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Integrating wood fuels into agriculture and food security agendas and research in sub-Saharan Africa

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Abstract

In sub-Saharan Africa (SSA), food security can be influenced by many factors including farmer productivity, access to soil amendments, labor availability, and family incomes (just to name a few). In this paper, we suggest that an additional issue contributes to food insecurity and has been historically absent from the discussion, namely access to cooking energy, particularly for very low income, food insecure individuals. This paper examines the most recent literature that describes the central role played by wood fuels, in particular firewood and charcoal, as a vital, though controversial, source of fuel used by the vast majority of rural and urban sub-Saharan Africans. We explore the reality that although the health risks of collecting and using firewood and charcoal in traditional manners are real, policy makers, researchers, and donors need to address the sustainability and viability of the current fuel types used by the majority of people. We end the paper with a series of practical suggestions for improving the wood fuel systems as they currently exist in the region.

Key words: cooking and heating energy, wood fuel, food and nutritional security, sub-Saharan Africa

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Introduction

The State of Food Insecurity in the World (FAO et al. 2015) report is a joint publication of the Food and Agriculture Organization of the United Nations (FAO), the International Fund for Agricultural Development (IFAD), and the World Food Program (WFP), that cited four primary drivers for the gap between hunger and undernourishment statistics for the majority of sub-Saharan Africa (SSA). These factors are economic growth, agricultural productivity growth, markets (including international trade), and social protection. Although all of these factors are critical, our aim in this paper is to make the case that energy availability for household use, specifically wood fuels, should be added to the short list of essential drivers of food insecurity for SSA. Before policy makers can integrate energy considerations into food security interventions, it is necessary to consider the state of wood fuel research and how it might be expanded to better serve applied social needs. To that end, this paper examines the most recent literature and the gaps that are articulated combined with an assessment of the current state of support for empirical research including several research questions that remain unanswered. We discuss the reservations that prevent wood fuels from being both studied and improved. We then provide some examples of means by which it is possible to reduce the negative impacts on health and the state of the environment while continuing wood fuel use.

The state of wood fuels and food security nexus research

A careful look at the most recent literature on biomass energy in Africa shows tremendous gaps in the empirical studies that have been conducted on wood fuel and food security and agricultural productivity (Sola et al. 2016). Sola et al. (2016) reviewed the 132 papers written on the topic, of which only 19 were empirical in method, to ascertain whether the link between biomass energy use and three hypotheses related to food security could be proven for SSA. These hypotheses were (1) that energy access influences dietary choices and nutrition, (2) that financial resources are reallocated to fuel purchases and thus impact food purchasing power, and (3) that the use of less desirable energy sources (going down the so-called "energy ladder") could reduce agricultural productivity. Sola et al. (2016) concluded that there was insufficient evidence to establish clear linkages between energy access and food security because the few studies of this topic were unable to account for highly context-specific factors that determine how households juggle competing demands for collecting or purchasing food and energy. They were, however, adamant that the geographic and social complexity of food and energy decision-making does not indicate that the relationships are weak or unimportant. Rather, there is a need for more comprehensive empirical work to be done in multiple locations that take into such relevant factors as family size and composition.

A few months after the Sola et al. (2016) paper was published, Mekonnen et al. (2017) released a new study in Ethiopia that examined very similar issues. The Ethiopian study was geographically limited to a livestock keeping region. Dung collection for fuel and fertilizer was a substantial issue. Mekonnen et al. (2017) found that burning dung resulted in reduced soil fertility and that growing firewood on-farm resulted in less off-farm firewood collection. This new work built on earlier work in Ethiopia that also showed that a scarcity of firewood has negative impacts on soil fertility. This earlier study showed that firewood scarcity results in the use of agricultural residues as cooking fuel instead of them being left in the farms where they undergo nutrient recycling that improves soil fertility. In the Ethiopian highlands, for example, the use of cow dung as a cooking fuel causes a loss of 14.95 kg of nitrogen per year, which affects households disproportionately in connection to firewood scarcity (Duguma et al. 2014). Burning cow dung was more common among farmers living farther away from forests. Both Mekonnen et al. (2017) and Duguma et al. (2014) indicated that when farmers move down the energy ladder toward less efficient or preferred fuel forms such as crop residues or cow dung, we can see a serious energy development problem in the making. The trade-offs between the ability to cook and the capacity to produce food become increasingly disadvantageous for people already at risk (Hosier and Dowd 1987; Mekonnen et al. 2017).

