SOCIAL AND ENVIRONMENTAL IMPACTS OF CHARCOAL PRODUCTION IN LIBERIA

By
Brieland Jones

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Faculty Advisors:
Professor Dorceta Taylor, Chair
Professor Ming Xu

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Abstract

In Liberia, where over 95% of the urban population uses charcoal, very little is known about the impacts of the life-cycle of the fuel on the livelihoods of the producers, who endure significant health, safety, and environmental risks for marginal gain in a highly lucrative industry. Population increases and deviations from the energy ladder model suggest that charcoal demand for heating and cooking in Sub-Saharan Africa will continue to increase through the year 2030 and beyond. Even with evidence of such high dependence across the continent, policies often fail to adequately address the social and environmental concerns associated with its life cycle. With the assistance of six trained Liberian university students, a social and environmental impact assessment was conducted in four Liberian counties and supplemented with interviews of primary decision makers from governmental and non-profit agencies. Over one hundred sixty surveys were conducted in four different counties and six agencies were consulted during this study. Extensive use of child labor, severe physical injury, gender disparities in income and education, and environmentally unsustainable practices are among the findings that highlight the social and environmental impacts of production. Current policy efforts fail to adequately address these issues that are far-removed from the eye of the public, but are essential to address. Recommendations from these findings follow that high efficiency technologies should be piloted in communities that have the capacity to maintain and test their effects on environmental degradation. In addition, education programs surrounding effective land management strategies should be a high priority for both government and aid organizations, as the results of this study suggest.

The use of United Nations charcoal consumption levels as a proxy for production is also examined, as findings suggest disparities with the figures. This research suggests a need to redirect policy efforts towards the social and environmental sustainability of an important contributor to GDP. These efforts would be particularly important in light of the new Sustainable Development Goals, Liberia's environmental objectives and her foreseeable dependence on charcoal.

Social and Environmental Implications of Charcoal Production in Liberia

1. Introduction

Large-scale charcoal production, primarily in sub Saharan Africa, has been a growing concern due to its threat of deforestation, land degradation and climate change impacts. It is cited as the most environmentally devastating phase of this traditional energy supply chain, and despite increasing per capita income, higher electrification rates, and significant renewable energy potential, charcoal still remains the dominant source of cooking and heating energy for eighty percent of households in Sub Saharan Africa (SSA) (Arnold et al, 2006; Zulu and Richardson, 2013). As a traditional fuel that has been used for hundreds of years, it serves as a lifeline for the rapidly increasing populations in the urban centers of the region, in addition to potentially significant portions of the rural population. Due to its low cost compared to other fuels like kerosene and liquefied petroleum gas (LPG) [1], as well as other factors that will be discussed in the coming sections, the demand for charcoal is expected to continue rising dramatically in the coming decades, despite best efforts by modern energy advocates. Charcoal use in SSA is predicted to double by 2030, with over 700 million Africans relying on it as a durable, preferred, and cheap source of energy [39]. With a forecasted increase in consumption, there is a great need to identify real versus perceived energy futures with respect to charcoal. Research has shown that large-scale transitions to modern energy sources will only occur once a certain income threshold is met, while other studies have indicated that even with large increases in earned income, the large majority of many SSA countries continue to utilize charcoal. If a continued reliance on

charcoal is suggested, there is an even greater need to evaluate and address the environmental and social issues associated with this highly influential, and largely informal, industry.

2. Common Misconceptions of Traditional Energy Dynamics

A review of the literature surrounding charcoal supply chains in Sub-Saharan Africa paints a clear picture that the demand for this energy source will not remain stagnant, but will increase dramatically through the year 2030 [2]. Even in countries where electrification rates are at their highest, as in Nigeria or Ghana, 60-70% of the population still use charcoal for cooking and heating [3], a finding identified in numerous studies that deviates from the traditional energy ladder model. Electricity rarely replaces charcoal as a fuel, though increases in income lead to higher usage of more refined fuels, like kerosene and LPG, to replace biomass; this helps to illustrate the negative, and often misleading, correlation found between charcoal and electrification. In some of the least developed countries, like Liberia, where less than one percent of the population is connected to grid electricity, 95% rely on traditional biomass fuels in the form of wood and charcoal [4]. In the growing urban center, Monrovia, charcoal is the primary fuel used for heating and cooking, as poor infrastructure, high cost, and low-income levels limit market growth for refined cooking fuels.

Case studies of charcoal supply chains in other Sub-saharan countries have recognized the significant contributions of these industries to employ large numbers of both rural and urban residents who may otherwise have few employment opportunities

[5, 6]. While it is certainly a lucrative industry for some, certain players who are key to its continued presence often earn marginal wages, and encounter additional challenges, compared to counterparts who possess more economic, political and social capital. Identifying this trend as common through industries across Africa, this research will highlight the social and environmental impacts that are sustained by, and largely affect, the rural charcoal producers of Liberia, one of the least developed countries in the world. Surveys and interviews of key stakeholders will inform future attempts by government and non-profit agencies to mitigate these impacts.

Current initiatives to mitigate the adverse effects of charcoal industries in SSA by promoting electrification and more refined fuels have their foundation in the assumptions of the traditional energy ladder model. Evidence from many Asian [7] and South American countries have supported this model, recognizing that as households in urban areas of developing countries increase their annual income, the fuels utilized by the household will divert from biomass (dung, wood and charcoal) to fuels higher on the energy "ladder" [8]. According to this model, each rung corresponds to a particular energy source and households will resort to using only a single fuel at any one time. Recently, however, research has gained a deeper insight into these trends, particularly in SSA, and in testing the validity of these models, scientists are now arguing against the assumption that has guided so many government and aid organizations in their efforts for the dissemination of modern fuels.

Hosier (1987) first identified gaps in the energy ladder hypothesis when he found that not only do economics play a role in a households' choice to switch fuels, other factors including convenience, culture and tradition significantly influence how strictly households adhere to this trend [9]. This would have implications for future household energy research. Masera et al (2000) added to this body of work by finding evidence to support a "multi-fuel ladder", where households may utilize several fuels at once depending on a number of factors other than cost, including resource scarcity, cultural preferences and health impacts [4]. Country specific case studies began to appear in large number; In South Africa, the greatest electrified country on the continent, 90% of households in one study continued to utilize woodfuels (i.e. charcoal) even after ten years since gaining access to electricity [10]. Similar results were found in Ghana, Tanzania, Zimbabwe, Botswana and many others across the continent [11, 12]. These results suggest that not only do economics play less of a role than previously thought, there are additional factors that limit the uptake of more modern fuels, especially in least developed countries where solid fuels play a major role in energy dynamics.

3. Review of Environmental and Social implications of charcoal production

Foreseeable dependence on charcoal, despite drastic attempts to establish reliable electricity and fuel infrastructure, should raise a number of concerns regarding the sustainability of this essential industry in regards not only to its economic value, but the proper management of forest resources as well as livelihoods of those most responsible for producing this fuel.

3.1 *Employment*

Charcoal industries in some of the top producing countries, namely Tanzania and Uganda, employ tens to hundreds of thousands of citizens, many of whom receive up to 70% of their annual income from this market [4, 13]. Even in countries where more progressive policies exist with regards to the charcoal industry, producers are still often disadvantaged with respect to income generation and labor support [14]. Ribot (1993,1998) conducted a commodity chain analysis on Senegal's charcoal industry, finding that despite substantial regulations, a majority of benefits, both economic and sociopolitical, accrue to merchants and wholesalers involved in the trade compared to producers [15, 16]. Rural producers, who often make up the largest portion of the employed force, generally lack the capital to increase their own earnings, or even maintain just above subsistence income [17]. This is particularly concerning, given that Senegal's charcoal trade is one of the most formalized industries in the region, with over 85 cooperatives and significant government resources allocated for regulation. In most countries in SSA, however, charcoal is left out of the formal economy [18]. While there are numerous efforts to mitigate destruction of forest resources through technological innovation, there exists a large gap in research on the true health impacts sustained by these highly vulnerable populations.

