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The socioeconomic and environmental impacts of wood energy value chains in Sub-Saharan Africa: a systematic map protocol

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Abstract

Background: The vast majority of households in Sub-Saharan Africa (SSA) depend on wood energy—comprising firewood and charcoal—for their daily energetic needs. Such consumption trends are expected to remain a common feature of SSA's wood energy production and supply chains, at least in the short- to medium-terms. Notwithstanding its importance, wood energy generally has low priority in SSA national policies. However, the use of wood energy is often considered a key driver of unsustainable management and negative environmental consequences in the humid and dry forests.

To date, unsystematic assessments of the socio-economic and environmental consequences of wood energy use have underplayed its significance, thus further hampering policy debates. Therefore, a more balanced approach which considers both demand and supply dynamics is needed. This systematic map aims at providing a comprehensive approach to understanding the role and impacts of wood energy across all regions and aspects in SSA.

Methods: The objective of this systematic map is to collate evidence from studies of environmental and socio-economic impacts of wood energy value chains, by considering both demand and supply within SSA. The map questions are framed using a Populations, Exposure, Comparators and Outcomes (PECO) approach. We name the supply and demand of wood energy as the "exposure," composed of wood energy production, harvesting, processing, and consumption. The populations of interest include both the actors involved in these activities and the forest sites where these activities occur. The comparator is defined as those cases where the same wood energy activities occur with i) available/accessible alternative energy sources, ii) regulatory frameworks that govern the sector and iii) alternative technologies for efficient use. The outcomes of interest encompass both socioeconomic and environmental impacts that can affect more than the populations named above. For instance, in addition to the direct socioeconomic impacts felt by participants in the wood energy value chain, forest dwellers may experience livelihood changes due to forest degradation caused by external harvesters. Moreover, intensified deforestation in one area may concurrently lead to forest regeneration in another.

Keywords: Wood energy, Woodfuel, Charcoal, Firewood, Value chains, Forests, Woodlands, Sub-Saharan Africa

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Background

Global energy demand is projected to increase rapidly in coming years, with population growth and lifestyle changes in developing economies placing ever greater demand on current energy supply grids. This may be particularly true for Africa, where economic development can be directly linked to energy demand: a 1% growth in GDP is projected to require 0.55% increase in energy production [1]. Moreover, Africa constitutes approximately 13% of the world population but consumed only 5.6% of the global energy supply as of 2001 (the latest data available) [2]. Therefore, it is expected that African per-capita energy use (ca. 41% of the global average) is likely to increase with growing trade, changing lifestyles and improving infrastructure [2].

Because of its generalised lack of access to modern energy sources such as kerosene, liquefied petroleum gas (LPG) and electricity [3], Sub-Saharan Africa (SSA) – with the exception of South Africa, where coal is an important fuel - has the largest proportion of its population relying on traditional biomass, mostly comprised of firewood and charcoal [4,5] (Table 1). SSA also represents the world's highest regional per capita wood energy consumption, with an average consumption of 0.69 m^3/year in 2011, compared with a global average of 0.27 m^3/year [6]. An estimated 93% of households in SSA depend on wood energy for their daily cooking needs. While firewood remains the preferred choice in rural areas [7], charcoal is especially popular in urban markets because of its higher energy content, ease of storage and transport, and lower smoke production compared to firewood [6-10]. Charcoal is likely to become even more important in the future as fossil fuels become less attractive due to environmental and financial costs [11] in [12]. Various case studies have reported an increase in charcoal use in SSA urban centres and this trend is expected to increase in the future, due to the absence of affordable alternatives [6,10,13-18].

Notwithstanding the importance of wood energy for household energy consumption and livelihoods, biomass energy generally has low priority in SSA national policies [7,19]. In fact, the wood energy sector tends to be "indirectly" regulated by a multitude of other sectors (e.g. the forestry codes, energy and land tenure laws). Those regulatory frameworks are indeed important, but the involvement of multiple agencies and ministries leads to overlapping and the unclear division of responsibilities as well as competing taxation [20,21]. Hence, wood energy policies end up having limited scope, regulatory gaps and inconsistencies, weak implementation, and they largely focus on regulatory measures instead of fostering investments for sustainable management of the sector [20,22]. The lack of adapted regulations and implementation also leads to i) states not benefiting from what would be one of the most important sectors in a large number of SSA countries, and ii) numerous forms of informal payments such as bribes, discretionary road charges, etc.