Chikaire et al. (2011), reporting on work done in Nigeria, indicated that fuel scarcity results in cash resources being used to purchase fuel, thereby reducing the households' ability to accumulate financial resources. Sourcing firewood from natural forests costs families both hours of time and human energy that could otherwise be utilized for productive activities such as agriculture. A recent study by Njenga et al. (2017) in the Kenyan highlands in Kiambu and Embu Counties hinted at the same conflict. The study showed that women lose 1 d in every five working days in a week and travel about 10 km carrying loads over 50 kg (Njenga et al. 2017). Further, the day they collect firewood they forgo an average farm laborer's wage of 250 shillings (equal to $2.50 USD). Women and children can suffer serious long-term physical damage from strenuous work without sufficient recuperation (IEA 2006), further impairing their productivity.

Scope and scale of wood fuel use in SSA

The damage done to the health of individuals is particularly important given the widespread use of wood fuels in SSA. On the continent as a whole, more than 90% of the population relies on either firewood or charcoal (IEA 2006). Charcoal is mostly used in urban centers. In Kenya, for instance, charcoal is used by 82% of urban and 34% of rural households (MoE 2002). Urban areas' reliance on charcoal holds true in Tanzania and Ethiopia as well, where urban households in Tanzania use 80% of the total charcoal produced. In Ethiopia, 70% of all charcoal produced is consumed by urban households, supplying 97% of their household energy needs (Yigard 2002; Ngeregeza 2003). Furthermore, charcoal use in Zambia is reported to have increased by 4% between 1990 and 2000, culminating in 85% of urban households relying on charcoal (Chidumayo et al. 2002). In contrast, firewood is the predominant form of wood fuel used in rural areas. In Kenya, 90% of rural households use firewood, compared with a meager 7% of the urban population (MoE 2002).

Dependency on biomass fuels among the rural population in Ethiopia is as high as 90% (Kumie et al. 2009). Use of wood fuel is rising due to population growth and emerging urbanization trends; for example, a 1% rise in urbanization has been linked to a 14% rise in charcoal consumption (World Bank 2009). Beyond the practical question of whether households can access sufficient biomass, the concept of food security includes cultural aspects of cooking activities. Each culture and subculture has their own unique food preparation culture that evolves (and has evolved) differently across communities based on needs and preferences. This idea of diverse cooking culture is not unique to SSA, but it does occur in other countries (Khandelwal et al. 2017).

Cooking and culture

The history of cooking culture originates with the use of fire in prehistoric times. Archeologists, primatologist, anthropologists, and related professionals have not agreed on the origins and time frame for the earliest deliberate taming of fire. There is, however, a consensus that cooking allowed humans to expand the range of foods we could eat, the capacity to extract nutrition from foods including meat, and, eventually, the ability of humans to live in non-tropical locations (Milton 1999; Gowlett and Wrangham 2013; Pyne 2016). Cooking food properly makes food safer, creates rich and delicious tastes, and reduces spoilage. Heating facilitates opening, cutting, or mashing tough foods. It also increases the amount of energy our bodies obtain from our food, as cooked food is easier to digest than raw food. Further, cooking enhances digestibility by gelatinizing starch and denaturing protein facilitating the work of digestive enzymes (Wrangham 2009). The need for some food types to be cooked for them to be safe and utilizable by human beings shows that food security cannot be guaranteed if there is no access to energy for cooking it (Bogdanski 2012). This is true even when nutritional studies to chart the specific impacts of cooking energy shortfalls are missing. This is further evidenced by the World Food Summit of 1996, which defined food security as a situation whereby all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Cooked food, and in some areas enough heat to take the edge off on a cold evening, are core attributes of a life well lived by this definition. All of these studies highlight the need to learn a great deal more about wood fuel use and the decisions that surround the choices households and individuals may make between fuel types and purchasing vs. growing vs. collecting fuels.