3.2 *Public Health and Safety*

Lack of regulation and the use of conventional methods for production permeate the industry. Throughout SSA, the use of traditional earth-mound kilns is commonplace (see figure 1). These "ovens" vary significantly in size and are made completely of

organic materials. The amount of time required to just prepare the oven for production can be up to two weeks; producers first dig a hole in the ground, saving the soil for later use. Extraction of wood from the surrounding forests is typically the most labor-intensive phase in the entire production process. Producers have been known to travel greater than two miles (30 minute walk, from personal communication with a producer) to cut, collect and haul wood to the production site. Once they have returned to the site, producers configure the wood in a specific way so as to ensure that the wood is evenly 'cooked'; this process has been refined over generations. Once the wood is configured in this way, it is topped with grasses and brush; soil is added last to allow the wood to undergo combustion in the absence of oxygen, or pyrolysis.

This process has direct linkages to negative social health outcomes. Lack of modern tools most often results in the use of human labor throughout the entire production process. In addition to the hazardous work conditions associated with the extraction of wood, building the kiln and packing the charcoal, doing so often constitutes a significant individual investment of time. Not including time spent during extraction and packaging, producers will often spend over two weeks vigilantly monitoring the kiln to ensure that the process of carbonization in the absence of oxygen, or pyrolysis, is properly conducted [16]. Extreme temperatures combined with volatile chemical compounds, including carbon monoxide and sulfur dioxide, create an extremely dangerous environment for any human, especially those without adequate safety protection. Producers are often known to spend the night within a few feet of a burning kiln to ensure that any gaps are quickly sealed. The United Nations Food and

Agricultural Organization (FAO) released a working document highlighting the dangers associated with industrial charcoal production in the developing world and the precautionary measures that should be taken by producers [19]. The sheer volume of guidelines published almost thirty years ago suggests the severity and potential danger of these working conditions. However, lack of proper knowledge, institutional capacity and financial resources prevents these safety measures from being taken in most areas that produce charcoal for residential use, contributing to the prevalence of moderate to severe injury and illness.

Health-related impacts associated with woodfuels have traditionally focused on effects from their consumption. Indoor air pollution (IAP) is the primary concern given the high concentrations of smoke and particulate matter released during woodfuel combustion. Smith et al (2002) documented trends in respiratory illness among disproportionate numbers of women and children as a result of IAP from woodfuel combustion throughout the developing world [20]. However, little is known about the health impacts endured by charcoal producers during extraction and production phases [21. For example, it is known that pyrolysis, the process utilized for the production of charcoal, releases significant amounts of gaseous by-products, including carbon monoxide, sulfur dioxide and others [22, 23] known to be deadly to humans in moderate concentrations through the use of dose-response studies [24]. Rural producers are known to work within close proximity to high temperature kilns that off-gas these highly toxic compounds, generating potential high risk for poisoning. In addition, use of primitive tools can potentially lead to moderate or severe injuries, which can prove fatal in rural

areas that lack access to adequate medical care. Academic literature and government reports refer to the working conditions of charcoal producers as unsafe [25, 26]; government officials and research papers alike mention these 'hazards' in passing. Additional indicators of social threats include widespread child labor, gender differences in education and production outcomes, extreme price variability often at the hands of merchants [16], and the lack of potential for poverty alleviation in current methods of production [27]. The lack of regulation in the charcoal industry creates the highest risk of exploitation and safety hazards [28], yet no studies have investigated in-depth the health and social risks associated with the production of this highly demanded fuel.

3.3 *Environmental Impacts*

Low process efficiencies, combined with unregulated actions of many producers, cause large volumes of wood to be harvested from nearby forests [29, 30, 31]. These areas are often sections of communally-owned land, but can also make up large portions of federally protected forests. As a result of weak, unenforced or disjointed forest policies, many countries in SSA are experiencing increased rates of deforestation from charcoal production in protected areas. Unlike the use of fuelwood for cooking and heating, which is often supplied from ground harvesting and has no major impact on environmental degradation [30, 38], current methods of charcoal production require vast amounts of resources for relatively little return.

This issue becomes compounded when considering the low replanting rates and poor land management practices that have been identified across the region. Lack of

resources; educational, financial or otherwise, has been cited as the major reason for such trends. Land tenure in many parts of Sub Saharan Africa is also particularly volatile. Customary land tenure often conflicts with that of a statutory nature, preventing adequate land management practices and ultimately contributing to the widespread degradation that exists today [32]. This can be especially devastating in post-conflict nations [33], where large in and out-fluxes of refugees and destruction or lack of ownership documentation further exacerbates already existing challenges. In some cases, whole communities live on land owned by a third party, ultimately leading to greater confusion among all stakeholders and creating an essential need for land tenure reform.

Photo 1. Large earth mound kiln

Photo 1 shows a typical kiln size in Firestone Rubber plantation; here, wood resources are readily available and producers often work together.

Photo 2. Small earth mound kiln

Photo 2 shows a kiln size that is more common in rural areas (this picture was taken in Bong country), where producers often do not have the social or financial capital to produce large quantities of charcoal.

The link between environmental degradation and rural livelihood is quite clear in the utilization of forest resources. Lack of emphasis on rural livelihoods in national energy and resource policies lead to widespread slash and burn practices, erosion and increasing levels of deforestation due to desperate attempts by rural communities to generate income through the exploitation of forest resources. These practices can have additional implications for soil composition, water resource availability, access and site productivity [34], all of which are directly linked with rural livelihoods. Larson et al (2007) provides comprehensive evidence that forestry laws and policies across the developing world are skewed in favor of the elite [35]. Efforts to mitigate these environmental impacts and promote social development are often concentrated in urban areas, where population densities and government resources make it relatively easy to enact these changes. Still, charcoal production in rural areas has been increasingly linked

to large-scale deforestation due to clear felling and agricultural land use following production. Previous work has been conducted in this area at the national level, highlighting the very real threat that current methods of production have on society and the environment. Mwampamba (2007) modeled current and future deforestation rates based on survey data gathered on extraction and replenishing habits of rural charcoal producers in Tanzania, the largest charcoal producer in SSA, finding that by 2028, public forest resources will be depleted if policy interventions are not put in place [39]. Similar methods from Namaalwa (2009) identified a collapse in the Ugandan charcoal supply chain by 2019 [40]. While these countries are some of the largest charcoal producers in the region, these findings hold grave implications for other nations whose population relies heavily on wood-based fuels. In addition, further research at local or sub-national levels can provide decision makers with information regarding geographical trends in energy dynamics. Attempts to criminalize this behavior by imposing fines, high taxes and restrictions on production levels are common and not only creates additional livelihood pressure on rural communities, but leads to a national charcoal dichotomy. Production of charcoal is seen as highly problematic and in need of swift action, while its purchase and consumption is so economically, culturally and pragmatically engrained into the general lifestyle that realistic transitions away from this fuel are, indeed, quite unrealistic.

4. Current Policy Efforts

Given the benefits that electricity, and modern fuels in general, can offer in regards to sustainable development, it is not surprising that the majority of national energy policies in SSA almost exclusively promote the provision of electricity through either centralized or distributed generation [36]. The stringent upholding of the energy ladder hypothesis is an expected outcome of many in the region [37]. However, as discussed previously, many fail to understand the true dynamics of household energy and their implications for those who provide it. Decision makers are focused too heavily on theoretical notions of energy without acknowledging demonstrated local or regional trends that counter previous hypotheses, such as that of the traditional perspective of the "energy ladder". In many cases, the desire for modern energy provision leads to misguided policies that can ultimately endanger the livelihoods of large portions of the population [38]; all of those involved in the charcoal supply chain, from producer to end-user. Current methods of charcoal production and their associated impacts; deforestation, land degradation and their impacts on climate change; as well as negative health outcomes of using traditional fuels have gained most of the attention of policy-makers and have ultimately painted this highly influential energy sector in a negative light in the context of realistic energy futures.

