya mkaa kwa kaya, kutambua changamoto zinazohusiana na matumizi ya mkaa katika eneo la utafiti, kutambua vyanzo vikuu vya nishati katika eneo la utafiti, na kubaini athari za kimazingira zinazohusiana na matumizi ya mkaa. Katika utafiti huu, muundo wa utafiti wa muda mmoja ulitumika. Ukubwa wa sampuli ulikuwa ni majibu 386 kutoka Kaunti ya Montserrado. Takwimu za kiasi zilikusanywa na takwimu za maelezo na mifano ya kurejesha zilitumika kwa msaada wa SPSS (Toleo la 20) katika uchambuzi wa makusanyo ya taarifa.

Matokeo yalionyesha kwamba kiwango cha elimu ya kaya, idadi ya milo kwa siku, bei ya mkaa na ukubwa wa kaya vilikuwa na uhusiano mkubwa wa kistatistiki ($p < 0.05$) na matumizi ya mkaa ya kaya katika Kaunti ya Montserrado. Zaidi ya hayo, waliojibu walitambua bei kubwa (22.7%), ubora mdogo (21.6%) na uchafu wa nyumba (20%) kama changamoto kuu zinazokabiliwa katika matumizi ya mkaa. Aidha, ilikuwa dhahiri kwamba ongezeko la matumizi ya mkaa ya kaya liliathiri uzalishaji wa mkaa. Zaidi ya nusu ya waliojibu (65.5%) walikubali kabisa kwamba uzalishaji usio endelevu wa mkaa ni moja ya vichocheo vya ukataji miti na (25.13%) walikubali kabisa kwamba uzalishaji usio endelevu wa mkaa pia huvuruga muundo wa udongo, hivyo kuharibu mazingira.

Kutokana na matokeo ya utafiti huu, ili kukabiliana na changamoto zinazotokana na matumizi makubwa ya mkaa na athari zake hasi kwa mazingira, ni muhimu kukuza mazoea ya nishati endelevu,

kuongeza usambazaji wa umeme wa maji, kuongeza uelewa kuhusu athari za kimazingira, kusaidia uzalishaji wa teknolojia zinazotumia nishati kwa ufanisi ili kupunguza matumizi na uzalishaji wa mkaa, kudhibiti sekta ya mkaa, na kuunga mkono utafiti na maendeleo ya teknolojia mbadala safi za nishati kama vile sola, na mabriketi pamoja na kuanzisha programu za elimu zilizobinafsishwa kwa matumizi na uzalishaji endelevu wa mkaa katika eneo la utafiti. Kwa upande mwingine, inaaminika kuwa uanzishwaji wa retort-kiln yenye gharama nafuu au Mfumo Ulioboreshwa wa Uzalishaji Mkaa utasaidia kupunguza athari mbaya kwa mazingira zinazosababishwa na mchakato wa uzalishaji mkaa. Zaidi ya hayo, kushirikisha jamii za mitaa, kutoa motisha, na kuimarisha ushirikiano kati ya wadau kutachangia zaidi kwenye mazingira endelevu ya nishati na uhifadhi wa misitu katika eneo hilo.

DECLARATION

I, Emmanuel Lewis, do hereby declare to the Senate of the Sokoine University of Agriculture that this dissertation is my own original work conducted within the period of registration and that it has neither been submitted nor is concurrently submitted in any other institution.

_____ _____

Emmanuel Lewis Date
(MSc. Candidate)

The declaration is confirmed by;

_____ _____

Dr. Greyson Zabron Nyamoga Date
(Main Supervisor)

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To the Management of the Forestry Development Authority, who solicited funding through the REDD+ program to underwrite the cost of my postgraduate degree program, their investment into building the human capacity of the FDA is highly commendable. Nation-building processes begin with transforming the minds and ideologies of the human capacity positively. The entire staff of the REDD+ program was so magnanimous and proactive in the timely delivery of funding to meet all requirements necessary for graduation. I am humble and grateful them.

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DEDICATION

This research work is dedicated to my wife Mrs. Marilyn N. Lewis for the immense sacrifices that she made in my educational sojourn and my life in general, may God bless you abundantly.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Over the years, households have heavily relied on biomass combustion for cooking, lighting, roasting, smelting, ironing, and boiling water. Choices and demand at individual levels in the energy portfolio are influenced by socio-economic, cultural, and demographic statuses (Garcia *et al*., 2012). The household's energy portfolio continues to play a major role in shaping the structural outlook of the environment. Households' choices on the type of energy consumption are affected by price stocks and weather variability (Dacuycuy & Dacuycuy, 2018). Individual decision-making processes at the level of the household on consumption of energy are inherent in the theory of utility maximization. Higher income, according to the energy ladder theory, influences the energy switching strategy of neoclassical consumers (Koopmans & Koppen, 2019). As it stands, some households and non-household charcoal consumers prefer the energy stacking strategy due to the insufficient power supply, power surge, and high price for electrical power in Montserrado County, Liberia (Modi *et al.,* 2014).

Global trends in charcoal production between 1965 and 2005 show rising output levels, with Africa at the top of the list (Onekon and Kipchirchir, 2016). Accordingly, about 33% of the total population of Liberia resides in Montserrado, and at least 95% of the urban population consumes charcoal (Brieland, 2015). Montserrado County continues to witness an unprecedented movement of people seeking greener pastures, sustained livelihood activities, and government jobs. The exodus of people migrating from rural to urban areas has

influenced household size, thus prompting a higher demand for charcoal.

It is now glaring that the consumption of charcoal remains unabated due to its availability and affordability, unlike electrical power. Notwithstanding, the government of Liberia has crafted an ambitious plan to increase electricity accessibility to 70% of the current population by 2030. However, the current figures show that less than 20% of the population has access to power at a rate of US$5.00 per 18kwh.

With the current situation regarding the inadequacy of affordable and reliable electricity, the demand for charcoal will continue to experience a high increase to meet the domestic energy needs of households and non-households, thus imposing immense pressure on the natural forest and its natural ability to replenish itself.

Numerous scholarly environmental studies have hypothesized that the main driver of deforestation in Africa is the extraction of forest for fuelwood. The collection of fuelwood for cooking and heating is a significant driver of deforestation in Africa, particularly in rural areas where there is a lack of access to modern energy sources (Namaalwa *et al.,* 2007; Hosonuma *et al.*, 2012; Getahun *et al.*, 2017; Ullah *et al.*, 2020). As a consequence, and in order to meet the growing energy demand, the tree stock is gradually being exploited, leading to deforestation and climate change in ecosystems. Therefore, in order to mitigate the adverse economic, social, and environmental consequences through an all-inclusive and comprehensive environmental policy, a clear understanding and analysis of the factors (socio-economic and demographic)

driving households and non-household fuel choices and demand cannot be overemphasized.

Charcoal consumption surveys are important for understanding the use and impact of charcoal in various regions and populations. However, conducting such surveys can be challenging, especially in estimating the actual driving variables contributing to the perpetual increase in consumption of charcoal and the per capita choices and demand due to population growth, urbanization, poverty, a lack of alternative energy sources, and cultural practices (Makanda *et al.,* 2017; FAO, 2020).

This study is therefore focused on building a comprehensive econometric model to visualize the effect of the price of charcoal, household's disposable income, number of meals per day, educational level of household head, marital status of household's head, and age of household's head. The output of this study will appropriately inform planners and decision-makers in the government and the private sector in crafting environmental and ecological policies for the net social welfare gain. To ensure access to affordable, reliable, sustainable, and modern energy for all (SDGs 7) and sustainable consumption and production patterns (SDGs 12), it can only be achieved in Liberia if human beings are continually reminded that their actions have the proclivity to either enhance the renewability characteristics of the environment or unintentionally deplete the natural capital, thus hampering sustained economic growth and development (UNDP, 2015).

1.2 Problem Statement and Justification

Charcoal is consumed by both households and non-household actors in many countries, including Liberia. However, in

addition to households, non-household charcoal consumers (in industries and services such as restaurants, slaughterhouses, breweries, and bakeries) use charcoal for a variety of reasons. The consumption of charcoal by households and non-households continues unabated, especially in urban communities in Liberia. Studies indicate that there are several influencing factors contributing to the high and increasing charcoal consumption in Liberia. These factors include urbanization, household dynamics, the high price of alternative energy sources like liquefied petroleum gas (LPG) for the majority of citizens, and an inadequate supply of electricity. By 2030, it is predicted that the amount of charcoal consumed in most sub-Saharan African countries will increase twofold (Puzzolo *et al.* 2019). This rise in demand for charcoal will require an estimated 544.8 million cubic meters of fuelwood and result in the production of 46.1 million tons of charcoal (Tassie *et al.,* 2021). Notwithstanding, the sustainable pattern of consumption by these statistical units leads to poverty reduction, welfare optimization, and environmental sustainability. However, the unsustainable behavior of household and non-household charcoal consumers influences forest degradation, deforestation, and greenhouse emissions (Houghton and Nassikas, 2018).

A study by Mwampamba *et al.* (2023) shows that national policies frequently emphasize unfavorable narratives about charcoal, charcoal producers, and charcoal users, depicting consumers as resistant to switching to alternatives. Due to the complex nature and the continuous increase in the consumption of charcoal, more contemporary researchers are now considering the demographic variables of households' heads in energy consumption (Keilman, 2003). According to Chidumayo and Gumbo (2013), who investigated the

environmental impacts of charcoal production in tropical ecosystems around the world, charcoal consumption and production in tropical countries around the world largely depend on natural forests, where natural regeneration is the main source of forest recovery. Doggart *et al.* (2020) looked at the influence of energy policy on charcoal consumption in urban households in Tanzania, where it was revealed that many households will continue to choose charcoal as their fuel of choice due to its affordability. A new strategy for the industry is required that highlights its beneficial effects while minimizing its unfavorable social and environmental effects. Bamesigwe *et al.* (2020) revealed that firewood and charcoal biomass are among the major causes of deforestation in Uganda and the sub-Saharan region. Furthermore, Mensah *et al.* (2022); Njenga *et al.* (2013); and Broto *et al.* (2020) research works have extensively focused on the adverse impact of charcoal production and consumption on both the health of the environment, the producers, and the consumers.

As per country-specifics, this theory has been discounted, and as a result, both rich and poor consumers of charcoal are in the study area. However, from the previous research's information on households' charcoal consumption, sustainability and its environmental impact have not been exhaustively revealed, especially in countries like Liberia, whose deforestation rate is increasing. In order to make a greater impact and contribute to the available knowledge base, this study therefore intends to evaluate the demographic variables of households' heads and their corresponding implication on charcoal demand in Montserrado County.

1.3 Objective of the study

1.3.1 General objective

The general objective of the study was to assess the factors influencing households charcoal consumption and the associated adverse environmental impacts in Montserrado County, Liberia.