Research funding and energy priorities

The scarcity of wood fuel research can be ascribed, in part, to the allocation of internal monies. National budgets in SSA countries allocate very limited research funds to wood fuels, focusing support on electricity instead. For example, the Republic of Mauritius reports only expenditures on electricity (Republic of Mauritius 2009). South Africa's Department of Energy lists six energy sources including coal but excluding biomass. The South Africans do admit that the traditional use of biomass for cooking is the largest part of household energy consumption in the country (Republic of South Africa and Department of Energy 2017). However, interest in funding research or programs to improve its use or sustainability is limited. The Republic of Tanzania takes a different approach, acknowledging that

90% of the population uses traditional solid biomass. In the draft national energy policy from 2015, the biomass strategy has two objectives: one to promote and scale up efforts of bioelectricity generation and the other to enhance the production and rational use of solid biomass resources (Ministry of Energy and Minerals, United Republic of Tanzania 2015). Kenya also includes biomass in its draft national energy policy (Ministry of Energy and Petroleum, Republic of Kenya 2015). The bottleneck for the development of biomass energy is, however, its low budget allocation, as most efforts are on rural electrification. Unfortunately, electricity is largely used for lighting, hence the failure by governments to address cooking and heating energy needs. In Tanzania, for example, <1% of the budget for energy is allocated to biomass energy (Sustainable Energy for All 2013).

Wishful thinking: Why can't we leave wood fuels behind?

The need for more nuanced research on wood fuel use and its impact on food security and agricultural productivity is hindered by more than just the usual shortages of research funding and the daunting scale and complexity of the issues. Wood fuel research studies an energy source that is unpopular (Daily Nation 2017). All energy sources result in pollution of some kind, be it chemicals used for fracking natural gas in the Marcellus Shale or the impact of greenhouse gases produced by burning gasoline in internal combustion cars. Cooking over an open fire, as is standard practice throughout much of Africa, produces clouds of smoke that are directly inhaled by cooks and their families. Smoke residues cover pots, walls, and ceilings of the kitchen, and cause clothes to smell. The health risk of indoor air pollution is well documented (Lim et al. 2012; Ezzati and Baumgartner 2017). In addition, significant environmental damage has been caused by uncontrolled cutting of trees for firewood and charcoal production.

In an era where progressive nations seek to fill their electric grids with power produced by wind turbines or solar collectors, it seems intuitively implausible to advocate for wood fuel use as it currently exists. International donors and even some energy scholars tend to reflect consensus priorities, investing in electrification and promotion of other "modern, clean and preferably renewable fuels" (Quitzow et al. 2016; USAID 2016). Even when the World Bank produced a report in 2011 entitled, *Wood-Based Biomass Energy Development for Africa: Issues and Approaches*, by 2016, the annual report of the Bank's Energy Sector Management Assistance Program (ESMAP) shows only one program related to biomass energy. That is a relatively conventional $2.2 million USD project in Uganda providing marketing and distribution support for improved cookstove manufacturers and distributors (World Bank 2011; ESMAP 2016). The Bank's priorities are clearly in support of expanding electric utilities.

It is tempting to simply call for biomass energy to disappear but that would require a radical alteration in the cooking practices and fuel value chains currently used by the majority of sub-Saharan African households. This might undermine food security in ways that are currently hard to predict given the unclear linkages cited previously. The low research, funding, and policy attention also results in a missed opportunity to transition current wood fuel systems into healthful and sustainable sources of affordable cooking energy that, among other things, reduce drudgery. Some efforts are being made on this front, however. For instance, the World Agroforestry Centre (ICRAF), one of the 15 centers of the Consultative Group on International Agricultural Research (CGAIR), working with smallholder farmers in about 30 countries in Africa, Asia, and Latin America developed a strategy in 2015 to direct its research on tree-based energy (Dobie et al. 2015).

To further understand the connections between (1) energy for cooking and nutrition and (2) agricultural productivity and energy, researchers could examine the following:

- Do changes in energy availability impact what people eat, leading to either an increase or decrease in nutritional content?

- To what degree do these changes happen and does household income influence the nutritional changes observed?
- Do households buy fuel to keep cooking traditional foodstuffs or do they change foods to keep energy costs constant?
- Do people change fuels based on cost and availability and does that mean they use biomass in ways that impact agriculture? For example, do households switch to dung when firewood is unavailable? Are trees cut, which then impacts the productivity of agricultural land?
- Do on-farm trees planted for fuel increase agricultural production?
- On a continental basis, does hauling firewood keep women from expanding the productivity of their farms in rural areas?