The majority of national governments in SSA show evidence of this through preventing a thorough discussion of charcoal in national energy and environmental policies, focusing instead on the current trends of negative social and environmental impact in the context of its production. A reactive approach has taken precedent in the

form of forest management policies that often go unenforced [5], taxation of producers and transporters that often goes undocumented due to high levels of corruption [39], and the development of initiatives (i.e. improved charcoal cookstoves) that directly or indirectly benefit urban actors, thus increasing the inequity gap between rural and urban communities [15]. Knopfle (2004) identified both men and women participating in production, but did not perform further analysis regarding inequities among these populations [40]. The perpetuation of documented gender inequities (i.e. income, education and employment) is alarming in light of the UN sanctioned Sustainable Development Goals (MDGs) and speaks to the need for further investigation [15, 16, 17, 31, 41].

In many cases, the infancy of energy and forestry policies requires charcoal, or woodfuels in general, to be acknowledged as a primary energy provider. Ambitious targets of electrification, emissions reductions and use of renewable energy blanket the bulk of energy policies in countries that do not yet have the institutional, financial or community capacity to realistically achieve these goals [42]; the majority of these countries have not yet conducted a comprehensive emissions inventory, limiting their credibility and effectiveness in developing emission reduction strategies. Similarly, few countries recognize charcoal production as a major greenhouse gas emitter, while large-scale production has been cited as a significant contributor. Certainly, electrification and the development of modern energy sources should be a part of the way forward. However, a balanced energy transition is essential in alleviating environmental and social pressures that remain primary concerns for many governments across the region.

These growing concerns over the aforementioned environmental and social challenges related to wood fuel (i.e. charcoal) markets have been associated with an increase in literature surrounding these trends. The scholarly journal, *Energy Policy,* released a special 2013 edition focusing exclusively on the issue of charcoal. These papers span multiple regions and disciplines on the African continent and have often led to significant improvements in a number of charcoal supply chains. However, many challenges still remain. Unemployment and low rural development are commonplace. West Africa is one region in particular that has struggled with these issues highly as a result of civil conflict. Over 90% of the population in the region uses traditional fuels for cooking and heating; a significant portion are employed in this sector as well, though due to the informal nature, estimates are difficult, if not impossible to obtain. This has grave implications for the rural communities who produce the essential urban fuel, yet are repeatedly marginalized through misguided policies and initiatives. While a number of case studies have been conducted in the region [5, 6, 16, 17, 18], more are needed to gain a deeper understanding of trends that have severe implications for the quality of life of many of these populations. Schure (2013) conducted the most recent review of charcoal economies in West and Central Africa, generally concluding that West Africa is better capable of addressing the social and environmental challenges associated with charcoal through formalization of the industry [14]. On the contrary, Liberia, just a decade out of a devastating civil war, is home to a charcoal industry that is ruled entirely by informalities and lack of regulation. It is evident that countries within the same region can differ dramatically due to natural, political and social capital, with Senegal being a

primary example. In addition, these countries are often in the scholarly spotlight. Despite the increasing threat of degradation of the last remaining rain forest and lack of social development in most of the country, Liberia continues to remain absent from scholarly literature regarding the nexus of energy, poverty and the environment. This paper will present a case study of Liberia, investigating the challenges that rural charcoal producers face in the context of these key factors, as well as a synopsis of current perspectives of government, NGOs and private stakeholders on this highly contentious issue.

5. Liberia: A Case Study

Liberia is situated on the coast of West Africa, bordered by Sierra Leone to the West, Guinea to the North and Cote D'Ivoire to the southeast. With An estimated 99.5% of the population relying on traditional fuels [30, 33] and approximately 40% of the remaining Upper Guinean Rainforest within its borders [43], there is growing concern of the impact of deforestation due to large-scale charcoal production. Non-government organizations focused on natural resource management, such as Flora and Fauna International (FFI) and Conservation International (CI), have recently brought attention to this issue through research and community-based programs. In 2007, CI released a study that utilized geographic information systems and remote satellite imagery to investigate the loss of forest cover as a result of large-scale forest clearing [44]. The authors highlighted the large areas of forest that were easily accessible due to proximity to major roads; these areas are primary targets of the growing number of rural charcoal producers primarily due to ease of access. Commercial agriculture production was listed

as the primary reason for the reduction in forest cover; while these systems are intimately linked, charcoal production was not explicitly mentioned in this particular assessment. Little information is publicly available on more recent trends in deforestation rates, especially as they pertain to charcoal. Lack of regulation largely prevents a targeted technical assessment of location-specific charcoal production. Reports sanctioned by various government agencies heavily promote the use of renewable energy technologies (RETs) despite the clear need for a more balanced focus. A white paper on the development of the electricity sector in Liberia, where the average annual income is $USD454 [45], stated that the transition away from charcoal would not be significant until this figure reaches $1,500 USD [46]. Additional findings suggest that this transition to cleaner cooking fuels and facilities will not occur until annual income is $18,250USD [47]. In light of these findings, a significant dependence on charcoal and lack of policy discussions surrounding the industry (and focused exclusively on electrification and modern fuels) remains [48]. Most of these documents highlight the negative effects of the use of biomass fuels, such as climate change impacts and public health concerns, and fail to propose effective management strategies that would benefit both urban and rural communities. Instead, the majority of charcoal-related programs are focused on the provision of improved charcoal stoves to populations in the urban centers. Identifying energy efficiency as a primary driver for environmental sustainability and reduction in current quantities of charcoal supplied to Monrovia, Conservation International and the Environmental Protection Agency are seeking funds from the Global Environment Facility (GEF) and other financial mechanisms for the dissemination of these high-efficiency stoves to urban communities that utilize charcoal for cooking.

According to consumption levels and current market price reported by the Liberian Environmental Protection Agency (LEPA) through research conducted by the National Charcoal Union, charcoal accounts for over $16M annually in gross domestic product (GDP), while grid connected electricity, that which is provided by an electric utility and metered, accounts for $8M. Despite high population dependence, in regards to both consumption and employment, and significant contributions to GDP, the charcoal industry remains a very informal one, with limited knowledge of social and environmental implications that has, to date, been focused on alleviating threats of deforestation as well as price increases on the demand side. The LEPA and similar organizations focus heavily on the environmental impacts of charcoal production in forested areas, as Liberia sits squarely on 40% of the remaining Upper Guinean Rainforest, a global biodiversity hotspot. Numerous studies have identified current production methods as a contributor to deforestation in the region [49,50], yet little data has been collected to initiate research on this issue in Liberia, and currently no data or reports exist on the social impacts of the current methods of charcoal production, which are generally cited as creating significant health and safety concerns [51]. Instead, the Liberian government has focused primarily on urban welfare programs that emphasize improved cook stoves to decrease both indoor air pollution and consumption of forest resources for charcoal production. The majority of government and aid resources are also funneling heavily into renewable energy projects, despite regional findings that un-link electrification with woodfuel consumption. In addition, current consumption data utilized by organizations working to mitigate the impacts of this industry, including the Liberian Environmental Protection Agency and the United Nations

Development/Environment Programmes, follow a similar path and are often used as a proxy for rural charcoal production data; this assumption often overlooks key trends in rural areas, such as rural consumption of charcoal and energy dynamics, and can deviate significantly from other source estimates.

