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Impact of Charcoal Production on Forest Loss: Case Study of BO, Moyamba, Port Loko and Tonkolili Districts in Sierra Leone

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Abstract
Charcoal production and sale is an informal sector that employs many Sierra Leoneans (producers, transporters and traders, local authorities and land owners). In rural towns and villages along or close to the highways, bags of charcoal and bundles of wood could be seen throughout the year for sale. Charcoal production in Sierra Leone is dominated by traditional earth kilns, which involve cutting of tress. The biomass energy consumption will increase at the expense of the declining number of forests, and the workload of women related to firewood collection will also rise in Sierra Leone leading to considerable forest loss. It has a negative impact on the environment in a number of ways, but mainly through the high annual rate of deforestation due to indiscriminate wood harvesting.
This study aims at assessing the effect of charcoal production on forest cover change in Sierra Leone so as to help mitigate climate change. To achieve this aim, the following objectives were investigated: (1) To identified the target tree species that are used in charcoal production in the study areas. (2) To determine the average monthly charcoal sold on the roadside (3) To determine the extend of charcoal produced per month per district, (4) consumption pattern and estimated forest cover depletion from charcoal production in the study areas
The study adopted both descriptive qualitative and quantitative research methods survey involving the use of semi-structured questionnaire, Focus Groups Discussions (FGDs) and interviewing of Key Informants (KII) with a target of 360 producers using a purposive/systematic random sampling technique. Descriptive statistical data techniques were used to analyze the field data. We use a hand held GPS to map kiln locations in a representative study area of tropical woodlands in study areas.
The results of the study revealed that charcoal production for urban domestic energy needs is a driver of forest loss in Sierra Leone. From forest loss calculations, charcoal production is responsible for the forest loss of about 1,630.13Ha of forest loss monthly on the average in the study areas. Domestic cooking account for the highest percentage (26.7%) as a charcoal used pattern.

Keywords: **Forest loss, degradation, charcoal production, biomass, deforestation, woodland**

INTRODUCTION

Charcoal is a premium fuel widely used in developing countries to meet household as well as a variety of other needs. More than 80% of urban households in Sub-Saharan Africa use charcoal as their main source of energy for cooking, and the demand are likely to increase. It is overwhelming to know in today's world that 1.4 billion people lack access to electricity, while 85% of them live in rural areas. As a result, the number of rural communities relying on the traditional use of biomass is projected to rise from 2.7 billion today to 2.8 billion in 2030 (Kaygusuz, 2012). The trend of charcoal production worldwide between 1965 and 2005 is increasing wherein Africa is leading. There has been an increased Africa's charcoal production from about 18.5 million tonnes in 1965 to about 49 million tons in 2005. The demand for charcoal will be twice the current by 2030 (Njenga et al. 2013).

Charcoal is also a major source of income for rural households in areas with access to urban markets (Zulu and Richardson 2012). Charcoal has several merits that make it attractive for heating and cooking. Compared with firewood, it has higher energy content, not bulky, durable, and more accessible and burns more cleanly [Akpalu et al., 2011]. Charcoal is readily available, cheap and sells at a stable cost that meets daily household cook as compared to modern alternative fuels (LPG) [Ellegard and Nordstrom, 2003].

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Charcoal production and sale has become big industry that employ many Sierra Leoneans (producers, transporters and traders, local authorities and land owners), this has become a major livelihood strategy in Sierra Leone. In rural towns and villages along or close to the highways, bags of charcoal and bundles of wood could be seen throughout the year for sale. Charcoal production in Sierra Leone is dominated by traditional earth kilns, which involves tree felling, cross cutting into reasonable length of logs, The biomass energy consumption will increase at the expense of the declining number of forests, and the workload of women related to firewood collection will also rise in Sierra Leone (Fayiah and Singh 2018) leading to considerable forest loss.

The targeting of particular tree species for the production of charcoal has made charcoal production and use a major driver of deforestation, which is an index of climate change. There are many tree species that are used for the production of charcoal in Sierra Leone with Pterocarpus erinaceus, Guibourtia copalloferra , Albizia zygia, Parinari excelsior, Dialium guingeense Piptadeniastrum africana and Acacia species been the most preferred. Apart from these, charcoal producers also target other softwood species like Gmelina arborea, Mangifera indica, Anisophyllea, which are also used to produce quality charcoal due to their high density and calorific value.