1.3.2 Specific objectives

To achieve the general objective, this study intends to:

i. Identify factors influencing households' charcoal consumption
ii. Determine the challenges associated with charcoal consumption in the study area
iii. Assess the main sources of energy in the study area
iv. Analyze the environmental impact of charcoal consumption

1.3.3 Research questions

The below questions aid in enhancing this research work:

i. What are the factors influencing households' charcoal consumption?
ii. What are the challenges associated with charcoal consumption in the study area?
iii. What are the sources of energy used in the study area?
iv. What are the main environmental impacts of charcoal consumption in the study area?

1.4 Literature Review

1.4.1 Charcoal consumption in Africa

A range of socio-economic factors, including poverty, urbanization, population growth, and weak governance drive charcoal consumption in Africa (German *et al.,* 2011). The demand for charcoal is driven by a range of socio-economic factors, including poverty, urbanization, population growth, and weak governance. In many African countries, households that rely on charcoal for cooking spend a significant proportion of their income

on fuel, with low-income households being the most affected. As urbanization and population growth continue to accelerate in Africa, the demand for charcoal is likely to increase, exacerbating the environmental and socio-economic challenges associated with its production and consumption. In Malawi, it is estimated that charcoal consumption in the four largest urban areas is 6.08 million standard bags per year. When calculated, it takes about 1.4million cubic meters of wood representing 15,000 hectares of forest land harvested per year (Patrick et al., 2007). In Nigeria, charcoal is widely used by people of all socio-economic strata for domestic energy. Onakoya et al. (2013) reported the rate of deforestation at 2.4% over the period 1990-2000 due to the increase in the prices of kerosene and cooking gas. Deforestation in the Country, Nigeria is reported to be about 300,000 hectares per year which is about 3.5% of the current area of forest and woodland (Darling et al., 2008).The associated environmental consequences are increase in flooding, microclimatic change, desertification, soil erosion, and biodiversity loss (Nnaji *et al.,* 2012).

Sustainable solutions for charcoal production and consumption in Africa require a multi-stakeholder approach that involves government, industry, civil society, and local communities. Some potential solutions include promoting the use of clean and renewable energy sources, improving the efficiency of charcoal production and distribution, and strengthening governance and regulation of the charcoal industry. For example, the promotion of alternative clean energy sources like LPG (liquefied petroleum gas) can reduce the demand for charcoal and improve air quality. The United Nations Millenium Development Projects recommended halving the reliance on traditional solid biofuel for cooking by 2015 so that household could switch from using less efficient energy sources to efficient energy sources. Households stand to accrue numerous benefits such as the improvement of standard of living for countries that rely on biomass for energy (Lee, 2013). Moreover, switching to cleaner energy can also provide access to education, health care, and give

women time to engage in income-generating activities since they are they are directly involve with charcoal utilization in homes. Similarly, improving the efficiency of charcoal production can reduce the amount of wood needed to produce charcoal, thereby reducing deforestation and greenhouse gas emissions. Stronger governance and regulation of the charcoal industry can also help reduce the negative environmental and social impacts associated with its production and consumption (Omoti and Ogunwale, 2008).

The production and consumption of charcoal has significant environmental impacts, including deforestation, soil degradation, and greenhouse gas emissions. Sustainable solutions for charcoal production and consumption in Africa require a multi-stakeholder approach that involves government, industry, civil society, and local communities. While the challenges associated with charcoal consumption in Africa are significant, there are opportunities for sustainable and equitable solutions that can promote economic development, improve health and well-being, and protect the environment Omoti, & Ogunwale (2008); Kuyper *et al.* (2014). However, there is a wealth of information available on the topic, and further research is needed to develop sustainable solutions for this complex issue.

1.4.2 Charcoal consumption in Liberia

The Liberia National Energy Policy has estimated that about 95% of the total population in Liberia rely on energy derived from Biomass (Republic of Liberia, 2009). The demand for charcoal is growing exponentially due to its affordability, cultural affinity, desirable performance characteristics, poverty and the limited cost-effective alternative in Liberia. Findings from the last empirical studies on biomass energy conducted in Liberia 2011 estimated that the total volume of charcoal consumed was 137,000 metric ton/yr. of which 75% was consumed by residents of Monrovia (Van der Plas, 2011). Hence, it is expected that the demand for charcoal will increase with an expected rate of urban population at 3.4% (World Bank, 2018).

Charcoal production in Liberia is largely informal and unregulated, with the majority of charcoal producers operating outside the formal economy. Charcoal production often involves cutting down trees in forests and woodlands and converting them into charcoal using traditional kilns. The production process is often inefficient, with significant amounts of wood being wasted and the resulting charcoal often of poor quality. This inefficiency contributes to deforestation and soil degradation, which can lead to a loss of biodiversity and increased greenhouse gas emissions.

The consumption of charcoal in Liberia also poses health risks, particularly to women and children who spend significant amounts of time in poorly ventilated kitchens. The burning of charcoal produces fine particulate matter and other pollutants that can cause respiratory diseases and other health problems. The use of charcoal as a cooking fuel is also a significant contributor to indoor air pollution in Liberia, which is estimated to cause around 4,000 premature deaths per year (Kamara *et al.,* 2019).

Efforts to promote sustainable charcoal production and consumption in Liberia have been limited, with most interventions focused on improving the efficiency of charcoal production and distribution. One notable initiative is the Liberia Forestry Support Program, which seeks to promote sustainable forest management practices and reduce the negative impacts of charcoal production on forests and local communities. The program supports the establishment of community-managed forests and the adoption of improved charcoal production technologies, such as the use of more efficient kilns and the promotion of sustainable harvesting practices (USAID, 2020).

1.4.3 Energy consumption in Liberia

Liberia is a low-income country located in West Africa, with a population of approximately 5 million people. The country has one of the lowest rates of access to electricity in the world, with only around 12% of the population having access to grid-connected electricity

(World Bank, 2021). As a result, the vast majority of households in Liberia rely on traditional biomass fuels, such as charcoal and firewood, for their cooking and heating needs. Charcoal is the most widely used cooking fuel in Liberia, with an estimated 96% of households relying on it for their cooking needs (Kamara *et al.,* 2019).

Efforts to promote sustainable energy consumption in Liberia have been limited, with most interventions focused on improving the efficiency of charcoal production and distribution. However, there is a growing recognition of the need to promote the use of clean and sustainable energy sources, such as solar and wind power, to improve energy access and reduce the negative impacts of energy consumption on the environment and public health

The high consumption of charcoal in Liberia is driven by limited access to electricity and clean cooking fuels, and has significant environmental and socio-economic impacts. Efforts to promote sustainable energy consumption in Liberia should focus on improving access to clean and affordable energy sources, such as solar and wind power, and reducing the negative impacts of traditional biomass fuels, such as charcoal, on the environment and public health (WB, 2021).

1.4.4 Charcoal consumption and environmental implications

Charcoal production and consumption have significant environmental and socio-economic impacts. The production of charcoal requires large amounts of wood, which can lead to deforestation and soil degradation if not managed sustainably. Additionally, the burning of charcoal produces greenhouse gases and contributes to climate change. The use of charcoal for cooking and heating also poses health risks, as indoor air pollution from burning charcoal can cause respiratory problems, especially in women and children who spend the most time in the kitchen. Sustainable charcoal production and consumption can help mitigate

these negative impacts. Sustainable charcoal production involves using efficient kilns that reduce the amount of wood required and minimize greenhouse gas emissions (Chidumayo and Gumbo, 2013). It also involves using sustainable forestry practices, such as replanting trees and preserving biodiversity. Sustainable charcoal consumption involves promoting the use of cleaner and more efficient stoves that reduce indoor air pollution and improve energy efficiency.

Efforts to promote sustainable charcoal production and consumption have been undertaken by governments, NGOs, and other stakeholders in various countries in sub-Saharan Africa. For example, in Tanzania, the government has implemented a program to promote sustainable charcoal production and consumption by providing training and support for charcoal producers and promoting the use of efficient stoves (Mwampamba *et al.,* 2018). In Kenya, a project called the Kenya Charcoal Project has been implemented to promote sustainable charcoal production and consumption by providing training and support for producers, and by promoting the use of efficient stoves and alternative fuels (Guta *et al.,* 2020).

Charcoal consumption has significant environmental and socio-economic impacts, but sustainable production and consumption practices can help mitigate these negative impacts. Efforts to promote sustainable charcoal production and consumption should focus on using efficient kilns, promoting sustainable forestry practices, and promoting the use of cleaner and more efficient stoves.

1.4.5 Theoretical framework

Numerous scholarly works have been done in the past with recommendations highlighting the critical correlations between the environment, population, poverty, and economic growth. Ecologists and environmental scientists have postulated that population growth and economic output per capita over the years have had a

cumulative adverse effect on the environment (Quivik, 2003) as sited in (Rosa *et al*., 2004). On the contrary, environmental Kuznet's curve (EKC) –Neoclassicist, Ecological Modernization Theory (EMT) and Lomburg have all asserted that environmental impacts are being upgraded by economic prosperity (Gürlük, 2011; Lomborg, (2001), 2007; Spaargaren & Mol, 1992).

The anthropogenic drivers (human factors) over the centuries have immensely contributed to environmental disturbances on the global scene. Literature review revealed that population and affluence (anthropogenic activities) have a devastating negative impacts thus leading to greenhouse gas emission, emission of ozone depleting substances and the ecological footprint (Rosa *et al*., 2004).

The consumption of charcoal in Liberia is a growing concern to the national government. The government of Liberia has made many interventions to curb its negative impacts on the environment and the health of the consumers. The formulation of market-based and regulatory policies by the Forestry Development Authority (FDA) and the introduction of the Reduced Emissions for deforestation and forest degradation (REDD+) are steps to mitigate the adverse effect on the environment. However, about 95% of the urban households in Liberia use wood-based energy as the preferred energy for cooking and heating (Goll *et al.*, 2014; Oladeji *et al*., 2018). Non-households' consumption in urban areas are also on the increase but a comprehensive empirical studies are yet to be done to ascertain the facts.

In spite of the marginal increase income per capita, high electricity rates, and renewable energy availability household's charcoal consumption remains a major source of domestic energy. About 80% of households in Sub-Saharan Africa consume this product (Arnold *et al.*, 2006; Zulu & Richardson, 2013). The increase in the demand for charcoal coupled with the average household per capita consumption has placed an unprecedented pressure on the tropical

forest, mangroves, and woodlands (Oladeji *et al.*, 2018). Aside from population density, environmental scholarly studies have identified households' demographic variables as being another issue of concern in nature resource consumption.

1.4.6 Demographic variables

According to studies, there exist numerous factors that affect choice and consumption of charcoal. These factors include: demographic (educational level, the gender of households heads, the age of the household, the size) among other factors (Kebede *et al*., 2010). Research has revealed that when a household's head disposal increases, the likelihood of an increase in the consumption of the resources is more likely (Keilman, 2003). About 70-80% of household's consumption on the national scene and greenhouse emission is linked (Moll *et al.*, 2005).