The organization responsible for the most substantial data collection regarding the charcoal market is that which has the fewest financial resources when compared to government agencies and aid organizations working in the country. The National Charcoal Union of Liberia (NACUL) was established in 2004. It is the only organization of its kind focused exclusively on capacity building within the charcoal industry and currently retains membership of approximately six hundred, most of whom are located within the urban and peri-urban areas outside of Monrovia. Little to no outreach has been conducted outside of these areas due to lack of financial resources and human capacity. In addition to holding stakeholder workshops, NACUL has conducted the research for estimates used in many government, NGO and private reports. Based on comprehensive quantitative data gathered from consumer surveys and border checkpoints (through which large quantities of charcoal are transported), NACUL estimated in 2005 that 36,500 tons of charcoal was supplied to Monrovia. This figure has been used as a baseline for the past ten years; however, population growth, traditional assumptions (i.e. only urban residents use charcoal for cooking) and lack of regulation could lead to much larger realistic estimates. NACUL continues data collection at major checkpoints despite small financial resources and limited human capacity. Large charcoal markets have evolved across Liberia, where elaborate transportation networks provide increasing amounts of

wood resources from the interior to the coastal urban center. Prior to revised regulatory policy, significant quantities of charcoal were being shipped across the border into Sierra Leone. This has dramatic implications for forest conservation and environmental protection as well as social development in rural areas, especially as multilateral aid organizations are focusing heavily on modern energy provision. No scholarly research has been undertaken to address these issues and better understand the capacity for successful energy transitions in this post-war nation. To better understand the conceived energy pathways in Liberia and to answer the proposed research questions; 1) what are the differences in perceived and realistic energy futures in Liberia, 2) what are the social and environmental implications of current production methods?

The benefits of charcoal for urban consumers are clear; its high energy per unit weight and reduced particulate matter (PM) deem it extremely valuable for the large majority who cannot afford more refined fuels. Charcoal's benefit to producers is, perhaps, more significant. As discussed, the industry contributes a significant portion to the country's GDP. Across the region, charcoal and woodfuel industries employ significant percentages of the population, providing much-needed income to those who have few alternatives. In many countries across SSA, current policies to mitigate environmental impacts associated with charcoal are aimed at the end user. This study will shed light on the status of current initiatives intended to mitigate adverse impacts associated with the charcoal industry, particularly within rural communities that often sustain disproportionate levels of impacts. Social and environmental indicators will be assessed and policy recommendations provided based on findings of the study. An in-

depth analysis will investigate the current challenges the country faces in regards to social development and environmental protection in the context of charcoal production. Bringing Liberia into sustainable development literature has the potential to build a greater research base and to begin creating networks of sustainability practitioners among communities, organizations, agencies and individuals.

6. Methods

Two methods of data collection were utilized for this study: 1) stakeholder interviews with officials from multiple government agencies, NGOs and private firms and 2) survey questionnaires administered to rural communities engaged in charcoal production.

6.1 *Research Assistants*

Six Liberian university students were hired as research assistants to administer surveys due to language barriers and geographic and cultural knowledge. Each student was trained in research methods and basic survey administration prior to conducting surveys for this research.

6.2 *Stakeholder Interviews*

Interviews were requested with heads of multiple organizations and agencies directly or indirectly affected by operations in the charcoal sector (see Table 1). Organizations were identified through published research and recommendations from other interviewees. Organizational perspectives were gained through discussion of topics

in the context of charcoal, including: organization role and perceptions of charcoal production and use, environmental protection, social development, current initiatives intended to mitigate negative effects, and perceived energy futures.

Table 1. Organizational Interviewees

Organization	Sector
Liberian Environmental Protection Agency	Government
United Nations Development Programme	Government
Ministry of Land, Mines and Energy	Government
Conservation International	Non-Government
Center for Sustainable Energy Technology	Non-Government
National Charcoal Union of Liberia	Non-Government
Buchanan Renewables	Private

6.3 *Community Surveys*

One hundred sixty surveys (n=160, 128 men, 36 women) were administered to charcoal producers in four counties in Liberia (Figure 1). Pre-determined sample sizes were difficult to obtain given the informal nature of production and lack of available information on producer demographics. Using a snowball method, where subsequent respondents referred the research team to others, surveys were conducted along roadside villages as most charcoal production occurs along major thoroughfares. The counties selected for this study were done so as a result of information gathered from stakeholder interviews; large-scale charcoal production is most prevalent within these locations (personal communication, LEPA Official). The intent of the survey was to gain a

snapshot of current working conditions and subsequent impacts (social and environmental) of charcoal production as well as highlight opportunities for future improvement. Surveys focused on indicators in the following categories: health and safety, gender equity and environmental sustainability.

Qualitative and Quantitative data were collected through oral administration of written surveys. Upon recommendations from officials and research assistants, questions were altered in cases where respondents were requested to gauge distance and/or time. For instance, rather than responding with how many miles they walk to the production site, they confirmed how many minutes it took them to walk to the production site. All respondents were voluntary and measures were taken to ensure objectivity and anonymity; no identifiers were kept that can link data to any respondent. Six Liberian university students were hired as research assistants to administer surveys due to language barriers, as well as geographic and cultural knowledge. Each student was trained for one week in research methods and basic survey administration prior to conducting surveys for this research.

6.4 *Data Analysis*

For the majority of data collected, the use of Chi-Square Contingency tables was most appropriate. Where quantitative data was collected, such selling price, income generation and quantity of bags produced per kiln, one and two-way analysis of variance (ANOVA) was utilized. Contingency tables and ANOVA tests were performed in R statistical package. An alpha level of significance of .05 was used for all tests.

7. Results

Despite numerous government reports on issues of charcoal production, no scholarly research has yet to address social, environmental and institutional trends impacting rural areas with respect to charcoal production in Liberia. Given the country's significant dependence on this fuel as well as the major economic impact the industry itself has in the country, the following section identifies the livelihood challenges facing rural communities who participate in charcoal production for income generation. The major indicators and findings cited in the results section are those about which little has been investigated in published literature.

7.1 *Environmental Indicators*

As seen from Table1, the majority of respondents actively harvest trees, which has been previously suggested as the primary indicator for deforestation associated with charcoal production. These trends still hold true on a regional basis, although a significant number of respondents in Margibi county ($X2 = 10.18$, $p = .012$) collect wood from felled trees. Many respondents in Margibi reside in Firestone Rubber Plantation, one of the largest in the region; due to more stringent extraction laws within the plantation itself, these respondents utilized significant amounts of scrap rubber wood from Buchanan Renewables operations, which extract only portions of rubber trees (Table 1). While at a local scale, this figure may help support the link between environmental regulation, land ownership and effective resource management strategies, a systematic approach that is currently lacking.

Photo 3. Charcoal production using Rubber scraps in Firestone Plantation

Photo 3. Large rubber wood branches not used by Buchanan Renewables are utilized by local residents to produce charcoal (man standing on kiln in background) in Firestone Plantation. While rubber wood is not as preferred as forest wood by locals, high resource availability and accessibility far outweigh preference in these cases.

While the active harvest of forest trees for charcoal production does not have a direct link to deforestation [52], the subsequent use of cleared land will have a major impact on forest regeneration. Because over fifty percent of both men and women utilize this land for subsistence farming purposes and there is little regulation of forestry practices, these areas are at high risk for long-term deforestation. In addition, all respondents utilized traditional earth-mound kilns, which are constructed with organic materials (i.e. dirt, shrubs and grasses). In general, charcoal production methods are highly inefficient and are a primary source of greenhouse gas emissions. Earth mound

kilns are the least efficient and have an estimated efficiency of approximately 10 - 20%[53]. With respect to land management, respondents in Grand Bassa county were much more likely to replant felled trees ($X2 = 8.89$, $p = .030$) compared to those in other counties. While the majority of respondents reported private land ownership, significant percentages of respondents in Grand Bassa and Bomi counties reported that they produced charcoal on community-owned land ($X2 = 13.28$, $p = .038$). In most cases, private land was owned by a third party who did not reside in the community in question. As a result, despite clearing of land owned by another party, respondents felt it was not their decision to replant because they did not personally own the land.

Figure 1. County Map of Liberia [54]

Table 2. Environmental Indicators across Counties

Indicator	Bomi	Bong	Grand Bassa	Margibi
Active Cutting	88.3	92.6	94.7	74.6*
Replanting	9	22	37*	22
Earth Mound Kiln	100	100	100	100
Primary Fuel	Wood - 37	Wood - 81	Wood - 82	Wood - 62
	Charcoal - 19*	Other - 19	Charcoal - 3	Charcoal - 31*
	Other - 44	--	Other - 15	Other - 7

* indicates significant differences among respondents (through Chi-Square)

Table 3. Charcoal production by county

County	Bags of charcoal produced
Bomi	96
Bong	33*
Grand Bassa	120
Margibi	114

* indicates significant difference among bags of charcoal produced.