As wood energy can be derived from natural forests, grown in plantations or from integrated on-farm production systems, its production and use is also part of the discourse about the sustainable management of SSA's dry forests and woodlands. Historically, research has focused on analyses of rates and drivers of deforestation linked to wood energy production (such as charcoal), often considered a key driver of unsustainable use in humid and dry forests [23-26]. The environmental impacts of potential technological and policy innovations as well as future wood energy demand have also been assessed [27,28]. The overarching conclusions of this work, and the narrative partly derived from them, are that wood energy production often has negative consequences for the environment, especially in "depletion hotspots" concentrated in South

Table 1 The number of individuals relying on traditional biomass (millions) as primary source of energy for cooking

	2009 (Actual)			2015	2030	Share of populations on biomass (%)		
Region	Rural	Urban	Total	Total	Total	2009	2015	2030
Africa	481	176	657	745	922	67	65	61
Sub-Saharan Africa	477	1,176	653	741	918	80	77	70
Developing Asia	1,694	243	1,937	1,944	1,769	55	51	42
China	377	47	423	393	280	32	28	19
India	765	90	855	863	780	75	69	54
Other Asia	553	106	659	688	709	63	60	52
Latin America	60	24	85	85	80	18	17	14
Developing Countries*	2,235	444	2,679	2,774	2,770	54	51	44
World**	2,235	444	2,679	2,774	2,770	40	38	34
Africa in % of World	22%	40%	25%	27%	33%			

*Includes Middle East countries.
**Includes OECD and transition economies.
Sources: [2,12].

Asia and East Africa [29], although there is generally a failure to distinguish between market-oriented, intensive and destructive collection, and the far less devastating impacts of rural collection for local consumption [26,30].

In response to the overall negative perception, the focus has shifted to the propagation of energy saving stoves and kilns, but adoption rates are often insufficient and the jury is still out on whether they result in any change in wood energy extraction rates [26,31]. Also, unsystematic assessments to capture the degrees of socio-economic and environmental consequences of wood energy have underplayed its significance, thus further hampering serious policy debates. Therefore, a more balanced approach which considers both demand and supply dynamics is needed (Figure 1). This systematic map aims to build on existing efforts [8,14,26,32] which have started to provide a balanced and comprehensive approach to researching wood energy.

Objective of the review

Primary question

What are the socio-economic and environmental impacts of wood energy value chains in SSA?

Secondary questions

What are the socio-economic and environmental impacts in SSA of wood energy supply under varying regulatory frameworks?

What are the socio-economic and environmental impacts in SSA of wood energy demand under varying regulatory frameworks?

We define "wood energy" as firewood and charcoal in this systematic map.

Questions are framed using a Populations, Exposure, Comparators and Outcomes (PECO) approach Table 2. This framework is frequently used to structure systematic maps of social and environmental studies, and is adapted here to include "Context" as a critical consideration of those regulatory frameworks that may affect exposures and outcomes alike.

Methods

Searches

Search strategy

The search strategy for this review aims to retrieve results of both high sensitivity and high specificity to the review question [33]. Defining searches of high specificity, or those that find a larger proportion of relevant studies within search results, without sacrificing the comprehensiveness allowed by broader searches of lower sensitivity, was facilitated by the repeated testing of search strings in the databases Web of Science (WOS) and CAB Abstracts to determine the effects of including or excluding specific words and phrases. Search strings were composed of population, exposure, and location terms derived from the