PROBLEM ANALYSIS

Despite its economic benefits, charcoal production continue to be a major environmental threat to forest lost and by extension land degredation. The process involves massive cutting of trees. It has a negative impact on the environment in a number of ways, but mainly through the high annual rate of deforestation due to wood harvesting (Bess and Koroma (2014). Understanding the charcoal situation has always been hampered by lack of reliable information, partly because only a very small fraction of charcoal production is recorded and assessment of the actual magnitude of use, and the impacts on forests and rural livelihoods, has consequently been difficult to determine although this has been the subject of considerable debate (Arnold and Persson, 2003). There is a wide accepted narrative on forest loss in Sierra Leone and generally in West Africa that is rapid, drastic and recent , the validity of this narrative depends on how one define “forest” (Wadsworth and Lebbie 2019).

As a result of this non monitored charcoal production activities, effective fight against climate change poses very serious challenge in Sierra Leone. In addressing climate change, renewable energy, food, health and water provision requires a coordinated global monitoring and modeling of many factors which are socially, economically and environmentally oriented (Hák, Janoušková, & Moldan 2016). The key driver to these development goals is provision of sustainable energy for all by 2030.

AIM AND OBJECTIVES

This study aims at assessing the effect of charcoal production on forest cover change in Sierra Leone so as to help mitigate climate change.

To achieve this aim, the following objectives were investigated: (1) To identified the target tree species that are used in charcoal production in the study areas. (2) To determine the average monthly charcoal sold on the roadside (3) To determine the extend of charcoal produced per month per district, (4) consumption pattern and estimated forest cover depletion from charcoal production in the study areas. (5) To provide recommendations that could help to reduce deforestation due to charcoal burning.

MATERIALS AND METHODS

Study Area

Sierra Leone is situated in Western Africa with a total land area of approximately 72,325 sq. km. According to Statistics Sierra Leone (2012), the population is estimated at 6.0 million in 2011 with a growth rate of 3.3%. The capital city of Freetown is located in the western area of the country and is home to approximately 1.25 million people (~21% of the total population). Sierra Leone has a tropical climate with hot and humid weather in the rainy season, which usually spans from May to October and a dry season, which typically spans from November to April. The country has an ambient temperature range of 27°C - 35°C and relative humidity varying from an average of 80% in the rainy season to about 50% in the dry season. The northern region is characterized by the savannah grassland and the southern region by the rain forest. The socio-economic and environmental impact of charcoal production was conducted in rural communities located in selected districts in the north (Port Loko and Tonkolili) and south (Bo and Moyamba) districts of Sierra Leone. Within each district three chiefdoms were selected as shown

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in figure 1. The survey was conducted in January to December, 2022 with the help of field assistants. The cateria for the selection of these districts and chiefdoms were based of the information gathered from Ministry of Energy, Ministry of Local Government and Rural Development, Ministry of Environment and Ministry of Agriculture, Forestry and Food Security.