Figure 1 and Tables 2 and 3 illustrate environmental impacts by geographical location in Liberia. Bomi, Bong, Grand Bassa and Margibi counties were suggested by government officials as those counties that produce the highest quantities of charcoal or are most environmentally impacted by industry operations.

7.2 *Public Health*

While charcoal production is the primary focus of this work, the consumption of woodfuels has significant livelihood and public health implications for rural communities who engage in production, especially women and young children. These populations most often sustain additional adverse effects associated with fuel combustion, including respiratory illness due to inhalation of high levels of particulate matter [55, 21, 23]. The majority (63.2%) of all respondents prefer to use wood exclusively as a cooking fuel, most often because it is cheap and widely available. Despite its use in varied environments (i.e. closed rooms vs. out doors), women remain at higher risk of these illnesses as compared to men, as they are typically responsible for meals and use wood as a cooking fuel. A significant portion of respondents in Bomi and Margibi counties (18.6% and 30.91%, respectively; $X2 = 41.13$, $p < .0005$) preferred the use of charcoal exclusively while others had no preference. One of the major benefits of charcoal is that it produces much less smoke, and therefore particulate matter, when compared to wood [56, 52]. These counties produce the largest quantities of charcoal by volume, yet further

research is needed to determine whether these communities are consuming charcoal as a result of excess supply or as a result of undocumented energy dynamics.

The use of axes and chainsaws, combined with heavy lifting, extremely high temperatures and lack of safety training create unsafe working conditions, as supported by a 75% injury rate among all respondents. Common injuries among affected individuals were moderate to severe lacerations and burns of the lower extremities that, in a developed context, would require immediate medical attention. Lack of adequate treatment often limits participation in income generating activities for an extended time, usually due to infection and vulnerability to other hazards. In three separate instances, respondents reported the death of a colleague due to these working hazards.

In addition to visible external injuries, the majority of women expressed that they felt dizzy, lightheaded and nauseated while, and for some time after, engaging in production tasks; these symptoms were not voiced by male respondents. Upon further discussion, this 'sickness' had become a chronic issue; while dehydration, hunger and physical exhaustion may be responsible for these issues, there may be a connection to poisoning from carbon monoxide and other gases released during combustion. No academic research has investigated the health impacts associated with chronic exposure to pyrolization processes, but there are strong links between literature on toxic gas (i.e. carbon monoxide) poisoning and their symptoms as well as long-term health implications. The completion of pyrolysis in traditional coal-producing communities requires women to be in close contact with bulk charcoal as well as 'fines', smaller pieces

of discarded charcoal, and powdered residues (see Photo 4). Numerous health studies [24] provide documentation of symptoms of carbon monoxide poisoning, which include nausea, vertigo and flu-like symptoms, exactly like those expressed by female producers. Hampson et al. (1994) conducted an early study showing that even well ventilated burning of charcoal briquettes resulted in high levels of CO poisoning; minorities and those of lower income brackets sustained greater impacts [57]. Acute exposure to compounds including carbon monoxide and levels of particulate matter that are often fifty times higher than the U.S. Environmental Protection Agency standard of outdoor air quality [23,58] will likely lead to these symptoms; chronic exposure, however, can have significant impacts on certain human development factors, like cerebral development and has grave implications for maternal health, including low birth weights [59]. Further research is required to investigate the cause of these symptoms in charcoal producers and whether they are linked to current community health issues.

Table 4. Social and Public Health Indicators

Indicator	Percent (%) of Respondents	n
Physical Injury	75	124
Sickness*	22	36
Use of child labor	57.1	94
Interaction with Government or non-government officials	1.82%	3
NACUL affiliates	0	0

*All women used the term 'sickness' to express feelings of nausea while working to pack the charcoal

Photo 4. Exposure to Environmental Hazards

Roles in charcoal production are often differentiated by gender; in Photo 4, women are working in direct contact with kilns that are releasing large amounts of toxic gases, while also handling small pieces of charcoal without taking adequate safety precautions.

7.3 *Child Labor*

Of all respondents surveyed, 57.1% routinely utilize child labor in the production phase. While children typically engage in less physically intensive processes (sorting and packing), they are by no means safe from serious health risks. Inhalation of toxic gases in young children is often more detrimental to healthy physical and mental development. In addition to severe public health risks, engaging in production processes limits time spent in primary and secondary school. This has grave implications for the already-low rates of education in charcoal-producing communities; the forecasted increase in charcoal demand in the coming years may expose more children to serious injury, while preventing them from engaging in educational activities, unless the social effects of energy are holistically considered in national policies.

7.4 *Gender Disparities*

While the absolute impacts sustained by charcoal-producing communities are significant, there are further disparities related to education, employment and income generation among men and women. Consistent with evidence found across the region, this study finds significant differences in the ability of men and women to maintain already-low standards of wellbeing in rural areas.

7.4.1 *Education and Employment*

The common trend of gender inequality found in both urban and rural areas of developing countries is supported with respondent data. Both educational and income generating opportunities are crucial for not only rural development in general, but particularly for women and young girls. 61% of women had received no education (compared to 24% of men); in each educational category thereafter, male educational attainment was significantly higher compared to females ($p < .0005$). In addition, 97% of women were either not employed (14%) or worked as subsistence farmers (83%). An equal percentage of males self-identified as unemployed, with 50% working as subsistence farmers and 25% engaged in trade positions (carpenter, electrician, etc.). No females held trade positions or were pursuing higher education.

Table 5. Education and Employment Indicators

Category		Male % (n)	Female % (n)
Education $p < .0005$	None	24 (31)	61 (22)
	Primary	38 (48)	31 (11)
	Middle	3 (4)	0
	High School	31 (40)	8 (3)
	University	3 (4)	0
Employment	None	14 (18)	14 (5)
	Farmer	51 (64)	83 (30)
	Trade	25 (32)	3 (1)
	Motorbike	7 (9)	0

7.4.2 *Income Generation*

There was a significant difference not only in the selling price between men and women (two-way ANOVA, $p < .05$), but also between counties ($p < .005$). Similarly, the number of bags produced per kiln differed between males and females (ANOVA, $p = .0209$); males produced 105 bags while females produced 64 bags, on average. This finding supports the trend of lack of bargaining power typically found in rural communities, particularly for women attempting to sell charcoal. In addition, males were much more likely than women to rent chainsaws ("powersaw") for commercial production, likely due to their higher earnings and social networks within, and outside, the community. Given greater access to these tools, this is likely to result in higher earnings for men per unit sold. Further differences in income generation by county suggest a need for more research on the true determinants of market price, especially given the differences in production volume.

Table 6. Income generation per bag of charcoal sold

Factor	Income per bag sold ($LD)	p-value
Men	179.5	P < .05
Women	173.5	
Bomi	170.3	P < .005
Bong	176.6	
Grand Bassa	200.4	
Margibi	184.5	

The exchange rate for $LD to $USD is highly variable, though is stabilized within a range of $LD70-76 per 1 $USD.

7.5 *Government Intervention*

The role that more formalized parties, like government and non-governmental organizations and aid agencies, play certainly influence the impacts sustained by charcoal producing communities and individuals.