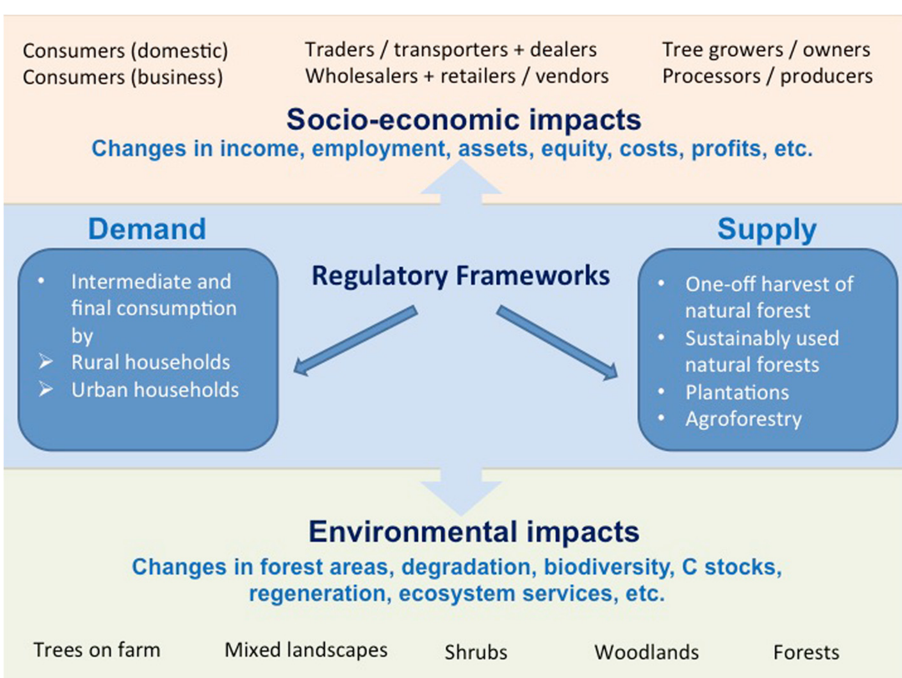

Figure 1 A conceptual framework to answer the question "What are the socio-economic and environmental impacts in SSA of wood energy supply and demand under varying regulatory frameworks"?

Table 2 PECO elements of the systematic map question

Populations	Exposures	Comparators	Outcomes	Context
Forests, woodlands, and shrublands (natural or planted), or farmlands, agroforests or landscapes consisting of the mixtures of those that supply firewood and charcoal in Sub-Saharan Africa (SSA) (see Additional file 1 for list of SSA countries)	Production, collecting, harvesting, processing, trading and consumption of wood energy	Before or without wood energy production, collection, harvesting, processing, trading or consumption activities	Environmental impacts, including deforestation, forest degradation, forest regeneration, and other changes in tree cover; secondary impacts on greenhouse gas emissions, carbon sequestration/carbon stocks, and non-carbon ecosystem services, water flow, erosion/sedimentation, biodiversity	Formal and informal regulatory frameworks that govern wood energy production, collection, harvesting, processing, trading and consumption activities, which include tenure systems, trade, energy, environmental laws and regulations.
Wood energy value chain participants (as specific economic groups): collectors, producers, traders, intermediate and final consumers in SSA	(Note: Production practices can include managed coppice systems, plantation forestry, assisted natural regeneration, and agroforestry)	Before or without substitute or alternative technologies (kilns and cookstoves) that affect demand/supply of wood energy	Socio-economic impacts on wood energy value chain participants, such as changes in employment, assets, income, household pollution, health, based on indicators listed in [34]	

PECOs in section 2, and combined using the following Boolean operators:

(P_1 OR P_2 OR P_3 …) AND (E_1 OR E_2 OR E_3 …) AND (L1 OR L_2 OR L_3 …), where P stands for population, E for exposure, and L for location terms.

For sources other than the three bibliographic databases, should any individual search yield >10,000 records, outcome terms will be added to the search string to further refine results. Where search engines do not support the use of Boolean operators, we will conduct simplified searches using key population, exposure, and location terms, as well as apply relevant topic filters where available. These will be fully documented for source. The full list of population, exposure, location, and outcome terms can be found in Additional file 1.