Households in Developing countries unlike developed countries, choices are inherent in the energy ladder theory or fuel switch (Heltberg, 2005). This theory states that with an increase in household's head disposal income, individual household will consume superior fuel. Contrary to this theory, other researchers identified gaps in the energy ladder model and asserted that besides income, influence of cultural or other factors like education, fuel availability, household consumption tradition and urbanization are all factors contributing to consumer preferences (Van Der Kroon *et al*., 2013). Demographic characteristics of household's head have therefore been hypothesized by researchers as key drivers to the perpetual increase in the utilization of biomass in most African countries from findings and Liberia is of no exception. What is of growing concern is to test those key non-economic drivers to test the magnitude of household's energy demand sensitivity to each of those variables in Montserrado County, Liberia.

1.5 Conceptual Framework

The conceptual framework demonstrates the expected relationships between independent variables or predictors (Social demographic variables, Income, Price, Supply and Technology) and the Dependent variable (consumption of charcoal in kg by both households and Non-households). It shows the conceptual differences between the variables of concern.

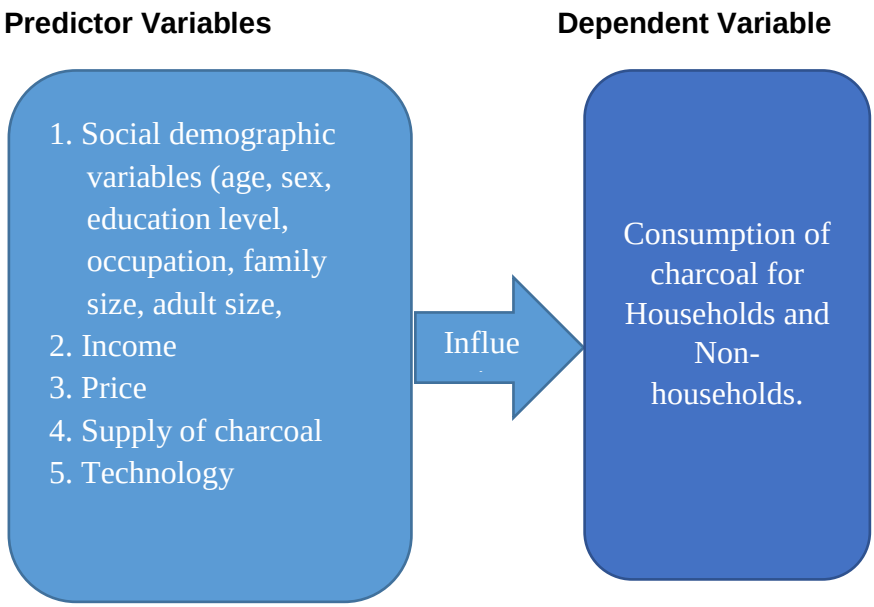

Figure 1.1: Conceptual model of household's charcoal consumption

1.6 Methodology

1.6.1 Selection of the study area

The study was conducted in Montserrado County, Liberia. This County was selected predicated upon its huge diversified population, its susceptibility to exodus of rural dwellers who seek greener pastures. Notwithstanding, with a relatively huge economic activities and better energy infrastructure, Montserrado accounts for about 65% of the total volume of charcoal consumed in Liberia. It is upon

this backdrop that Montserrado County was selected. Notably, most of the households use charcoal for cooking and heating, while non-households also use charcoal for cooking and other needs. Montserrado County is situated on the Northern part of Liberia with capital Bensonville. Its population according to the 2008 census was 1,118,241 with an area of 1,927.7 square kilometers (738.5 square mi). Montserrado County is noted as the smallest in size of the Counties which has about 33% of the total population in Liberia, its population density is 599.7 per square kilometers. Montserrado County has an average household size of 4.7 people, a reduction from 5.4 at the 1984 census (MCDA, 2012). Montserrado County has four districts: Careysburg, Todee, Greater Monrovia, and St. Paul River. Each district has its own unique characteristics. Due to logistical constraints and cost, a spot consumption survey or surveys of short duration were used.

1.6.2 Research design

A cross-sectional research design was used in this study. Data were viewed and collected from the population of interest at one specific point in time. The key characteristics of a cross-sectional design is that the study takes place at a single point in time; variables are not manipulated; it gives researchers to view many characteristics at the same time (age, income, gender, etc); and it can give information about the activities in a given population (Levin, 2006). During data collection, questionnaires were used to collect vital information on the household demographic characteristics and socio-economic status of the respondents for households and non-households respectively. In addition, personal observations and focus group discussions were used for data collection.

1.6.3 Study population

The study's population included all households in Montserrado County that consume charcoal, specifically in the four districts: Careysburg, Todee, Greater Monrovia, and St. Paul River. The selection of these four districts was based on their status as the

most populous counties, centers of economic activity, and having a high prevalence of charcoal consumption. Hence, efforts to promote sustainable charcoal production and consumption in Montserrado County and other parts of Liberia are crucial for reducing the negative environmental and health impacts of charcoal production and consumption.

1.6.4 Sampling techniques and sample size

A combination of both multi-stage and purposive sampling were used in the study. The population was divided into groups after which the clusters are chosen at random. In the First stage, Montserrado was selected purposively due to its population, multiplicity of tribes and energy infrastructure. The second stage involved purposive selection of specific heads of households in the study area to understand the percentage of the population consuming charcoal and to make statistical inferences about the population of interest. Third stage, the sample size was determined from the sampling frame using Boyd *et al.* (1981) and a 10% sampling intensity, whereby 10% of each sampling frame was considered as the sample size.

1.6.5 Data Collection

1.6.5.1 Primary data

Primary data were collected using questionnaires with both closed and open-ended questions which was customized to reflect the demographic characteristics of the unit of measurement, household and the socio-economic status of the head of the household. Questionnaires were also developed for the non-household users, the daily sales, the daily consumption and the size of the customer base.

1.6.6 Data Analysis

Objective 1: Identify the factors influencing households charcoal consumption in the study area

Multiple linear regression was used as a method of analysis for this objective. As the model was used to determine the key influencing factors that are associated with household charcoal consumption in the study area.

The multiple regression equation used for analysis is as explained below:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_7 x_7$$

Where:

Y = Consumption (Kg per household)
β_0 = Constant Variable
X_1 = Age of household (Years)
X_2 = Marital status
X_3 = Household size (Total number of people in a household)
X_4 = Price of charcoal (Unit price of charcoal)
X_5 = Income (Wages received by household)
X_6 = Education Level
X_7 = Number of meals (meals per day)
ε = Error Term

Objective 2: Determine the challenges associated with charcoal consumption

Content analysis together with descriptive analysis was used as methods of analysis for this objective. Through multiple response analysis, challenges regarding charcoal consumption were obtained and reported in a sy**s**tematic manner.

Objective 3: Assess the main sources of energy sources in the study area

Descriptive analysis was used as method of analysis for this objective. Different energy sources that were used in the study area

were analyzed descriptively showing statistics of the respondent's main source of energy.

Objective 4: Analyze the environmental impacts of charcoal consumption

Descriptive statistical analysis was used as a method of analysis for this objective. Through the use of a Likert scale analysis with 4-point rating scale, which was used to determine the environmental impacts of charcoal consumption among the respondents.

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CHAPTER TWO

Paper One

2.0 Factors Influencing Household's Charcoal Consumption in Montserrado County, Liberia

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Factors influencing household's charcoal consumption in Montserrado County, Liberia

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Key words: Efficient energy, Affordability, Traditional fuel, Multiple Linear regression, Inter-energy switching.

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Abstract

In sub-Saharan African Countries, charcoal is still preferred as the main source of energy use by the majority, and its importance is not only as a source of energy but also for generating employment and income among its producers. The current study intends to look into factors related to household charcoal consumption in Montserrado County, Liberia. Specifically, the study aims to assess socio-economic factors affecting household charcoal consumption and to identify the challenges associated with charcoal consumption. The study adopted a cross-sectional research design whereby data were collected once from 386 respondents who are charcoal consumers in Montserrado County. Quantitative data retrieved from the questionnaires were analyzed by using SPSS version 20 in which descriptive and inferential statistics were determined. Results from the multiple linear regression analysis showed that factors such as education level, number of meals, price of charcoal and household size were statistically significantly associated with household charcoal consumption in the study area. Furthermore, the high price of charcoal, low quality of charcoal and dirtiness of homes were the top three challenges affecting charcoal consumption in the study area. The study recommends the government formulate policies for improving accessibility to other alternative energy sources such as gas and electricity affordably and reliably to encourage inter-energy switching among households to ensure sustainable per capita consumption of charcoal.

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Introduction

The majority of households in developing nations depend largely on wood fuel as their main energy source. Clean and efficient energy such as gas, electricity and kerosene are considered to be among the main drivers for sustained economic growth and development. Hence, their unaffordability in terms of price, inaccessibility, unreliability in supply and unavailability have constrained households to consume traditional fuel known as charcoal for cooking, boiling, and ironing (Suliman, 2013). Since the beginning of time, charcoal has been used for a variety of reasons, including medicine and art, but by far its most significant usage has been as fuel for metallurgy, cooking, industry, and automobiles. When high heat is required, charcoal is used as a standard fuel. It may be ground up to produce carbon black for use in chemical processes, and it was crucial to the development of early chemistry (Abdolahi, 2014). The energy balance is dominated by biomass-based fuels, primarily charcoal and firewood are the primary sources of energy in both urban and rural regions due to the extremely restricted access to electricity and other renewable energy sources (Nyoni, 2014).

Almost one-third of the world's population still uses wood as their primary source of fuel for cooking, and many small businesses rely heavily on fuelwood and charcoal as their primary energy sources for tasks like baking, processing tea, and manufacturing bricks. Around the world, wood harvested from forests is utilized to make charcoal and fuelwood at a rate of 50% (Dam *et al.* 2017). Notwithstanding, limited access to cleaner energy services has prompted about two and a half billion of the world's population to use traditional biofuel (charcoal) for cooking, boiling, and ironing (Kowsari and Zerriffi, 2011).

In Africa, about 80% of urban cities are engaged in biomass combustion for cooking (Zulu and Richardson, 2013). The estimated use of wood fuel and charcoal in Africa is 90% (East Africa 94%, North Africa 96%, Central Africa 87%, South Africa 49%, and West Africa 92%). According to official figures, Africa produced 30.6 million tons of charcoal in 2012, which was sold for between USD 6.1-24.5 billion.