Interviews with officials from the LEPA, United Nations Development Programme and Conservation International all confirmed common challenges that plague most developing nations attempting to address such a complex and far-reaching issue; there is too little data and too few resources to initiate a shift in how government and aid agencies' approach them. To date, most of the efforts have been directed at urban cook stove programs, similar to other countries. Government and aid officials often suggest that end-user efforts are most feasible given the destruction of forest resources in unregulated rural areas. Increasing stove efficiencies, they argue, will certainly help to reduce forest resources extracted from rural areas. Initial findings of social indicators were presented to these officials, all of whom were surprised by such adversity faced by

rural producers. In addition, a systems approach was emphasized, citing the example that reducing urban demand may not only be ineffective at reducing deforestation, but may create even greater hardship for the thousands of citizens that rely exclusively on these forest resources for income and, essentially, survival. All officials interviewed confirmed the use of transportation and consumption data collected by the National Charcoal Union of Liberia, an organization receiving small funds to conduct limited research. The same figure, 36,500 tons, has been reported consistently over the past several years. In contrast, consumption estimates of 243,000 tons provided by the United Nations and Food and Agricultural Organization, dwarf those provided by NACUL. This is particularly concerning since UN and FAO estimates are often provided by national environmental or development organizations; in the case of Liberia, the most comprehensive consumption data is being gathered by NACUL. The significant discrepancy between these figures and lack of new data suggest that a collective approach should be taken in gathering accurate data as one of the first steps in modifying its energy policy.

The National Charcoal Union of Liberia (NACUL) is comprised of approximately 550 members who are mostly involved in the selling of charcoal products within urban and peri-urban areas of Liberia's capital city, Monrovia. NACUL serves as the sole advocate for charcoal producers in the country regarding fair wages, market access and research and sustainable development of the industry. Still, limited resources prevent NACUL from expanding into other sectors of the supply chain, particularly into more rural areas. No charcoal producers participating in this survey were current members of

NACUL or had they been approached by any NACUL affiliate. Similarly, all but three respondents had not had prior interaction with any NGOs or aid agencies regarding issues related to charcoal production. Of the respondents who had confirmed prior interaction, all were located within Grand Bassa County.

The Center for Sustainable Energy Technology (CSET) provides support related to outreach and installation of sustainable energy technologies. Through an interview with one of CSET's top officials, the authors confirmed that this organization provided significant support to one particular community in Grand Bassa County in the form of a high-efficiency prototype kiln (Photo 5). In addition, workshops were held to inform the community of current issues threatening the industry. Overall, both replanting rates were higher and choice of wood depended on availability rather than preference, suggesting that NGO intervention may play a positive resource management role in the community, as has been illustrated in other communities across the region.

Photo 5. High-Efficiency kiln in Grand Bassa County

Photo 5. The initial installation of this technology was guided by CSET with poor oversight on information transfer. No data had been collected while the unit was in operation and it currently sits unused.

8. Discussion

Efforts to transition to more sustainable systems will certainly confront obstacles, as one of the greatest challenges is to balance economic, environmental and social interests in both the short and long term. The economics of the charcoal market in Liberia are far from perfect; few studies have been conducted on price determinants, which remain the primary concern for those who rely on its fuel characteristics so heavily. Still, the environmental and social wellbeing of this

major industry cannot be overemphasized, as long term economic prosperity is intimately linked with these often overlooked contributors.

One major concern among government and aid officials remains the outdated production estimates first obtained by NACUL over a decade ago. These numbers still make appearances in government reports and other published documents, yet their validity remains far from certain. Through interviews with the executive director of NACUL, it was learned that these estimates account for only those bags of charcoal transported to Monrovia and counted at government checkpoints. Findings of this study revealed that significant percentages of rural residents choose to utilize charcoal as a cooking fuel, leading to the unintentional omission of potentially large amounts of charcoal from production data. This fact alone suggests that charcoal production estimates are potentially much higher, thus increasing the need for urgent action with regards to sustainable production and adequate land management.

Additional concerns lie in the use of earth mound kilns, a highly inefficient means of production that currently consumes an unnecessarily large amount of forest resources. Even while these kilns have a 100% use rate among producers, there are few efforts that focus on increasing efficiency in the production phase. These efficiencies can be as low as ten percent, while other types of kilns currently deployed in Kenya and Brazil, which are made of brick, metal and clay, can reach efficiencies of 30-40%. While these systems have few demands in the way of

complex and rare materials, the biggest challenge remains the education and outreach among charcoal producing communities as to the benefits of these technologies.

This finding coincides directly with current efforts to increase efficiency in the use phase. This push to decrease consumption levels has potentially unexpected consequences for the hundreds, likely thousands, of rural charcoal producers. Policies that aim to decrease consumption through the deployment of more efficient cook stoves are certainly well intentioned and logistically practical. Targeting dense urban populations is likely to achieve significant improvements in standard of living among hundreds of thousands of residents. Even small reductions in woodfuel use can be significant with regards to deforestation and land degradation impacts. However, the decreased consumption, and therefore decreased demand, will further exacerbate the standard of living for the numerous rural charcoal producers. Driving down the price and physical demand of charcoal is likely to stifle the charcoal production markets, on which a large and currently unknown percentage of the rural population relies.

Adequate land management remains an issue for a number of reasons; ownership, education and access to forest resources. The majority of charcoal producing communities who participated in this study did not own the land where production took place. In most cases, the land was owned by a third party, and the producers could not, or would not, consider replanting for lack of education and

fear of retaliation by land owners. Despite this, however, interesting and hopeful trends emerged from Firestone and Grand Bassa counties. Before discussing these trends, a bit of history is required. Firestone Rubber plantation is one of the largest of its kind in the world. Rubber trees, while productive and lucrative, have relatively short useful lives. Once they start producing rubber, this phase lasts for around ten years, when the tree no longer produces viable quantities. Over its 90-year tenure in Liberia, Firestone has perfected its method of rotational rubber tapping and cutting unproductive trees to maximize profits. Felled trees were typically hauled off site and discarded with no further use. Buchanan Renewables arrived in Liberia in 2007 to begin commercializing this process of removing unproductive trees and using them for biomass power generation. Not all parts of the tree were utilized by the company, but with hundreds of thousands of tons of usable rubber trees, even scraps were plentiful.

Charcoal producers in Margibi county (where Firestone resides) began using these wood scraps to produce charcoal. Rather than cutting and hauling forest resources from a great distance, they were able to access large amounts of wood and reduce the time and labor associated with production. Surveys revealed the decreased rates of active cutting in Firestone, while interviews with producers in the area confirmed that working directly with Buchanan Renewables allowed them to produce greater quantities with less input.

Similar outcomes were found in Grand Bassa county, where the non profit Center for Sustainable Energy Technology focused its efforts in production efficiency. From the study survey, only three respondents indicated previous interaction with a non-profit or government agency, all of which were located in Grand Bassa county. In addition, replanting rates were significantly higher in this county compared to others, suggesting that intervention and outreach related to production led to more effective land management techniques. As shown in Figure 5, CSET designed and built a high efficiency kiln to be piloted in Grand Bassa county. According to interviews with CSET's Executive Director and producers in Grand Bassa, the kiln was in operation for just over five months with no data collected on its performance. Poor maintenance and information transfer limited the continued use of the kiln and it currently sits rusted and unused.