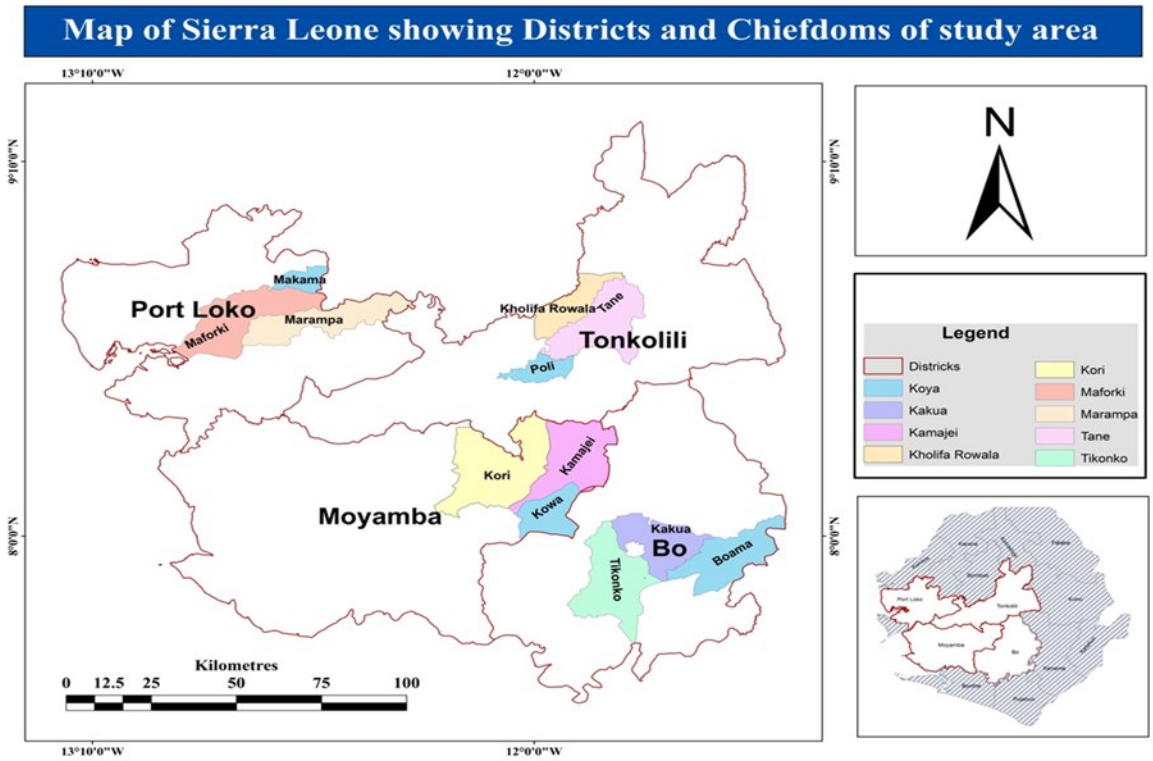

Figure 1: Map of Sierra Leone showing the study areas (Bo, Moyamba, Tonkolili and Port Loko districts).

Biophysical field survey

The field surveys collected data about basic components of the charcoal production process. During January to December 2022, field assistances visited 150 kilns in 20 charcoal production sites distributed in the districts of Port Loko (6), Tonkolili (6), Bo (4), Moyamba (4). These locations were selected, based on discussion with national energy and environmental experts, District Forest Officers and local charcoal producers, to obtain a complete representation of charcoal production conditions in the study areas. The visited kilns were dated and geocoded. For each production site the kilns were geo-referenced, number of bags of charcoal produced per kiln, the kiln locations were mapped with a hand held GPS unit, and preferred tree species for charcoal production were noted. Brief survey on charcoal consumption was conducted in the district headquarter towns and also average monthly sales at roadside.

Table: 1. Respondents Layout of sampling of pattern of questionnaire for charcoal producers

District	Number of samples randomly selected			
	Chiefdoms/districts	villages/chiefdoms	Producers/village	Sample size/ district
Bo	3	3	10	90
Moyamba	3	3	10	90
Tonkolili	3	3	10	90
Port Loko	3	3	10	90
			Total number of respondents	360

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Data Collection and Processing

The primary data required were collected using qualitative and quantitative data collection methods. The two key methods applied were Key Informant Interviews (KIIs), and Focus Group Discussions (FDGs) for collecting qualitative data, quantitative data was collected through field visits to production and roadside sales sites. Informal interviews were conducted with traditional charcoal producers and other key stakeholder (local authorities, energy experts, forestry officers in the forestry department of the Ministry of Agriculture, Forestry and Food Security, and non-governmental organizations). A total of twelve (12) KIIs were conducted, using a semi-structured qualitative Key Informant Interview guide (KII guide). Semi-structured questionnaires were used as the data collection tools for this study. Prior to data collection, research assistants were imparted with training on the questions to answer the objectives of this study. After the training, a pre-test of the questionnaire was done to validate the tool and also ensure that all the researchers had clearly understood the issues to probe from the respondents. This involved the lead researcher having discussions on the topic with five forestry officers from the forestry department in the Ministry of Environment. The data collected was validated to get the relevant data from the study. The validated data was coded for easy classification in order to facilitate tabulation and to generate figures. The tabulated data was then analyzed quantitatively by calculating various percentages where possible. Data on consumption pattern was collected from the district headquarter towns. The surveyed of respondents and production sites were conducted as indicated in table 1. To analyze statistical data, the study used Microsoft Excel and the Statistical Package for Social Science (SPSS version 20).