African continent with the fastest population growth at 2.45% in 2021, the continent's yearly population growth rate is exceptionally high and is expected to stay over 2% for the ensuing 20 years (UN, 2021). The consumption of charcoal is being influenced not only by projected high population growth and urbanization but also by other factors such as economic, social and environmental factors (Masera *et al.*, 2003). Charcoal and firewood are the two major sources of biomass energy in Liberia. Charcoal trade as a livelihood economic activity in Liberia has helped in poverty alleviation for the Forest Dependent Community (FDC) and contributed immensely to about 10% of the country's GDP (World Bank, 2018). The per annum demand for charcoal since 2018 is estimated at 337,000 metric tons and about 75% is consumed by residents of Monrovia (World Bank, 2019). Currently, charcoal and firewood is the preferred energy source for cooking in Montserrado County. However, increasing demand is more likely due to the lack of affordable, available and reliable clean energy sources and the rate of urbanization. This energy deficit has influenced the high increase in household consumption of the forest-based product mainly charcoal which is adversely affecting the environment due to households' financial incapability to purchase modern energy conversion technologies (Elias and Victor, 2005). Studies conducted in Liberia have estimated that more than half of the total population residing in Montserrado County are experiencing limited access to electricity and other cleaner energy sources like gas, and kerosene (MCDA, 2012). Studies by Goll *et al.* (2014); Brieland, (2015); Oladeji *et al.*, (2018) and World Bank, (2019) have stressed the need for capacity enhancement programs, Law enforcements programs, and a more economically competitive economic model for a realistic analysis of the factors influencing the progressive increase in household's charcoal consumption in Liberia. It is estimated that the annual growth rate of the urban population is 3.4% and it is expected that the demand for charcoal

in the next 20 years may exceed 500,000 by 2030 (World Bank, 2019). Montserrado County has witnessed over the years an unprecedented increase in the number of households (MCDA, 2012). Liberia's National Energy Policy has estimated that about 95% of Liberia's population relies on biomass energy for cooking (MCDA, 2012). Hence, to bridge this gap, non-economic factors need to be incorporated into the model to test the statistical significance of these variables to household charcoal consumption. Therefore the current study intends to look into factors related to household charcoal consumption in Montserrado County, Liberia. The current study should help to understand the factors influencing charcoal consumption among households in the study area. Moreover, the findings of this study are consistent with the twelfth goal among the 17 Sustainable Development Goals which is responsible consumption and production, to achieve sustainable management and efficient use of natural resources by 2030 (UN, 2015). Furthermore, the findings of this study are in line with the Liberia Forest Sector Project (2016 – 2023) whose key issue is to produce and consume charcoal from sustainably managed community forests (World Bank, 2016). The results of the study also offer suggestions to the policy formulation organs on adequately forest sustainability.

Objective of the study

Main objective

To evaluate factors related to household charcoal consumption in Montserrado County, Liberia

Specific objectives

To assess socio-economic factors related to household charcoal consumption. To assess the challenges associated with household charcoal consumption.

Methodology

Description of the study area

Montserrado County (Fig. 1) is the oldest county in the country, almost as old as the Republic of Liberia itself. Montserrado County is a county in the northwestern portion of the West African nation of Liberia containing its national capital, Bensonville.

Fig. 1. Map showing Montserrado County.

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The county is bounded South by the Atlantic Ocean, Bong County on the North, Bomi County on the West and Margibi County on the East. Montserrado County is susceptible to a massive exodus of people seeking government jobs, and successful business because it is the commercial hub, and a place dominated by almost all 16 tribes of Liberia. It has two main climatic conditions, the rainy season from May to November and the Dry season between December to February. The average temperature ranges between 21 and 36°C with an annual average rainfall of about 1905mm (MDA, 2012).

Montserrado is the smallest county by size, but the largest in a population comprising approximately 33% of Liberia's total population. The primary reason for choosing Montserrado County as the study area is because of the high population and per capita charcoal consumption. The county accounts for about (65%) of the total demand for charcoal (LFSP, 2019). Hence, the demand is more than ten times greater than in any other county in Liberia.

Research design

The cross-sectional research approach was used in the current study as it allowed for the collection of comparable data from family households who use charcoal for cooking at once (Neuman, 2014). The design was chosen because it is affordability, relatively quick to conduct and permits significantly faster data collection without compromising data quality (Setia, 2016).

Sampling techniques and sample size

A combination of multi-stage sampling and purposive sampling was used. At stage one, Montserrado County was purposively selected.

At stage two, Specific household heads from the four selected districts of Montserrado County (Table 1) were selected through purposive sampling so as to get a specific household who are charcoal users. The sample size was determined according to Boyd *et al.* (1981) where the intensity of 10% from every sampling frame.

Data collection

Primary data were collected from respondents using a pre-structured questionnaire with both open and closed-ended questions. Further, ten focus group discussions (FGD) were conducted, the FGDs involved 15 participants comprising elders, community leaders, student representatives, women, and youth leaders. A total of 150 participants were involved in these discussions. To ensure the validity and reliability of the collected data, the data-gathering tools were pre-tested in the study area, before the actual data collection to guarantee familiarity and clarity. Collected data during the piloting the data collection tool were not included in the study's final analysis.

Data analysis

Quantitative data collected through the questionnaires were analyzed using the Statistical Package for Social Sciences (SPSS version 20) whereby both descriptive (frequencies and percentages) were determined. A multiple linear regression model was used to estimate the correlational relationship between household charcoal consumption, and socio-economic factors. Differences or associations between variables were considered statistically significant if the p-value was ≤0.05. For the case of qualitative data that was collected through FGDs, content analysis was used, whereby the answers from the members were categorized into meaningful themes.

Results and discussion

Respondent's demographic and socio-economic characteristics

Demographic and socio-economic characteristics of the respondents show that majority of the respondents (57%) were males while (43%) were females (Table 2). Farsi *et al.* (2007) indicated that female-headed households are statistically significant due to the fact that charcoal utilization and daily household food preparations are in the preview of women. These studies were consistent with Mekonnen and Kohlin (2009) who postulated that the probability of female-headed households

consuming either charcoal or a mix of solid and non-solid fuel was high. Charcoal consumption could experience a downward consumption trend if alternative energy sources were available, accessible and reliable in Montserrado County. Results showed that respondents with ages between 36-60 years were active groups constituting about 57% of charcoal actors. This was followed by ages ranging between 0 - 34 years consisting of about (35%) of charcoal users and lastly the group of ages above 60 years which constituted 8.8% of the charcoal users. This shows that most of the charcoal consumers were in middle age consistent with Liberia's demographic dividend as enshrined in the National Development Agenda (PAPD, 2018) where about (53%) of the population are between the ages 15 – 64 years constituting the working age. These are income earners who have the financial capability to purchase at will.will power to the energy market system.

Table 1. Sampling frame and sample size.

County	District	Study population (Sampling frame)	Sample size (n)
Montserrado	Greater Monrovia	1500	150
	Careysburg District	900	90
	Todee District	900	90
	St. Paul River District	560	56
	Total		386

Results further indicate that majority (42%) of the respondents were married. These homes were better organized and optimistic about improving their energy strategies if electricity was affordable and reliable. On the other hand, about (29%) of the respondents have attained a college-level education. These respondents are literate (Venance *et al.*, 2016). Literate charcoal actors are assumed to have a better understanding of sustainable practices on charcoal consumption (Emana *et al.*, 2017) and can easily adopt new, efficient and modern environmental cooking technologies contrary to those without any formal education who are less informed and less likely to adopt new cooking technologies.

Household size was also a major socio-economic factor. Results show that the majority of the respondents (48%) had a household size of more than 6 people. This implies that households in the study areas comprised more people, hence, the per capita charcoal consumption is likely to be higher than in other counties. This is consistent with the study done by Venance *et al.* (2016) who reported that the higher the household size the more likely the source of energy is consumed. Furthermore, the descriptive analysis shows that about (40%) of the respondents were not employed (Table 2). This suggests that the majority of the household in the study area have low or no income at all and hence adopting an alternative source of energy apart from charcoal is a bit challenging for them. Notwithstanding, household heads with comparatively high incomes engaged in inter-fuel stacking.

Factors influencing household charcoal consumption

A multiple linear regression model was used to determine factors influencing household charcoal consumption. Explanatory variables included age of household, marital status, education level, income, household size, number of meals and the price of charcoal. The actual estimates of causal effects were obtained by using these control variables (Hunermund and Louw, 2020). Results in (Table 3) show that no variables had a tolerance value (>1) and VIF value (> 10). This observation confirms that there was no violation of the multicollinearity assumption in this current study as stipulated by Pallant (2011). In addition, the Durbin-Watson's d tests were used to test for auto-correlations. The results showed that the Durbin-Watson's is 1.78 for the full which falls within the values of $1.5 < d < 2.5$, implying that there is no auto-correlation (Kutner *et al.* 2005). Hence, there is no auto-correlation in the multiple linear regression data. The coefficient of determination (R^2) in the regression model for the full sample was 77.1% (Table 1.3).

Table 1. Respondents Demographic and Socio-economic Characteristics (n = 386).

Characteristic		Frequency	Percentage
Sex	Male	220	57
	Female	166	43
Age	0 – 35 years	134	34.7
	36 – 60 years	218	56.5
	Above 60 years	34	8.8
Marital status	Single	153	39.6
	Married	161	41.7
	Divorced	24	6.2
	Widow	43	11.1
	Cohabitation	5	1.3
Education Level	Illiterate	85	22
	Elementary	33	8.5
	Junior high	54	14
	College	113	29.3
	University	95	24.6
	Post graduate	6	1.6
Household size	Less than 3	57	14.8
	Between 3 – 6	144	37.3
	Above 6	185	47.9
Occupation	Not employed	152	39.4
	Employed	137	35.5
	Entrepreneur	97	25.1

The linear regression results in (Table 3) show that on average, the price of charcoal was statistically significant ($p < 0.001$) with household's charcoal consumption. However, it had a negative beta coefficient of 0.14. A one-unit increase in price will decrease households' consumption of charcoal by 0.14kilograms ceteris paribus, consistent with the demand theory of consumption. However, the nature of the product and its significant role in residential energy use in Montserrado County, households still consume charcoal irrespective of the increase in price. This implies that if there are alternative energy sources that are cost-effective and maximize consumers' satisfaction domestically, the probability of linear switching is likely by households. This will reduce the consumption of charcoal, thus saving the environment and the tropical forest. However, it was not statistically significant in the sub-samples representing the districts separately. The finding is consistent with the finding by Nyembe, (2011) who reported in his findings that the price of charcoal was negatively related to household's charcoal consumption that is when the price of charcoal rises majority of the households' switches to other energy sources which are cheaper and affordable than using the same energy source at a higher price. A similar finding was reported by Babsola and Opii (2022), Mekonnen and Kohlin (2008) and Nur, (2021).

Table 3. Regression results of full sample and the four districts.

Variables	Full sample (n = 386)		Greater Monrovia (n = 150)		St. Paul River (n = 36)		Careysburg (n = 90)		Todee (n = 90)	
	Sig.	B	Sig.	B	Sig.	B	Sig.	B	Sig.	B
Age	0.332	0.37	0.903	0.007	0.939	-0.011	0.563	0.077	0.958	0.007
Marital status	0.486	-0.04	0.907	-0.04	0.328	0.090	0.107	-0.122	0.417	0.063
Household size	0.04*	0.103	0.154	-0.71	0.158	0.216	0.001***	0.421	0.000***	0.606
Price of charcoal	0.000***	-0.14	0.370	-4.38	0.951	0.014	0.062	0.266	0.060	-0.274
Monthly income	0.508	-0.04	0.013*	0.667	0.096*	-0.012	0.007***	-0.03	0.851	0.0128
Education level	0.014**	-0.20	0.000***	-293	0.108	-149	0.432	-0.5*	0.801	0.015
Number of meals per day	0.001***	0.123	0.341	0.047	0.030**	-328	0.001***	0.387	0.001***	0.426
R^2	0.771		0.58		0.42		0.53		0.4	

However, the energy deficit scenario in Liberia has constrained households to perpetually consume charcoal at a higher price due to scarcity of the alternative energy sources. With the current situation in Montserrado County and on a per-district level, consumers are not exposed to alternative energy sources where the market system allows them to freely choose at an optimal level at minimum cost.