Strategies for sustainable wood fuel cooking and heating energy systems in SSA

With the high dependence on and predicted increase in the use of wood fuel in SSA, there are real concerns about the negative impacts on health and the environment associated with the unsustainable harvesting of wood, inefficient kilns, and inefficient cooking appliances (Iiyama et al. 2014; Njenga et al. 2014). Further, the impacts on food and nutrition security from lack of access to affordable cooking fuel and the wastage of women's capacity in productive activities are of concern. In some places in East Africa, collecting firewood takes about 6–8 h per trip and requires 8–12 km of travel (Agea et al. 2010; Munien and Ahmed 2012). There are, therefore, calls for the development of sustainable wood fuel production and cooking systems. Fortunately, technological options exist that can make the production of wood fuel sustainable and efficient for domestic use, as discussed below.

Use of multipurpose trees on-farm for wood fuel supply

Multipurpose trees are cultivated by over 90% of households in Maragwa, Murang'a County, Kenya, and 40% of households in Embu County, Kenya, depend exclusively on on-farm trees for firewood (Githiomi et al. 2012; Njenga et al. 2017). Sourcing firewood from trees on the farm reduces time and body energy otherwise spent on collecting firewood from the forests, and saves income spent on purchasing cooking fuel. The farmers also develop a pruning regime in which they prune the trees during the dry season, allowing the wood to dry and hence burn cleaner with less smoke (Njenga et al. 2017).

The production of charcoal could also be made sustainable. For example, in Rwanda charcoal is produced as an integral part of agricultural intensification. It is estimated that virtually all charcoal in Rwanda is made from planted trees, increasing around 2.5% per year, primarily from *Eucalyptus* woodlots on private as well as community land (Drigo et al. 2013). In Nyanza, Kenyan farmers are growing the preferred *Acacia* tree species for charcoal using a six-year rotation and more efficient kilns (Oduor et al. 2012). The trees are intercropped with crops and (or) pasture, and beekeeping takes place on the same plot. Efficient kilns reduce wood wastage, emissions, and are less destructive of the soil (Bailis et al. 2015).

In summary, making charcoal sustainable implies working on all its stages from supply to utilization, a strategy that is attracting attention from various stakeholders. For example, the FAO (2017) publication on the charcoal transition presents this proposition in the form of a green charcoal value chain that involves the efficient and sustainable sourcing, production, transport, distribution, and use of charcoal. This green value chain results in improved human well-being and social equity, as well as reduced environmental risks and ecological scarcities (FAO 2017). The report further states that the green charcoal value chain is low carbon and resource efficient. Green charcoal value chains address the negative impacts of unsustainable charcoal production and use systems that may attract higher support by policy makers, private sector, and donor agencies. This would also address the cooking energy needs of the majority of the population in urban SSA.

Fuel briquettes: Diversifying wood fuels

To bridge the wood fuel deficit, diversifying the sources and types of biomass cooking and heating energy is critical. For example, resource, recovery, and reuse of energy through briquetting organic waste or byproducts offers an excellent opportunity to produce cheaper and cleaner cooking and heating energy. Briquettes are made either by molding biomass materials using bare hands or compressing it using manual or automated machines. The briquettes can then be used like charcoal or firewood (Njenga et al. 2013a). Women prefer production technologies that are easy to work with and that require less use of body physical energy, whereas men and young people are more interested in using machines (Asamoah et al. 2016).

Briquettes have a number of benefits, including the following.

- They are a cheap cooking and heating fuel. For example, cooking a traditional meal of 500 g of green maize mixed with 500 g of dry beans, enough for a Kenyan standard household of five people, costs 3 Ksh ($0.04 USD) for 850 g of charcoal dust/fines plus soil briquettes, 26 Ksh ($0.35 USD) for 890 g of conventional charcoal, and 45 Ksh ($0.6 USD) for 0.36 L of kerosene. Cooking the meal with charcoal briquettes thus costs 88% and 93% less than cooking the meal with charcoal and kerosene, respectively (Njenga et al. 2013b).
- The use of briquettes can generate income and save money used on cooking energy. For instance, in the Kibera informal settlements in Nairobi, Kenya, households that produce briquettes for home use and those that purchased them saved about 70% and 30% of income spent on cooking energy, respectively, (Njenga et al. 2013b).
- Briquettes burn evenly with fewer of the harmful emissions caused by certain raw materials, binders, and the production process. A briquette made from 80% charcoal dust and 20% soil produces three times and nine times fewer carbon monoxide and fine particulate matter emissions than wood charcoal, respectively, and burns for one and half times longer (Njenga et al. 2013a, 2013b).
- Briquettes also contribute to saving trees that would otherwise be cut down for wood fuel, contributing to the cleaning of urban neighborhoods by recycling organic waste.