Sources of literature

Bibliographic databases:

- Web of Science (Thomson Reuters)
- CAB Abstracts
- Scopus (Elsevier)

Institutional websites and databases:

- Oxford Radcliffe Science library (focus on specialist collection of the former Oxford Forestry Institute)
- International Information System for Agricultural Science and Technology (Agris), Food and Agricultural Organization of the United Nations (FAO) [34]
- United Nations Development Programme (UNDP) [35]
- United Nations Environment Programme (UNEP) [36]
- The World Bank [37]
- Consortium of International Agricultural Research Centers Library [38]

Internet search engines

- Google Scholar (only the first 500 hits) [39]

Grey literature

Discussions with subject experts indicated the presence of significant archives of grey literature that would be valuable for inclusion. Some of these will be retrieved from institutional searching (see above). However, in order to capture published and grey literature that may not have been indexed electronically either in the bibliographic databases or institutional databases and website, we will contact subject specialists for additional peer-reviewed and grey literature that they believe to be relevant to answering the review question. A hand-search of the forestry collections of the Bodleian library at the University of Oxford will also be conducted with the help of specialist librarians[a].

Search languages

Searches will be conducted in English. French, Spanish, and Portuguese will be used to search for relevant studies in Google Scholar.

Estimating the comprehensiveness of the search

Initial scoping searches performed on CAB Abstracts, Web of Science, and Scopus yielded c. 5000 potentially relevant studies. Comprehensiveness of the search in the three bibliographic databases will be checked against a reference set of papers of high relevance to the systematic map questions. Searches will be refined until at least 90% of the reference studies are retrieved.

Publication bias

Potential publication biases will be addressed by comparing study results from peer-reviewed journals with those from the grey literature [40].

Study inclusion criteria

Eligibility criteria are defined in Table 2, and will be applied at the title, abstract and full text screening stages to identify relevant studies for the review and exclude ineligible studies. The main selection rule is to include a study if it meets at least one condition in each of population, exposure, comparator, and outcome criteria. Where relevant comparators are lacking, a study will nonetheless be initially included if it presents relevant outcomes that could help better formulate policy options.

Studies will be excluded if they examine demand for wood energy from outside SSA that is not linked to supply within SSA, if they study other sources of energy or technologies but does not target relevant populations or outcomes as defined above, or if they are review or referencing papers that do not also contain primary data.

Potential effect modifiers and sources of heterogeneity

The spatial and temporal scales used in assessing wood-energy supply, demand and related policies can affect study outcomes, direction and intensity of change, as can different environmental, social, economic and political conditions in the study sites. A list of potential effect modifiers and sources of heterogeneity that will be recorded are listed below.

- Temporal and spatial scale
- Human population density at local and market-shed scale
- GDP, population growth
- Surrounding landscape
- Vegetation
- Type of management (large-scale, industrial vs. smallholders)
- Road infrastructure/network
- Travel distance/time to next market
- Level of urbanisation and proximity to urban centres
- Type and scale of economic activities
- Forest policy framework (categories used, recognition of agroforestry)
- Long-term climate change and risk of extreme climatic events

Study screening

POC, PS, MI, WZ, DGa, and DGu will take part in the study screening process. First, the reviewers will check all retrieved hits for relevance based on titles. Following the first screening, abstracts of the included articles will be read to further determine the suitability of the articles for the review. The included articles will be read in full to determine their suitability for the review. At the beginning of each screening phase, kappa analysis will be undertaken on a sample of 50 articles to ensure that study inclusion criteria are applied consistently. Should the kappa statistic fall below a satisfactory level of agreement (0.70), additional rounds of pilot screening will be conducted until the kappa statistic reaches 0.70 or higher. In cases where reviewers make opposing decisions with regard to inclusion or exclusion of a particular article, a group decision will be made following discussions to reach a consensus.

Study quality assessment

Studies identified within included articles will be assessed according to the quality assessment criteria by the review team. We recognise the potential for quality assessment to be somewhat subjective because of the breadth of our review question. In order to minimise subjectivity, an initial set of ten studies will be assessed to determine inter-reviewer agreement on the application of the quality criteria. These criteria include the relevance, reporting standard and experimental design of each study, used to assess susceptibility to bias and rigor of reporting; these criteria are further detailed below. Two reviewers from the review team will appraise the quality of all included studies and where discrepancies exist on the application of the assessment criteria, they will be harmonized by the team of reviewers.