Household size was statistically significant with charcoal consumption and also exhibit a positive relationship with a coefficient of 0.103kilograms. This implies that a one-unit increase in the size of the household results in an increase in the household's charcoal consumption by 0.103kilograms. Moreover, the size of the family determines the quantity of food cooked and the quantity of charcoal to be used. Earlier stated, Montserrado County is the official set of National government that continues to experience an increase in population which has affected household size. This implies that if proper decentralization of major economic activities is initiated by the Central government, household size will be at a minimum level, thus affecting charcoal consumption negatively. Comparatively, similar results were also observed in the two sub-samples districts of Todee and Careysburg while the remaining two districts had different results. Greater Monrovia exhibited a positive relationship even though it wasn't statistically significant. St. Paul River district results on household size were neither significant nor had a positive relationship. Similar findings to the full sample were reported by Hetberg (2003) and Mekonnen and Kohlin (2009). They found out that households with large family sizes were more likely to consume charcoal and wood and less likely to consume kerosene, gases and other alternative sources of energy. Furthermore, the findings by Kyereh *et al.* (2019) reported that households with a greater number of males are considered to be active members and can produce more volume of charcoal than households with fewer numbers. Household size is a crucial factor in determining the consumption of charcoal since the increase in household size affects the ability of households to move to cleaner fuels.

Results on the number of meals (Table 3) are statistically significant with household's charcoal consumption and it shows a positive relationship. Results from the analysis show that households' charcoal demand sensitivity to changes in the number of meals per day are positively correlated.

A one-unit increase in the number of meals per day leads to an increase of 0.123 kilograms of charcoal in a specific household. Comparing the results of the full sample to the sub-samples of the district it can be observed that results are similar with the exception of the Greater Monrovia district which the number of meals was not statistically significant but similarly had a positive relationship. Similar results were reported by Sabuhungu *et al.* (2015) and Babalola and Opii (2013) that the number of meals per day increases charcoal consumption. Greater Monrovia district has comparatively better infrastructure as compared to the other districts. Moreover, the socio-economic and demographic characteristics of household heads in Greater Monrovia district are fairly good as compared to the other districts. Household heads have better market information and are exposed to other alternative energy sources as compared to the other districts.

Table 4. Challenges on charcoal consumption.

Challenge experienced	Frequency	Percentage
High price	252	22.7
Low quality	239	21.6
Dirtiness of homes	233	21
Limited supply	218	19.7
Long distance	166	15

Further results on education level (Table 3) show that it is statistically significant with household's charcoal consumption, but however results from the analysis show a negative relationship between education level with charcoal consumption. This implies that when a household head advances in education by one unit, household charcoal consumption declines by 0.2kilograms holding all other factors constant. Hence the more educated household heads the more the awareness of using environmentally friendly energy sources therefore the less charcoal consumption. However, only Monrovia District had similar results to the general sample while the remaining districts had insignificant results on education level. The finding is consistent with the findings by Yusuf *et al.* (2021), Paudel *et al.* (2016) and Dagnachew *et al.* (2019) that level of education knowledge has an impact on charcoal consumption, household heads with higher education are more likely to be economically capable and less likely to consume of charcoal. Conversely, household heads with no formal education are more likely to consume traditional fuel and less likely to adopt energy-efficient technology. This implies that education has the ability to influence fuel choices thus making the energy transition process from inferior energy to superior and clean energy easy. However, findings by Zulu and Richardson, (2013) argued that access to a high level of education with poor income yet has no impact on charcoal consumption. Therefore, for energy security, most households practice a fuel-stacking strategy in the wake of uncertainties.

Other factors such as the age of the household, marital status and income were not statistically significant in the household's charcoal consumption. But compared with the district level separately, three Districts of Greater Monrovia, and Careysburg for the aspect of income were statistically significant with positive and negative relationships. In general, considering the full sample, results (Table 3) on income show a negative relationship with charcoal consumption. That is to say, a one-unit increase in household disposable income declines the consumption of charcoal by 0.039kilograms.

This implies that those households with higher incomes will automatically gravitate to the available superior energy sources. Although the finding was not statistically significant they are consistent with the energy ladder hypothesis that household income influences their ability to purchase superior energy sources (Van der Kroon and Van Beukering, 2013). Furthermore, different studies have reported similar findings Baland *et al.* (2018) and Mpenyejekumana *et al.* (2021) that household income affects the readiness to adopt and use modern cooking technologies.

This implies that this result, like other studies, discounts the energy ladder theory and thus considering other factors in the model will help in understanding those relevant influencing variables that are affecting household charcoal consumption in Montserrado County, especially with income in disposable income.

The age of the head of household had a positive relationship with charcoal consumption but was not statistically significant in the model. As the age of the head of household increases the consumption of charcoal increases by 0.37kilograms. The marital status of the respondents was not statistically significant and had a negative relationship. Meaning that marital status had no influence on charcoal consumption.

Challenges in consuming charcoal

Multiple response analysis results show different challenges experienced by charcoal users (Table 4). The first reported challenge that was common for the majority of the respondents was the high price of charcoal which accounted for nearly a quarter (22.7%) of the respondents. Findings in a study by Nabukalu and Giere (2019) showed that charcoal pricing depends on better quality and origin. Charcoal from different areas comes with different prices and hence, better quality charcoal is compromised with a higher price in the study area. Notably, there are those consumers who prefer soft charcoal due to its lower price and the fast rate at which it burns while others prefer hard charcoal because they consider it more economical with a slower burning rate. However, the Norconsult Tanzania Limited report of 2002 revealed that the cost of charcoal varies slightly depending on the particular season, during the rainy season price of charcoal is higher and it lowers during the dry season. Furthermore, the study by Sankhayan and Hofstad, (2000) on production and spatial price differences for charcoal revealed that there is no statistical evidence of price increase or decrease with distance. Therefore, the price of charcoal is not only influenced by one factor but the price fluctuates depending on various reasons as explained by the previous studies explained above. Low quality of charcoal was the second mentioned challenge with accounted (for 21.6%) of the respondents, whereby low quality of charcoal was seen as an obstacle in the consumption of charcoal for daily uses (Table 4). Findings by Nabukalu and Giere, (2019) show that the quality of charcoal depends on the price used to purchase charcoal. Lower prices result in low quality however, due to some topographical aspects there may be some charcoal wood varieties that are of low quality in nature. Moreover, the limited supply of charcoal was another challenge due to the natural and artificial scarcity of charcoal. Some producers engage in hoarding in order to create artificial scarcity, thus increasing prices arbitrarily for their own financial gains. Nabukalu and Giere (2019) believe that scarcity of charcoal arises sometimes due to some ecological reasons such as exceeded deforestation which prohibits charcoal producers from cutting down trees over a period of time hence resulting in inadequate supply. However, Branch and Tiitmamer, (2022) reported in the literature that charcoal production will cease due to the ongoing global effort to ensure reliable and sustainable energy for all meeting the 7th Sustainable Development Goal. Similarly, literature by Tippayawong *et al.* (2020) reveals that charcoal production is likely to degrade the environment hence, production should cease and the introduction of a better source of reliable energy of smokeless charcoal from plant residues which is more environmentally friendly as compared to wood charcoal. Furthermore, long distances and the dirtiness of homes as among other challenges facing the consumption of charcoal.

Conclusions and Recommendations

Based on the study findings and the discussions presented, it is concluded that education level, number of meals, price of charcoal and household size were statistically significant associated with household charcoal consumption in Montserrado County. Education level plays a significant role in the consumption of charcoal. Most households prefer charcoal as compared to alternative energy sources due to its affordability, reliability and accessibility. Households with a higher level of education, income and better social status tend to engage in energy stacking strategy compared to those of lower socioeconomic status in Montserrado County. Household size largely influenced the quantity of charcoal to be used. Further, the high price of charcoal, low quality of charcoal and dirtiness of homes were the top three challenges affecting charcoal consumption in the study area. Due to urbanization, population expansion and non-economic factors, household charcoal consumption may rise further if programs to enhance sustainability are not initiated and enforced. Charcoal usage directly contributes to deforestation and forest degradation. This research recommends that national government institute policies the will promote, support and enforce the use of alternative energy sources like gas,

solar and coal briquettes which are clean and low-carbon emitters than charcoal and introduce customized programs for sustainable production and consumption of charcoal.

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CHAPTER THREE

Paper Two

3.0 Household Energy Consumption and Its Implication on the Environment in Montserrado County, Liberia

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3.1 Abstract

Charcoal is the primary energy source for Liberians, especially in urban cities where the bulk of the population lives. Charcoal production is frequently perceived to have devastating ecological and environmental consequences, and government through the Forestry Development Authority and non-governmental organizations have been especially concerned about these charcoal-related impacts on the forest resource. The most frequently mentioned impact is deforestation, or the removal of the forest cover. The current study intends to look into the source of cooking energy and the related environmental impacts in Montserrado County, Liberia. Specifically, the study aims to determine the available sources of energy used for cooking and to determine the environmental effects associated with charcoal production. The study used a cross-sectional research design, with data collected from 386 households in Montserrado County. Semi-questionnaires and Focused Group discussion checklists were used to collect quantitative data and qualitative data, and descriptive statistical analysis together with Likert scale analysis and content analysis were used to analyze the data. The study results showed that, charcoal is the most (51.9%) used form of energy for cooking in most of the households and the charcoal production has caused devastating environmental impacts. Also, the results on the impact of charcoal consumption showed that deforestation was the major impact in Montserrado County (65.5%). Therefore, any successful effort to combat the environmental effects of charcoal production in Liberia must necessarily tackle the current unsustainable nature of charcoal production and consumption. Conclusively, compared to other cleaner energy sources charcoal is relatively very cheap, available, reliable and accessible throughout the year. However, charcoal has devastating effects to the environment which causes deterioration of the environment as the result of high rate of charcoal production to meet the growing consumer's residential energy needs for cooking, boiling and ironing. To reduce the devastating effect of charcoal as domestic energy, which was prevalent as compared to

the other energy sources, the introduction and education of charcoal producers to the usage of a low –cost retort-kiln or Improved Charcoal Production System (ICPS) is paramount; the development of an inclusive energy policy aimed at promoting cleaner energy accessibility and affordability to all income earners in the study area.