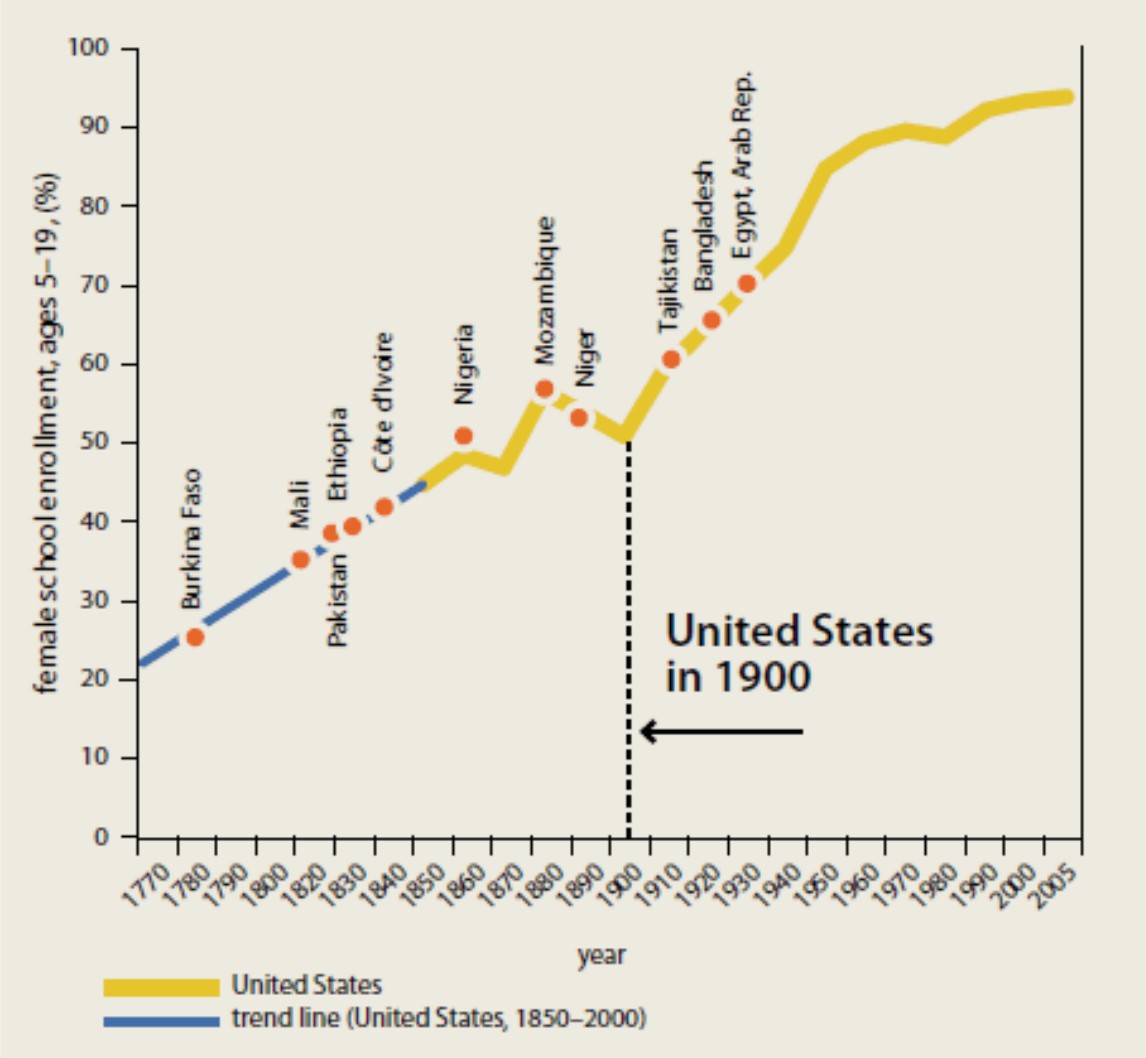
Similarly, while the majority of respondents in Bomi, Bong and Grand Bassa counties actively cut forest and/or rubber trees, producers in Firestone gained access to wood through utilizing surplus scraps left over from industrial operations. Active cutting alone does not coincide with environmental degradation, as land management strategies will help to maintain forest resources. Producers in Grand Bassa county were much more likely to replant trees once they were cut. Surveys indicated a correlation between replanting behavior and interaction with government and aid agencies related to land management practices.

The social and public health risks associated with production were clearly identified in this study. In all categories, females sustained more adverse impacts than their male counterparts. These findings suggest that women who engage in production are less educated, earn less per bag of charcoal produced, have fewer alternative employment opportunities and are further adversely affected by traditional gender dynamics, as compared to their male counterparts. In Liberia, women comprise 54% of the total labor force, including both formal and informal industries. They produce an estimated 60% of agricultural products and conduct 80% of trading activities in rural areas. In addition to this, they are almost exclusively responsible for household chores, including those that may be potentially harmful to their public health and social status.

Illiteracy rates among woman age 15-49 in Liberia are an estimated 60% compared to 30% for men [60]. This figure aligns directly with findings from this study, where 61% of the females surveyed had acquired no level of education, compared to 24% of men. Figure 2 highlights the current status of female enrollment in school among specific West Africa countries in comparison to the U.S.; Liberia falls below that of Burkina Faso. While the issue of child labor is distinct from gender specific education, it has many similarities considering that one in four children in least developed countries (i.e. Liberia) are working in conditions that may be detrimental to their mental or physical health, educational attainment and social wellbeing. As discussed, the charcoal industry in Liberia is necessary to meet the energy needs of the majority of the urban population. Even

those living in rural areas are now using charcoal rather than fuelwood. The growing demand for charcoal in the coming years will increase pressure placed on rural communities, who often enlist young children into physically dangerous, and sometimes fatal, work for little, if any, compensation. This risk is multiplied when considering rural access to adequate schools. The United States Department of Labor provided estimates on sectoral child labor percentages in Liberia, where regulations are making significant progress but enforcement remains far from productive61. Child labor in charcoal production is one of four sub-sectors, including diamond mining and sexual trafficking, where data is unavailable. Findings in this study are certainly not exhaustive, but can provide a starting point for those institutions focused on the effects of informal industries on wellbeing of rural residents.

Figure 2. Female Enrollment in School [62]



Source: WDR 2012 team estimates based on U.S. Census and the International Income Distribution Database (I2D2).

Note: Values between 1760 and 1840 are based on female school enrollment trending between 1850 and 2000.

The urgent need for adequate healthcare is highlighted in this study's findings. Maternal mortality in Liberia is among the highest in the world, at 994/100,000 births. This is highly due to malnutrition, but circumstances associated with lack of employable skills increase the risk of hazards. Carbon monoxide emissions from burning charcoal have been linked to numerous adverse

health effects, and in certain cases can prove fatal. While no research has investigated the exposure of charcoal producers, particularly women based on their roles in the process, to these high levels of carbon monoxide, there is certainly a link between their health, their household chores (cooking with charcoal) and producing charcoal, where much of their time is spent in extremely close proximity to kilns that are emitting significant amounts of toxic gases.

Despite these significant inequities among this population, both absolutely and in terms of gender, producers collectively are responsible for providing the fuel that the large majority of the country relies on.

9. Conclusion

Liberians will be highly dependent on charcoal as a source of heating and cooking fuel for the foreseeable future. Current energy policy contradicts findings both in this study and across the region; charcoal has a much higher social, environmental and economic impact that previously thought. In its current state, while the charcoal industry is economically valuable, it has disproportionately adverse effects on social development of rural producers in addition to environmental degradation as a result of inadequate and disjointed policy measures that tend to benefit their urban counterparts. Negative externalities resulting from improper land and resource management along with significant health and safety risks are born almost exclusively by the rural poor, who offer the benefit of cheap, reliable fuel. Organized efforts on the part of government and aid agencies, as well as organizations like the National Charcoal Union, highlight this imbalance, as most charcoal related programs are aimed at the dissemination of improved

cook stoves for urban consumers or technologies that reduce pressure on forest resources. These policies fail to address indirect, but significant, impacts sustained by the large rural labor force, who depend often exclusively on income generated from charcoal production. In addition, current practice in SSA, as in Liberia, suggests a duality of charcoal regulation, where charcoal production in rural areas is often seen as a punishable act, or one where financial gain can be achieved in the form of bribes or unsanctioned taxes. In urban areas, charcoal retailers are commonplace, with very few opportunities for extortion, as government officials are often in lines with the rest.