A checklist will be used to examine the quality elements in each article for inclusion, although no overall quality score will be calculated. Instead, each element will be assessed independently and reported upon as part of an appraisal of the quality of the evidence base. Relevant articles will be appraised using the following criteria:

- **Clarity of study site selection criteria** – Is the choice of study site selection clear and justified? This decision will be based on the explanations provided by study authors regarding a study site's relevance in answering research questions, and is particularly important for the selection of case and control sites in terms of their comparability.
- **Sources of data** – Are the sources of data reliable, complete and available in the article? The reliability of data will be assessed based on the authors' acknowledgement of potential biases and if triangulation is performed to ascertain research results.
- **Methods** – Are methods clear and replicable? Is the sampling frequency, duration of study, and

Table 3 Data to be included in the systematic map database

Nature of evidence	Sources of evidence (journal types and subjects, grey literature)
	Type of study (socio economic, environmental)
Representativeness and coverage of evidence	Geographic coverage (scope, location, scale)
	Focus (firewood, charcoal, other related energy sources)
	Populations (value chain participants, including sample sizes, gender, and land tenure; forests, including sample sizes, forest type, and agro-ecological zone)
Measure of changes/ impacts	Nature of outcomes reported (increase, decrease, no change/neutral) for the following indicators:
	Socio-economic outcomes (income, employment, asset, equity, costs, profit)
	Environmental outcomes (deforestation, forest area, degradation, biodiversity, C stocks regeneration, ecosystem services)
	List of outcomes that are not comparative in nature, but relevant to answer the review questions
Context	Regulatory framework described (trade, energy, environment)

sample size (e.g. extrapolations, generalizations) appropriate for answering the question(s) posed by the study?

- **Study design** – Is the study design clearly reported: Before-After (single time or time series), Control–Impact, Before-After-Control–impact, asymmetrical designs (multiple controls for which the data are not paired in time.

We will test these quality criteria on key references, which will then be refined further during the process of data extraction and in consultation with the advisory group.

Data extraction and presentation

The aim of the data extraction is to assess the existence of socio-economic, environmental and other changes on the target population due to the wood fuel production, processing, trading, consumption, and policy implementation. To extract information from selected studies, tables will be designed to compile quantitative and qualitative data from each of the relevant studies selected. Table 3 summarises the main data categories that will be included in the map to provide information about the evidence base, knowledge gaps and possible future systematic review questions.

Where insufficient data are provided, we will contact authors to acquire additional data. To present the evidence base, we will provide a database[b] and supporting narrative of all the relevant articles that have been reviewed, summarising and presenting descriptive statistics in tables, graphs and charts on quantity, type, focus, study location, and target population of reviewed articles. We will further conduct descriptive analysis on outcomes as they relate to the target population.

The results of the systematic map will be published as a CEE Systematic Map with an associated searchable database as well as summarised in a CIFOR policy brief. We will also endeavour to present the outcomes of the map at relevant forums/conferences, and to disseminate results through the advisory group and relevant working groups to inform decision makers in government, civil society, and research and development organisations.

Endnotes

[a]The Bodleian library was an international repository of forestry literature following the creation of the Imperial (later Oxford) Forestry Institute, with a focus on tropical forestry and silviculture, and is therefore considered to be an important source of grey literature http://www.bodleian.ox.ac.uk/science/resources/ofis.

[b]An MSAccess© database will be provided.

Additional file

Additional file 1: Search terms and strings.

Competing interests
There are no known competing interest. This work has been conducted with the financial assistance of the UK Department for International Development, through its KNOW-FOR program grant to the Center for International Forestry Research, and funding partners who have contributed to the CGIAR Fund.

Authors' contributions
POC, DGu, MI, CM, YK, RN, and PS conceived the study. POC, PS, MI, AC, JY, and WZ collaborated in the design of the study and contributed to the initial draft of the manuscript, with writing led by POC and PS. The final draft of the manuscript received substantial inputs from all authors. PS conducted literature searches at the Bodleian libraries of the University of Oxford to inform the search strategy, while WZ conducted literature searches at the Center for International Forestry Research. All authors read and approved the final manuscript.

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