Key words: Environmental consequences, deforestation, Ecological, Unsustainable nature, Environmental effects

3.2 Introduction

In sub-Saharan Africa, one of the primary causes of forest degradation is the manufacturing of charcoal for urban energy use (Nyamoga, 2019) and (Sedano *et al.* 2016). The majority of Africans living in cities and suburbs rely mostly on wood fuels for cooking and heating (Nyamoga and Solberg 2019; Prasad, 2011). These are a significant source of family income in sub-Saharan Africa, where they produce more than 80% of the country's primary energy supply (Chiteculo *et al.,* 2018). The primary causes of this forest degradation are fuelwood gathering and charcoal manufacture (Gumbo *et al.,* 2013). Numerous strategies have been used internationally to stop deforestation and forest degradation. The Food and Agriculture Organization (FAO) reported in October 2006 that deforestation accounts for 25 to 30 % of the release of greenhouse gases as charcoal production and use are increasing globally rather than decreasing. Charcoal production not only affects forest resources but also the entire environment. According to the World Population Review (2022), Brazil is the leading country with a high rate of deforestation in the whole world. Hence, the production of charcoal to meet household's residential energy demand in urban cities is considered an important driver of degradation (which maintains the forest canopy but causes losses of carbon) and eventual deforestation in Africa (Boucher, 2011).

Studies show that charcoal production is among the significant contributing factor in Africa's deforestation (Ryan *et al.* 2012). One of the main contributors to deforestation is the use of wood as a major source of cooking energy (Lusambo, 2021). In conjunction with population increase and development, the production and use of these wood fuels have increased, affecting the sub-Saharan Africa's deforestation rate (Nyamoga, 2019). Nearly 43 billion trees, most of which are found in South Africa, Ethiopia, and Nigeria, are found on the continent of Africa, which is home to 26% of the world's land that is classified as forest (Igini, 2022). Trees has immense quantity of carbon and it constitutes about 50% of the wood's weight (Boucher,

2011). Due to the potential for deforestation, land degradation, and climate change effects, large-scale charcoal manufacturing, particularly in sub-Saharan Africa, has become a significant issue of concern (Jones, 2015).

More than two thirds of Liberia's land is covered by forests, which total 6.69 million hectares (Nthara and Srivastava, 2020). According to the Global Forest Watch (2022), about 9.16Mha of natural forest covered 97% of Liberia's land area in 2010. It lost 128 kha of natural forest in 2021, which is equal to 75.4 Mt of CO2 emissions. Half of the people in Liberia reside within 2.5 kilometers of a forest, whereby, these households spend more than three hours a day gathering forest items for consumption and for sale, which generates 35% of their revenue (Nthara and Srivastava, 2020). About 95% of Liberians rely on conventional biomass fuels like wood and charcoal because less than 1% of the population has access to grid electricity a s a result of inadequate infrastructure, high costs, and low-income levels making charcoal as the main fuel used for heating and cooking in Monrovia, a developing metropolitan center (Goanue, 2009 and Jones, 2015).

Due to the fact that only a relatively tiny portion of the continent's production is evaluated and recorded, Africa’s charcoal industry is weaker (Zulu and Richardson, 2013). As a result, there has been discussion over the true extent of usage and its effects on rural livelihoods or forest degradation. Different studies by Clement, (2019); Sedano *et al.,* (2022); Tasie *et al.,* (2020); Nyalusi, (2015) focus mostly on forest degradation and charcoal production on how they are related or looking at how the impacts of charcoal production activities on the environment. There is little information regarding the energy consumption and effects of charcoal production on environment in Montserrado County, Liberia. Therefore, the current study intends to fill this knowledge gap by specifically looking at the cooking energy sources and the environmental impacts caused by charcoal production in the study area. The key findings from this

study will help to understand the major source of energy used by most of the households in Montserrado County, Liberia. The results of the study also offer suggestions to the policy formulation organs on adequately forest sustainability. The study is also aligned with Sustainable Development Goals number 7, 13, 12, and 15 which aim at affordable and clean energy, climate action, responsible consumption and production, and life on land respectively.

3.3 Objective of the study

3.3.1 Main objective

To determine the energy and charcoal effects on the environment in Montserrado County, Liberia.

3.3.2 Specific objectives

i. To determine the source of energy in the study area
ii. To determine the environmental impacts associated with charcoal production in Montserrado County

3.4 Methodology

3.4.1 Description of the study area

This study was carried out in Montserrado County (Figure 3.1). Montserrado County is the oldest county in the country, almost as old as the Republic of Liberia itself. Montserrado County is a county in the northwestern portion of the West African nation of Liberia and it hosts its national capital, Monrovia. Montserrado is the smallest county by size, but the largest by population comprising approximately 33% of Liberia's total population. (25%) of the county, population is engaged in charcoal-making activities. The county is bounded on South by the Atlantic Ocean, Bong County on the North, Bomi County on the West and Margibi County on the East. The primary reason for choosing Montserrado County as the study area is because it dominates the market on charcoal and it accounts almost over (65%) of the total demand hence, more than ten times greater than any other county in Liberia. However,

respondents for data collection can be obtained easily as compared to other counties.

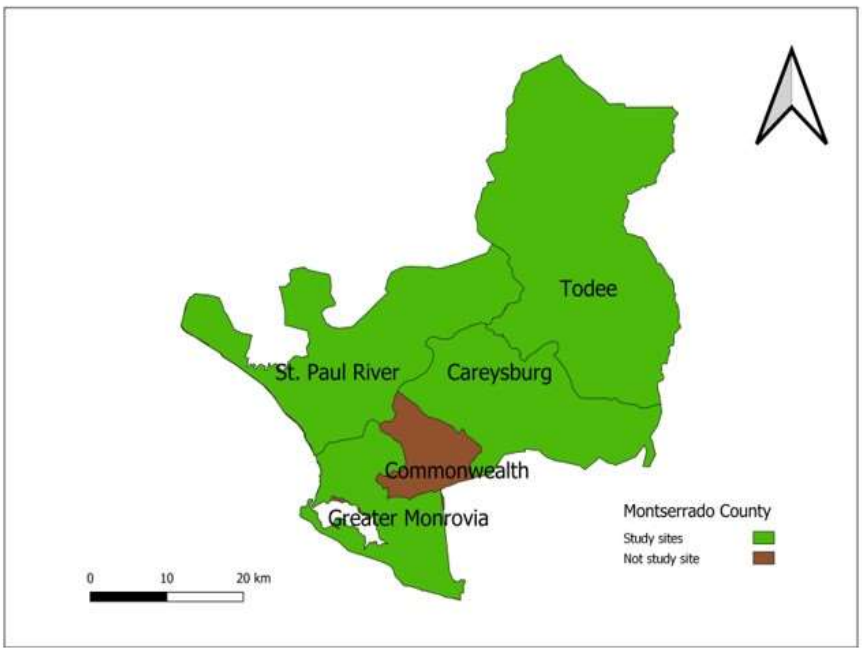

Figure 3.1: Study area
Source: Author's Construct

3.4.2 Research Design

A cross-sectional research design approach was used in the current study as it allowed for the collection of comparable data from family households who uses charcoal (Neuman, 2014). The design was chosen because it is affordable and permits significantly faster data collection without sacrificing data quality (Setia, 2016).

3.4.3 Sampling techniques and sample size

A combination of multi-stage sampling and purposive sampling was used. At first, Montserrado County was purposively selected. Secondly, the household heads from the four selected districts of Montserrado County (Table 3.1) were selected through purposive

sampling so as to get specific household who are charcoal users. The sample size was determined according to Boyd *et al.* (1981) where the intensity of 10% from every sampling frame were adopted.

Table 3.1: Sampling frame and sample size

County	District	Study Population (Sampling Frame)	Sample Size (n)
Montserrado	Greater Monrovia	1500	150
	Careysburg District	900	90
	Todee District	900	90
	St. Paul River District	560	56
	Total		**386**

3.4.4 Data Collection

Primary data were collected from respondents using a semi-structured questionnaire with both open and closed-ended questions. Further, ten Focused Group Discussion (FGDs) were conducted, the FGDs involved 15 participants comprising of elders, community leaders, student representatives, women, and youth leaders. A total of 150 participants were involved in the discussions. To ensure validity and reliability of the collected data, the data gathering tools were pre-tested in the study area, before the actual data collection to guarantee familiarity and clarity. Collected data were not included in the study's final analysis.

3.4.5 Data Analysis

Descriptive analysis was used as method of analysis together with Likert scale analysis to analyse the quantitative data. Quantified

data concerning usage of different energy sources in the study area identified by the respondents was analyzed**.** Also, several environmental impacts due to charcoal consumption was analyzed. Moreover, content analysis was used in analyzing qualitative data from the FGDs by using Nvivo Software.

3.5 Results and Discussions

3.5.1 Respondent's demographic and socio-economic characteristics

According to the study findings, the demographic and socio-economic characteristics of the respondents show that the majority of the respondents (57%) were males while 43% were females (Table 3.2). However, according to Farsi *et al.* (2007) female-headed households were statistically significant with household's charcoal consumption because females are the ones who are directly involve with the affairs of the kitchen. They periodically decide the weekly residential menu, know the quantity and quality of food to prepare and the quantity and quality of charcoal per the different types of food. Males headed homes will always opt for a cleaner energy that is environmentally friendly (Esty and Winston, 2009). Results showed that, respondents with the age between 36-60 years was active group constituting about 56.5% of charcoal actors followed by the age group between 0-34 years (34.7%) of charcoal users and the group of people above 60 years (8.8%). Respondents in this category were preoccupied with what have been done in the past and were unwillingness to adopt. One of the respondents said;

> "*I have been practicing this for the past 30 years and I feel comfortable in using the traditional cooking methods*".

Results further show that, about 42% of the respondents were married. During the consumption survey, it was noticed that such homes were organized and were knowledgeable of their daily allotment for charcoal consumption. The issue of adoptability to modern cooking technologies and fuel stacking strategy was highly

likely in these homes. According to the aforementioned results (Table 3.2) about 29% of the household's heads attained a college level education. These respondents were regarded as literate and the findings were consistent with Venance *et al*. (2016) and as such the probability of having a better understanding of sustainable charcoal consumption practices and adoptability was highly likely ceteris paribus. These results coincided with Emana *et al*. (2017) who hypothesized that adoptability for the educated household's heads to new and efficient technologies was easy.

Household size was also an important socio-economic variable. Results show that majority of the respondents had a household size with more than 6 people. This implies that it will require huge quantity of charcoal for food preparation because household size and charcoal consumption are directly correlated ceteris paribus This is in line with the study by Venance *et al*. (2016) who reported that the higher the household size the more energy is consumed. Furthermore, about 39.5% of the respondents were not employed (Table 3.2). This suggests that majority of the household in the study area have low or no income at all and hence adopting alternative source of energy apart from charcoal was a challenge for them.