Estimate of Forest Cover or Woodland Depletion from Charcoal Production

All (100%) charcoal producers sampled said that the charcoal which they produced is from traditional earth kilns. This means that the charcoal is produced from inefficient kilns. This data was used together with the quantity of charcoal produced per month per district to estimate forest cover depletion. To estimate forest cover loss from charcoal production and use, the formula put forward by (Msuya et al 2011) was used as follows:

$$Fs = Ms \times Ek \times \frac{1}{S}$$

Where; Fs = Forest needed to produce a single sack (27Kg) of charcoal;

Ms = Mass of a single sack (kg charcoal sack);

Ek = Kiln efficiency (kg of wood per kg of charcoal 15%);

S= Stock density (ton of wood/ ha forest 1000/10000).

Hence, the following calculation was adopted.

$$Fs = 27 \times \frac{15}{100} \times \frac{1000}{10000} = 0.405Ha$$

0.405 hectares of forest are depleted for production of a bag (27kg) of charcoal with production efficiency of 15%.

The formula is based on two assumptions: (1) the assumption of 93% stem harvest, (2) the charcoal is produced from traditional (inefficient) kilns efficiency of 15%. Results obtained were presented in the form of a table. The field work investigated the production methods and collect data from the producers on the number of bags of charcoal from different kilns, average monthly roadside sales were monitored three times in the month and the average noted, kiln locations were geo-referenced and map produced to account for the quantity of charcoal produced per district.

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RESULTS AND DISCUSSION

Status of Charcoal production

Fieldwork provided information to characterize key components of the charcoal production activities. While charcoal production can vary in response to local and specific situations, their main characteristics are shared throughout the study area. Charcoal producers in the visited sites normally apply a selective logging system based on tree species and tree size using trees above a minimum cutting diameter of 15 cm (STD 4 cm). Producers show a strong preference for Pterocarpus erinaceus, Albizia zygia, Parinari excelsior and Dialium guingeense Piptadeniastrum Africana Lophiira lancelota, Albizia adianthifolia. Fifty-five of the visited kilns contained combination of the preferred tree species. Trees used for charcoal production are collected from tradition slash and burn agricultural system in the Bo and Moyamba districts from an average cutting area of 0.31 ha (STD 0.28 ha). The DBH of trees cut for charcoal making ranged from 10 cm to 50 cm, with an average of 33 cm. Most cut trees (80%) had a DBH between 15 and 45cm and the fallow period is about 10 -15 years.

For both Port Loko and Tonkolili districts wood is been sourced from the large trees in the savannah grass land, the trees are felled around the kiln location although the variation can be large depending on the density of suitable trees. Based on this number, a hectare of woodlands could supply timber to build a maximum of three kilns. The kiln locations are usually selected based on the availability of suitable trees in the area and the access to trails and roads. There is strong linear relationship between the volume of the kiln and charcoal production. The average kiln produces 150 sacks of 27 kg. The length of the visited kilns varies from 2 to 26m, with an average length of 8.1m (STD 4.6m), and 29% and 7% of the kilns are larger than 15 and 10m respectively. The average width of the kilns in the area is 3.5m (STD 0.5m) and the average height is 2.1m (STD 0.3). Producers are now forming groups to produce large quantity of charcoal and also hire transport to deliver charcoal to the urban market, sometimes sell directly to the consumers to make more profits (FGD).

Choice of Tree Species Utilized for Charcoal Production

Charcoal is generally classified into two broad types: ‘iron coal’ and ‘soft coal’. Iron coal is made from harder tree species (i.e., Lophiira lancelota, Pterocarpus erinaceus, Parinari excelsior, Terminalia albida) which tend to yield high quality (longer lasting) charcoal that is therefore in greater demand and more expensive. Soft coal is made from softer tree species (i.e., Gmelina arborea, Mangifera indica, Phyllocosmus africana) that yield a cheaper, faster burning type of charcoal. The data collected from the charcoal producers, the most preferred tree species for the production of charcoal in Port Loko district, was Pterocarpus erinaceus, while in other districts there are still more options. In some cases, all tree species are used to produce charcoal when the demand is high and when there is scarcity of wood in some production areas. Consequently, the species utilized vary in every region, however, each district has its own respective species utilized for charcoal production due to the variation in species composition of vegetation in several districts. Table 2 present the ranking of ten most preferred tree species for charcoal production in Sierra Leone. Table 2 shows the frequency of use of different species for charcoal production based on the response of the interviewees (producers) as demanded by charcoal consumers. The highly preferred tree species based on use frequency and respondents ranking were found to be Phyllocosmus africana, D. glomerata, M. decoideus, P. africana, D. guingeenses and G. copallifera, because of their high density and availability. On the other hand, other species were also found to be utilized as additional in several production areas due to shortage and absence of the preferred species.