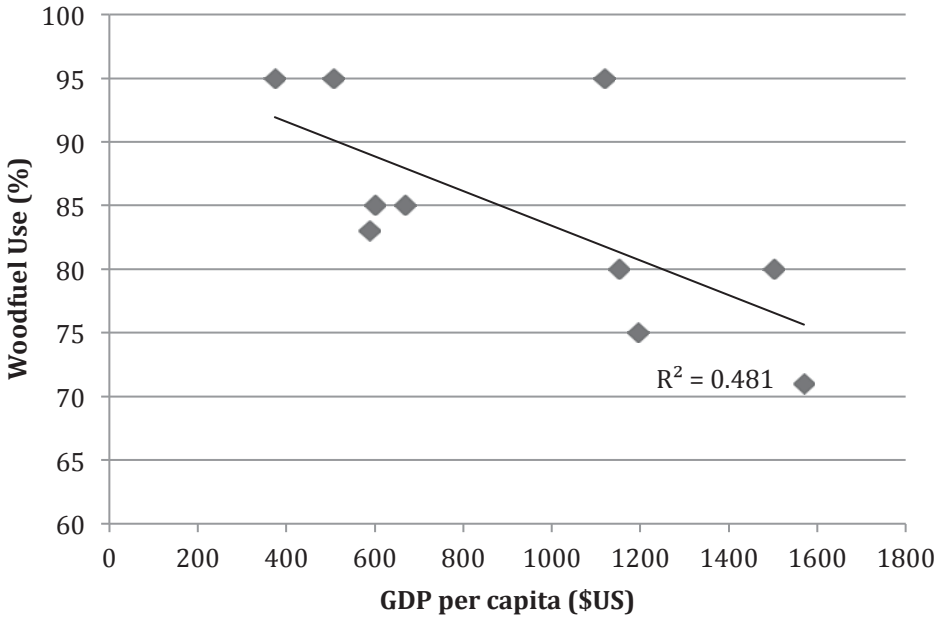
Despite these grim findings, there is hope found in the willingness of communities to both engage with local organizations as well as embrace sustainable energy technologies, such as high efficiency kilns63, that have potential to dramatically reduce adverse social and environmental impacts associated with charcoal production. As such, policies for the charcoal end-user should be equally complemented with policies that promote public health improvements, environmental protection and greater opportunities for access to a market that will continue to grow in the coming years. Proper land use management techniques, such as replanting, along with utilization of high-efficiency kilns, can significantly lower the impacts associated with an industry that is vital to the national economy. In light of the 2015 Sustainable Development Goals and numerous findings across the continent, results of this study and others suggest that an exclusive focus on modern energy services should be redirected to consider these traditional and widespread energy sources that have significant economic, environmental and social impacts. The evaluation of these findings along with current resources can

help map a ‘plan of action’ for policy and decision makers alike in working to alleviate these pressures on rural communities.

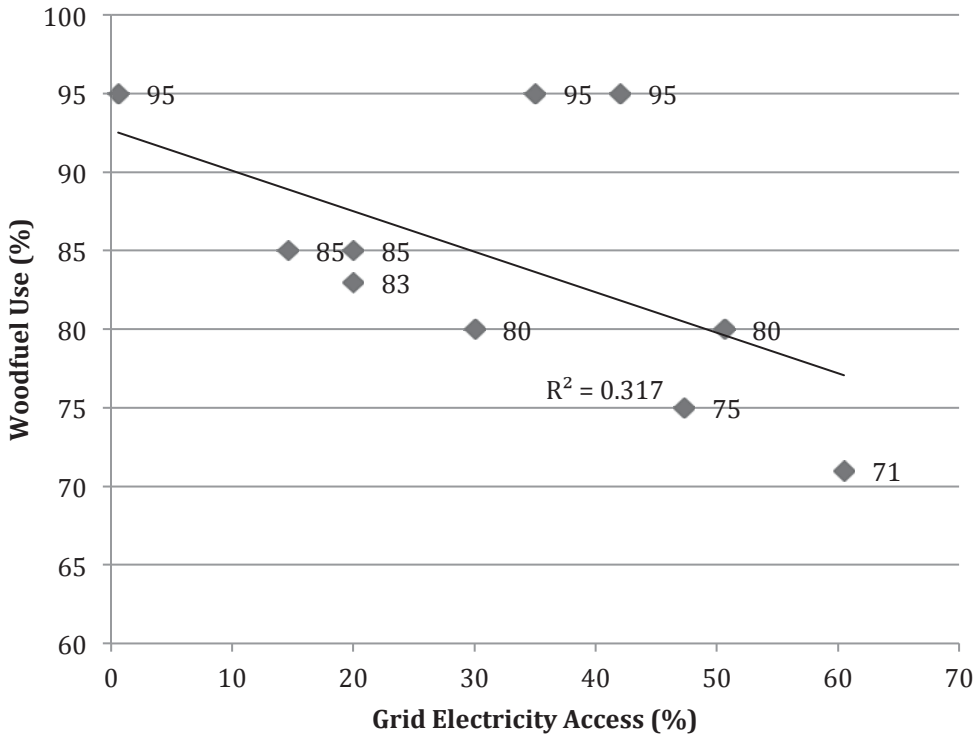
Appendix 1. GDP per capita ($US 2012) [3]

Country	GDP per capita	Electricty Access	Wood-fuel Use
Ghana	1570	60.5	71
Nigeria	1502	50.6	80
Cote D'ivoire	1195	47.3	75
Mali	1151	30	80
Senegal	1119	42	95
Togo	669	20	85
Burkina Faso	600	14.6	85
Benin	588	20	83
Mauritania	506	35	95
Liberia	374	0.58	95

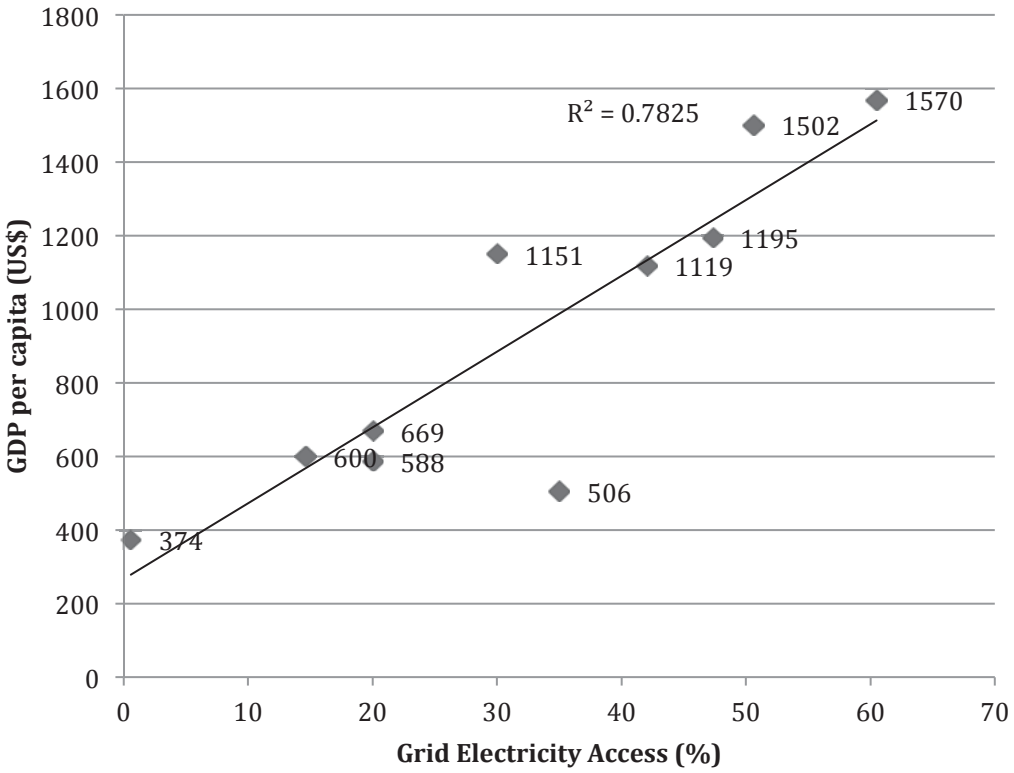
Appendix 2. Woodfuel Use vs. GDP Per capita for countries in West Africa [3]



Appendix 3. Electricity Access vs. Woodfuel Use for countries in West Africa [3]



Appendix 4. Electricity Access vs. GDP per capita in West African countries [3]



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