Table 3.2: Respondents Demographic and Socio-economic Characteristics (n = 386)

Characteristic		Frequency	Percentage
Sex	Male	220	57.0
	Female	166	43.0
Age	0 – 35 years	134	34.7
	36 – 60 years	218	56.5
	Above 60 years	34	8.8
Marital status	Single	153	39.6
	Married	161	41.7
	Divorced	24	6.2
	Widow	43	11.1
	Cohabitation	5	1.3
Education Level	Illiterate	85	22.0
	Elementary	33	8.5
	Junior high	54	14.0
	College	113	29.3
	University	95	24.6
	Post graduate	6	1.6
Household size	Less than 3	57	14.8
	Between 3 – 6	144	37.3
	Above 6	185	47.9
Occupation	Not employed	152	39.4
	Employed	137	35.5
	Entrepreneur	97	25.1

3.5.2 Types of energy sources used for cooking in Montserrado County

Different types of cooking energies were identified in Montserrado County. Table 3.3 shows that, charcoal is the major consumed source of energy for cooking in all the four districts (Greater Monrovia, St. Paul River, Careysburg and Todee). Findings show

that, more than half (52%) of the respondents in the selected four districts use charcoal as the main cooking energy source. Whereby, Todee is the leading district that uses charcoal as their main source of energy with (60%) of the respondents adhering to charcoal, followed by Careysburg district with more than half of the respondents (56%) using charcoal and St. Paul River only (50%) responded to charcoal as their source of energy. While Monrovia District had the least percentage (45.3%) of using charcoal as the source of energy as compared to other districts. This implies that, charcoal consumption is highly practiced in almost all of the households and non-household residents. This is highly influenced by the low level of income among the members of the four districts as charcoal is mainly sold in small sacks which are very cheap and affordable by households as compare the other available energy sources. The results are in line with the study by Nyamoga *et al*. (2022) who reported that income level has a significant effect on the choice of the type of energy consumption among most of the households in sub Saharan countries. It is expected to be the predominant energy source for years because it is affordable, accessible, and convenient to use compared to other forms of energy (i.e. electricity and petroleum gas). The price, affordability, of charcoal as compare to other efficient energy sources may seem more economical from the consumer's point of view but the opportunity cost is enormous, environmentalist must be emphatic that the price of charcoal is a mirage. According to research conducted, the true cost of charcoal is not the amount paid daily to meet the cooking needs of households but rather benefits such as environmental values. How well does the price represent the lost to provision of the forest ecosystem services? If only we can find a balance between this economic activity and its related consequences, the economy will benefit. Furthermore, in Monrovia and St. Paul districts, electricity was the direct substitute to charcoal consumers (interchangeability) while in Careysburg and Todee districts charcoal was the direct substitute to firewood consumers ceteris paribus. This transition was facilitated by improved socio-

economic statuses of household's heads and the infrastructure development of the districts.

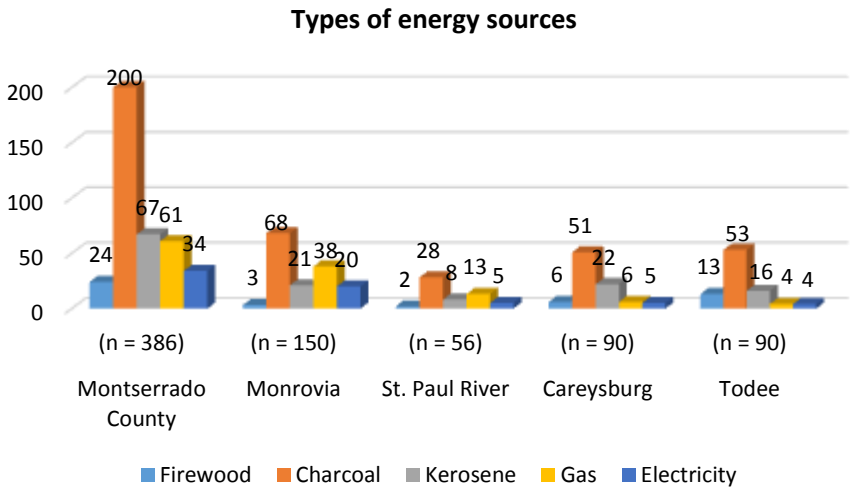

Figure 3.2: Types of energy sources in the study area

Moreover, the primary type of energy for cooking in Africa is fuelwood, and charcoal (Bensch *et al.,* 2021; Meng *et al.,* 2021). Although, these traditional cooking methods are often inefficient and contribute to deforestation and greenhouse gas emissions (Meng *et al*., 2021). According to the International Energy Agency (IEA), Africa's energy demand is expected to increase significantly in the coming years, with a growing demand for modern and clean cooking solutions. Efforts are being made to promote the use of clean cooking solutions, such as biogas, and electric stoves, which are more efficient and environmentally friendly. However, the transition to clean cooking solutions faces several challenges, including affordability, accessibility, and cultural preferences for traditional cooking methods.

Table 3.3: Types of energy for cooking in Montserrado County and its districts

Type of energy	Montserrado County	Monrovia	St. Paul River	Careysburg	Todee
	(n = 386)	(n = 150)	(n = 56)	(n = 90)	(n = 90)
Firewood	24 (6.2)	3 (2)	2(3.6)	6(7)	13(14)
Charcoal	200 (51.9)	68 (45.3)	28 (50)	51(56)	53(60)
Kerosene	67 (17.4)	21 (14)	8(14.2)	22(24)	16(18)
Gas	61 (15.8)	38 (25.3)	13(23.2)	6(7)	4(4)
Electricity	34 (8.8)	20 (13.3)	5 (9)	5(6)	4(4)

NB: Number in brackets represent percentages.

3.5.3 Impact of high rate of charcoal consumption

The most mentioned impact of high rate of charcoal consumption were identified by the majority of the respondents as illustrated in (Table 3.4) including deforestation as among the impact high rate averaging about 65.5% of the respondents equivalent to 235 people strongly agreed that deforestation was the major impact, 32.12% of the respondents equivalent to 124 agreed, 2.38% of the respondents equivalent to 27 people disagreed. This finding is similar to the study by Hofstede (2009) and Grainger (2013) who found out that in almost all countries where charcoal is produced expressed concern about the deforestation and forest degradation that occurs as a result of the production process. Moreover, Luoga *et al.* (2002) found that the removal of 4.64 t/ha for charcoal production on public lands in Tanzania's Morogoro region exceeded the mean annual increment of 3.15 t/ha, implying that harvesting was causing forest degradation through changes in the structure and composition of the vegetation.

Furthermore, results in Table 3.4 show that, the impact on soil occurs on an area with high rate of charcoal production. About 25.13% of the respondents strongly agreed, 22.54% agreed, 34.72% disagreed and 17.61% strongly disagreed. These findings are in line

with the study by Rodrigues and Junior (2019) who reported that the extreme heat generated during the carbonization process, as well as the digging to make a pit and/or soil to cover the wood pile, have a significant impact at the kiln site. Low impact occurs in the vicinity of the kiln where the wood is harvested. Soil impacts in the harvested area are likely to be comparable to those of any low impact forest clearing that does not result in land use change.

Greenhouse gases emissions particularly CO_2 was another impact. Table 3.4 shows that 13.47% of the respondents strongly agreed, 36% agreed, 29% disagreed and 22% strongly disagreed. The result implies that there is some level of awareness among the respondents about the impact of greenhouse gas emissions, particularly CO_2 emissions. A majority of the respondents either strongly agreed or agreed that greenhouse gas emissions, particularly CO_2 emissions, have an impact. However, a significant percentage of respondents (29%) disagreed or strongly disagreed, which suggests that there may be some lack of awareness or understanding among a subset of the respondents about the impact of greenhouse gas emissions on the environment. These findings support what has been reported by Withey *et al*. (2019) that emissions from charcoal production contribute more to global warming than emissions from charcoal combustion.

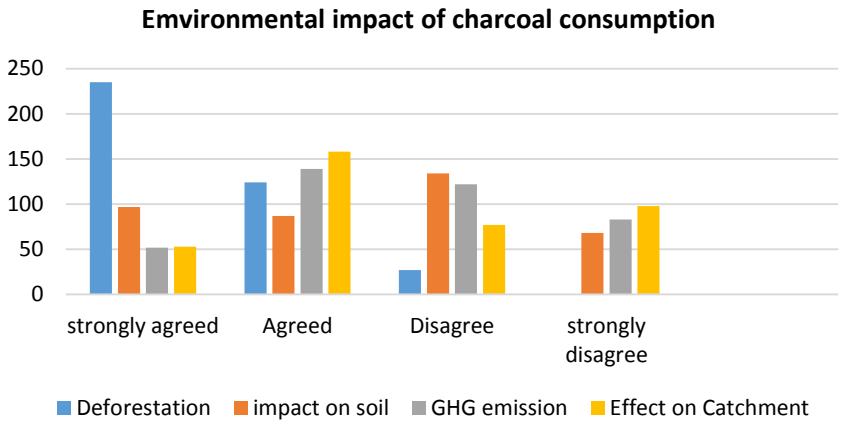

Figure 3.3: Likert Scale analysis 4 response scale on environmental impact of charcoal

Effects on catchment hydrology has also been identified as the environmental impact of high rate of charcoal production. Table 3.4 show that about 14% of the respondents strongly agreed, 41% agreed, 20% disagreed and 25.35% strongly disagreed. This means that on charcoal production around the water catchment areas there is an increase in discharge of river water. The results are similar to Rajaei *et al*. (2018) who reported that the immediate result of forest clearing is an increase in runoff from watersheds. The capacity to supply regular and efficient electrical power by Mt. Coffee Hydropower Plant in Harrisburg Township, Careysburg district Montserrado County is diminished especially during the dry season as a result of forest degradation caused by the unsustainable harvesting of the forest resource for economic reasons. The anthropogenic activities tend to negatively affects normal economic activities thus increasing the hardship to local communities.

Table 3.4: Environmental Impacts of High Charcoal Consumption

Impact	Strongly Agree		Agree		Dis agree		Strongly Disagree	
	Count	Percentage (%)	Count	Percentage (%)	Count	Percentage (%)	Count	Percentage (%)
Deforestation	235	65.5	124	32.12	27	2.38	0	0
Impacts on soil	97	25.13	87	22.54	134	34.72	68	17.61
Greenhouse gases emissions	52	13.47	139	36.01	112	29.02	83	21.5
Effects on catchment hydrology	53	13.73	158	40.93	77	19.96	98	25.38

3.6 Conclusions and Recommendations

3.6.1 Conclusions

Based on the study findings, it can be conclusively established that charcoal serves as the primary source of energy for cooking in all four districts under investigation. Notably, among these districts, Todee emerges as the prominent area where charcoal is extensively utilized as the main energy source. Conversely, Monrovia District exhibits the lowest consumption of charcoal when compared to the other districts, indicating that alternative energy sources may be more prevalent in this locality. The study has provided clear evidence that the high rate of charcoal consumption has considerable ramifications, as indicated by the majority of the respondents. Of particular concern is the impact of deforestation,

which was identified by a substantial majority of respondents as the primary consequence resulting from the high rate of charcoal consumption.