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Table 2: Respondents' preference of tree species for charcoal production

Scientific name	Family Name	Rank	Frequency
Guibourtia copalloferra	Fabaceae - Caesalpinioideae	1	67
Albizia zygia	Fabaceae	2	55
Parinari excelsior	Chrysobalanaceae	3	48
Dialium guingeense	Leguminosae	4	40
Piptadeniastrum africana	Fabaceae	5	37
Pterocarpus species	Fabaceae	6	32
Margaritaria decoideus	Phyllanthaceae	7	27
Dichrostachys glomerata	Leguminosae	8	23
Albizia adianthifolia	Fabaceae	9	18
Phyllocosmus africana	Ixonanthaceae	10	13
Total number of respondents			360

Charcoal production technologies, wood source, and output per kiln

In the southern region the wood for charcoal production is sourced from the traditional farming (slash and burn) system, whilst in the northern region the wood for charcoal production is sourced from big trees in the savannah areas. The most common charcoal production technology observed in the study area was the earth mount kiln (85%) in all four study districts (Bo, Moyamba, Port Loko and Tonkolili), the pit kiln account for only (15%) and only practiced in the Bo district (Table 3).

Table 3 Charcoal Production Technologies and Site per District in the study areas

District	Production site	Production Technology
Bo	Farmland	Pit method and Earth mount kiln
Moyamba	Farmland	Earth mount kiln
Port Loko	Savannah land	Earth mount kiln
Tonkolili	Savannah land	Earth mount kiln

Average monthly Charcoal Production per District and Sales

Figure 2 presents results for the average monthly charcoal production per districts and sales. The average quantity of charcoal produced per month per district varied, the highest production was documented in Port Loko District (1,500bags/month); while the lowest production was Moyamba District (750bags/month) (Table 3). Similarly, the selling price varied per district with Freetown market selling at an average price of Le120 per 50kg bag which is much higher than the sales at production sites with price range of Le55 to Le75. The price of charcoal is influenced by seasonal variation with the raining season attracting higher price, especially in Freetown and other big cities.

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During the raining season (May to September) charcoal production is markedly reduced leading to scarcity of charcoal which eventually increase the price, The demand for charcoal rises from october to December which months a marked with lot of activities as presented in Figure 2. Figure 3 presents charcoal production process and road side marketing of charcoal in Port Loko District,

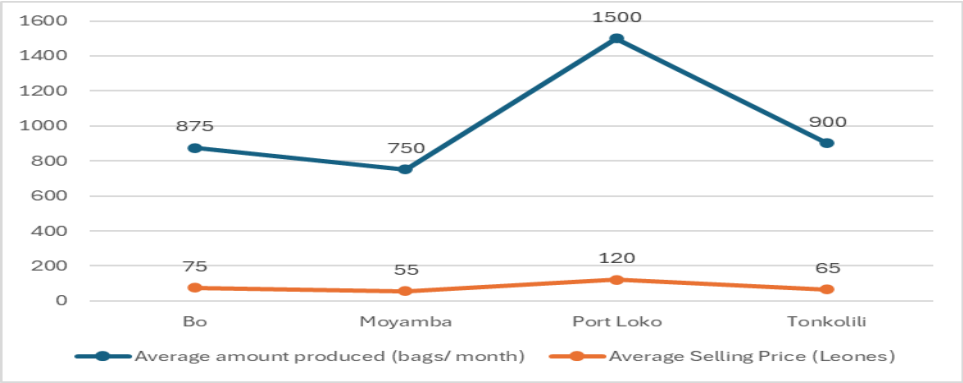

Figure 2: Average amount of charcoal produced and average selling price per month in the study areas

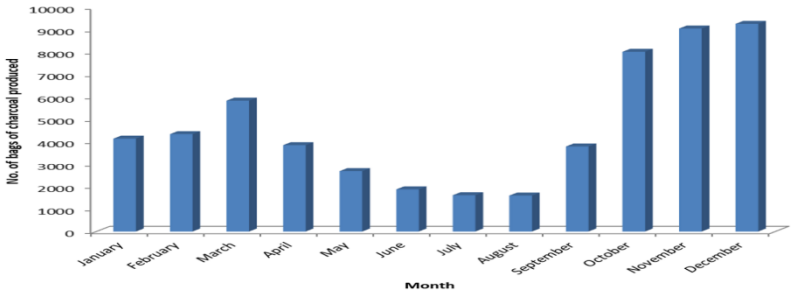

Figure 3: Average monthly roadside sale of charcoal in January to December 2022

Figure 3: Charcoal production and road side marketing

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Estimate of Forest Cover or woodland Depletion from Charcoal Production

Figure4 presents results of the average amount of charcoal produced and forest loss per month in the study areas.

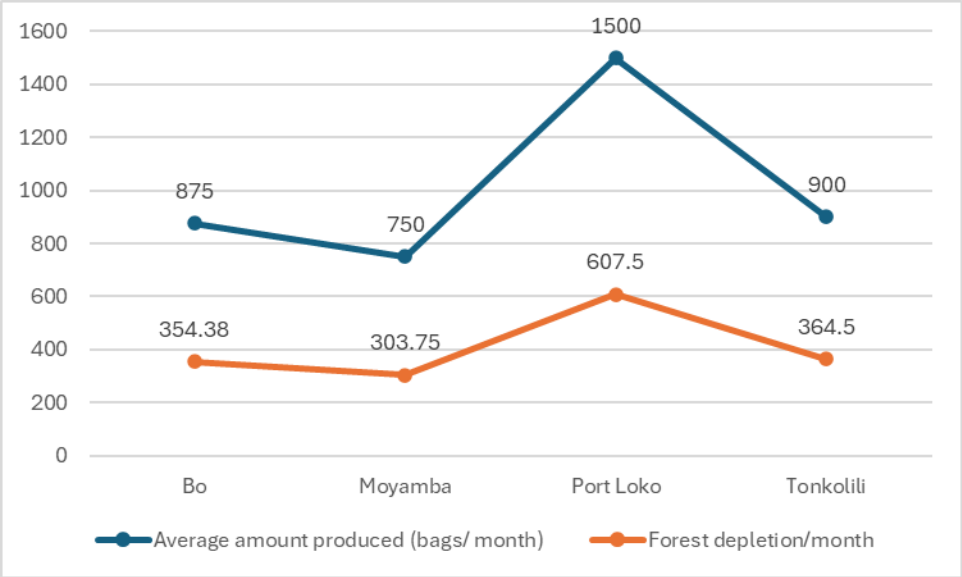

Figure 4: Average amount of charcoal produced and forest loss per month in the study areas

From the forest loss calculations as described by Msuya et al. (2011), 0.405 hectares of forest are depleted for production of a bag (27kg) of charcoal with production efficiency of 15%. Therefore, on the monthly basis charcoal production in the four selected district alone is responsible for the forest loss of about 1,630.13 Ha. The rate of forest cover depletion could be reflected in the tree species and even their growth rate, their spatial distribution on the land surface, as well as the production methods used in the production of charcoal i.e. earth mound kilns. The result of this study is in accordance with work done by (Vuyiya et al. 2014), they asserted that human activities especially charcoal production is a key driver of tree species and forest cover depletion.

CONCLUSION

With charcoal remaining an important household energy source in the foreseeable future in Sierra Leon, improving sustainability of charcoal value chains receives renewed attention. Improving efficiency of the pyrolysis process is one of the interventions that can have high potential gains in saving wood input and reducing GHG emissions. The results improve our understanding of spatial and temporal dynamics of deforestation associated to charcoal production and the production is informal. The findings of this work indicate that charcoal production can contributor of forest and woodland loss, it is closely related to traditional farming system in the southern region. In the charcoal producing districts, charcoal production was largely independent from agricultural expansion in the northern region. From the calculation, charcoal production is responsible for the forest loss of about 1,630.13Ha of forest loss monthly on the average in the study areas.

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