3.6.2 Recommendations

As means of mitigating the adverse effects of deforestation and forest degradation in Liberia, it is recommended that:

i. Promote Sustainable Energy Alternatives: To mitigate the environmental impact of high charcoal consumption, it is essential to encourage the adoption of sustainable energy alternatives for cooking and heating. Initiatives promoting the use of cleaner energy sources, such as biogas, solar cookers, or improved cook stoves, should be implemented and supported.
ii. Awareness and Education Campaigns: Launching targeted awareness and education campaigns can raise public awareness about the negative consequences of excessive charcoal consumption, particularly deforestation. Informing communities about the environmental, social, and health implications will encourage more responsible energy choices.
iii. Strengthen Forest Conservation Measures: Collaborate with local communities and authorities to implement and enforce effective forest conservation measures. Encouraging sustainable forest management practices can help reduce the indiscriminate cutting of trees for charcoal production.
iv. Policy Interventions: Develop and implement policies that promote sustainable energy practices and regulate the charcoal industry. This may include incentives for using alternative energy sources and measures to curb illegal and unsustainable charcoal production.
v. Community Engagement: Involve local communities in decision-making processes related to energy use and conservation. Engaging with residents can help identify their specific energy needs and find culturally appropriate and acceptable solutions.

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CHAPTER FOUR

4.0 GENERAL CONCLUSIONS AND RECOMMENDATIONS

4.1 Summary of Major Findings

The following is a condensed overview of the key results and discoveries from the study, presented in a chronological order as outlined in the two manuscripts. The summary aims to highlight the major findings in a clear and concise manner, while also providing a logical flow of information that mirrors the order of presentation in the original manuscripts.

4.1.1 To determine households' charcoal consumption influencing factors

This objective aimed to determine households' charcoal consumption influencing factors in the study area. Whereas, the findings showed that education level, number of meals, price of charcoal and household size were statistically significant associated with household's charcoal consumption in Montserrado County**.** Moreover, age of household was positively associated with charcoal consumption despite of not being significant Education level plays a significant role in the consumption of charcoal.

4.1.2 To determine challenges associated with charcoal consumption in the study area

In objective two, the study aimed to determine the challenges associated with charcoal consumption in the study area. The results of the study indicate that there are several challenges that affect the consumption of charcoal in the study area. Among these challenges, the high price of charcoal is a major concern that has significant implications for households and their ability to afford this essential energy source. This is further exacerbated by the low quality of charcoal available in the local market, which can impact the effectiveness of the fuel for cooking and other household activities. In addition to these factors, the dirtiness of homes resulting from the

use of charcoal is another key challenge that affects the overall quality of life for residents in the area.

4.1.3 To determine the main source of energy in the study area

Objective three of the current study aimed to look at the main source of energy in the study area. The study findings revealed that that charcoal is the mostly used energy source for cooking, where Todee District experience a greater number of respondents (60%) that opted for charcoal as the main source of energy while Monrovia being having the least number of respondents (45.3%) who opted for charcoal as their main source of energy.

4.1.4 Determine the environmental impact of charcoal consumption

Objective four of the study aimed to determine the environmental impacts of charcoal consumption. The study findings showed that the charcoal consumption has effects to the environment, deforestation being the most agreed mentioned environmental impact by the respondents.

4.2 Conclusions

Based on the study findings and discussions, several factors were identified as statistically significant in association with household charcoal consumption in Montserrado County, Liberia. These factors include education level, number of meals, price of charcoal, and household size, all showing notable correlations with charcoal consumption. Households with higher education, income, and social status tend to adopt energy stacking strategies, utilizing multiple energy sources, including charcoal. Conversely, lower socio-economic status households rely more heavily on charcoal as their primary energy source. Household size also plays a significant role, with larger households consuming more charcoal, likely due to increased cooking and heating demands. The study further revealed three main challenges affecting charcoal consumption: high prices, low quality, and resulting household dirtiness. Additionally, the

impact of urbanization, population growth, and non-economic factors may further contribute to increased charcoal usage, posing risks to deforestation and forest degradation in Liberia. Overall, charcoal emerged as the predominant energy source for cooking in all investigated districts, with Todee district showing the highest consumption and Monrovia District displaying the lowest, indicating the possible prevalence of alternative energy sources in the latter.

4.3 Recommendations

Based on the findings of the study, several recommendations can be made to promote more sustainable and efficient use of charcoal in Montserrado County.

i. Promote Sustainable Energy Practices: Implement programs to encourage the use of sustainable energy sources for cooking and heating, such as biogas, solar cookers, and improved cook stoves. These alternatives can reduce the dependence on charcoal and mitigate the impact on deforestation.

ii. Raise Awareness and Education: Conduct awareness campaigns to inform communities about the environmental consequences of excessive charcoal consumption, particularly deforestation. Educating households about the benefits of sustainable energy options can foster responsible energy choices.

iii. Regulate Charcoal Industry: Enforce policies and regulations to ensure sustainable forest management and responsible charcoal production practices. This can help curb deforestation and ensure the quality of charcoal available in the market.

iv. Support Research and Development: Invest in research and development to improve the affordability and efficiency of alternative energy technologies. Making clean energy

solutions more accessible can drive adoption and reduce reliance on charcoal.

v. Engage Local Communities: Involve local communities in decision-making processes regarding energy use and conservation efforts. Engaged communities are more likely to adopt sustainable practices that align with their specific needs and cultural values.

vi. Introduce Incentives: Offer incentives or subsidies to encourage households to switch to cleaner energy sources. Lowering the financial barrier can make sustainable options more appealing.

vii. Monitoring and Evaluation: Establish a robust monitoring and evaluation system to track progress in reducing charcoal consumption and its impact on deforestation. Regular assessments will inform future strategies and ensure the effectiveness of interventions.

viii. Collaboration and Partnerships: Foster collaboration among stakeholders, including government agencies, NGOs, and private sectors, to create comprehensive and effective strategies for sustainable energy adoption and forest conservation.

APPENDICES

Appendix 1: Household Questionnaires for charcoal consumption in Montserrado County.

Section A: General Information

1. Name of Enumerator----------
2. Date interview conducted (mm/d/yy) ----------
3. Village----------
4. Town----------
5. District----------

Section B: Socio-Economic Variables of The Household

6. Age of the respondent in years:
7. Gender of household head: 1=male [ ], 2= female [ ]
8. Level of Education of the household: 1=Illiterate [ ], 2=Elementary [ ], 3= Junior high [ ], 4=College [ ], 5=University [ ], 6=others [ ], (specify)----------
9. Marital status of the household head: 1=Single [ ], 2= Married [ ],3=Divorced [ ]
   4=Widow or Widower [ ], 5=Others (please specify) ----------
10. How many adults in the household: 1=none [ ], 2=less than 3 [ ], 3=3-5 [ ], 4=6 above [ ]
11. Size of household:
12. What are the ages of each household member? Please specify
13. Household head occupation: 1= not employed [ ] 2=employed [ ]
14. If not employed, please specify source of income…….
15. Household head monthly/daily income (LRD): ----------
16. How many household members are employed?

Section C: Household Consumption of Charcoal

17. Does your household consume charcoal? 1=yes [ ], 2=No [ ]
18. If yes, what do you use charcoal for? 1=Cooking food [ ], 2=Boiling water [ ],
    3=For ironing [ ], 4=Others please specify----------
19. What other type of energy source do you use? 1=Kerosene [ ], 2=Electricity [ ], 3=firewood [ ], 4=Gas [ ], 5=Others please specify----------
20. State the type of cooking stove: 1=traditional stove (cook pot) [ ], 2=energy serving [ ], 3=gas stove [ ], 4=Electricity [ ], 5=Others specify----------
21. What can you say as the main reason for consuming charcoal? 1=affordable [ ], 2=available [ ], 3=higher energy content [ ], 4=others specify----------
    (select only one please)
22. What are things you look for when buying charcoal? 1=quality [ ], 2=cost [ ], 3=others please specify----------
23. What price you pay for a unit of charcoal?

Unit	Cost (LSD)
Plastic bag (small) in kg	
Plastic bag (medium) in kg	
Plastic bag (large) in kg	
Rice bag in kg	
Others (specify)	

24. How much of charcoal do you consume in kg daily: please specify----------
25. How many meals you do prepare per day? ----------
26. What do you say about the price of charcoal in kg? 1= reasonable [ ], 2=too high [ ], 3=lower [ ], 4=other specify

27. What are some of the problems in consuming charcoal? 1=high price [ ], 2=long distance [ ],3= low quality [ ],4= limited supplies [ ], 5=others specify----------
28. What can be done to minimize the problem you have mentioned in question 25? Explain----------
29. Do you experience changes in the supply of charcoal? Yes [ ], No [ ]
    1=Increase, why? ----------
    2=Decrease, why? ----------
30. When do you experience changes in the price of charcoal? Please specify ----------
31. What price do you pay for the alternative energy sources?

Unit	Cost (LSD)
Kerosene	
Gas	
Electricity	
Firewood	
Others please specify	

3.2 What are the challenges do you face which are associated with charcoal consumption?

33. What are the environmental impacts caused by charcoal production?

34. Does charcoal production increase the risk of deforestation and forest degradation?
    1=Strongly agree 2=Agree 3=Disagree 4=Strongly disagree

Appendix 2: Non-Household Questionnaires for charcoal consumption in the in Montserrado County.

Section A: General Information

1. Name of Enumerator----------
2. Date interview conducted (mm/d/yy) ----------
3. Village----------
4. Town----------
5. District----------
6. Business type ----------

Section A: Non-Household Consumption of Charcoal

7. Do you use charcoal? 1=Yes [ ] , 2= No [ ]

8. If yes, what do you use charcoal for? 1=Cooking food [ ], 2=Boiling water [ ],
   3=Others please specify----------

9. What type of energy source do you use? 1=Kerosene [ ], 2=Electricity [ ], 3=firewood [ ], 4=Gas [ ], 5=Others please specify----------
10. Daily consumption of charcoal in kg? ----------
11. State the type of cooking stove: 1=traditional stove (cook pot) [ ], 2=energy serving [ ], 3=gas stove [ ], 4=Electricity [ ], 5=Others specify----------
12. What can you say as the main reason for consuming charcoal? 1=affordable [ ], 2=available [ ], 3=higher energy content [ ], 4=others specify----------
    (select only one please)

13. What are things you look for when buying charcoal? 1=quality [ ], 2=cost [ ], 3=others please specify----------
    ----
14. What price you pay for a unit of charcoal in kg?

Unit	Cost (LSD)
Plastic bag in kg	
Rice bag in kg	
Others (specify)	

15. What can be done about the situation in question? Explain----
    ----
16. Do you experience changes in the supply of charcoal? Yes [ ], No [ ]
    1=Increase, why? ----------

    2=Decrease, why? ----------
    ----
17. When do you experience changes in the price of charcoal? Please specify ---------
    ----
18. What price do you pay for the alternative energy sources?

Unit	Cost (LSD)
Kerosene	
Gas	
Electricity	
Firewood	
Others please specify	

19. What is the size of your customers? ----------
    ----
20. How many meals you do prepare per day?
21. What are the challenges do you face which are associated with charcoal consumption?
22. What are the environmental impacts caused by charcoal production