Improving efficiency in cooking with wood fuel

Improving efficiency in wood fuel cooking appliances saves fuel and reduces emissions. Fortunately, many types of improved cookstoves exist that show promising results for improving quality of life and reducing the time spent in search of firewood. In rural Kenya, a gasifier stove reduced fuel consumption by 40% compared with the traditional three-stone open fire and produced charcoal for additional cooking or for use as biochar for soil improvement (Njenga et al. 2016). Use of a rocket mud stove reduced fuel consumption by 34% compared with the traditional three-stone open fire (Ochieng et al. 2013). In Ethiopia, households switching from a traditional three-stone open fire to an improved model saved between 20% and 56% of firewood (Duguma et al. 2014). In rural India, an improved cookstove reduced annual consumption of fuel by 41% compared with the traditional cook stove (Singh et al. 2014).

Some cases exist where improved stoves reduce emissions. In rural Kenya, the gasifier stove reduced emissions of monoxide (CO) and fine particulate matter ($PM_{2.5}$) by 40% and 90%, respectively, when using a gasifier cook stove compared with the traditional three-stone open fire (Njenga et al. 2016). In the mid-hill region of Nepal, indoor concentrations of $PM_{2.5}$ and CO were found to be reduced by 63% and 60%, respectively, after one year of using the improved stove (Singh et al. 2012). In southwestern Bangladesh, 98% of women had health and lifestyle improvements after using an improved earthen stove (Alam et al. 2006).

Unfortunately, to gain the full benefit from improved cookstoves, especially in terms of reducing indoor air pollution, households need to adopt the new stoves to the exclusion of using open fire. Evidence from many biomass-using areas of the world indicates that, for reasons that are not researched in sufficient detail, cooks prefer to continue using open fires for some cooking purposes. In some areas, cookstoves are quickly abandoned because they break and cannot be fixed, they are not appropriate for cooking certain dishes, or the fuels that they use require extra time to prepare (Njenga et al. 2016; Hollada et al. 2017).

Several important questions need to be answered given the prevailing situations in each location. What technology will work? How does it work? For whom does it work? What modifications need to be made?

Conclusions and recommendations

For SSA, using wood fuel energy for cooking and sometimes heating is a reality for the majority of the population. Cooking energy has implications for food and nutrition security and as such, in the sub-Saharan African context, it should be considered as a critical issue. As illustrated in this paper, wood fuel technological solutions exist for addressing the negative impacts of the existing unsustainable wood fuel systems. However, for this to happen there is need for financial and policy support. Further, the existing research indicates that the complex issues that connect the use of women's time, environmental degradation, competition for agricultural nutrients, and a host of other factors surrounding wood fuel energy use remain poorly understood. This research gap will not be filled as long as wood fuel use remains ignored because the assumption is being made that a 21st century economy must move up the energy ladder.

What we do know is that wood fuel is widely used, it has a long history of use, and there are food cultural barriers, widespread poverty, and daunting geographic conditions that make other forms of fuel unpopular or unavailable. Rather than wait until we know the exact nutritional or agricultural productivity impacts of wood fuel use—information that we may never have the capacity to fully collect, it is important to expand the work being done on improving wood fuel systems with clear attention paid to the impacts of such improvements on food security and agricultural productivity.

Key scholars in energy studies have been working to integrate a human-centered understanding of energy production, use, and impact on society in ways that could be productive for those who are interested in an integrated food security, agricultural productivity, and energy nexus. Sovacool's (2014) groundbreaking analysis of energy research indicated that SSA studies make up <4% of all peer-reviewed journal articles in the field. Moreover, the topics that would help develop a more effective wood fuel system such as technological innovation and gender, energy justice, differences between energy needs in developed vs. developing countries, and modernization of energy use, just to name a few, are all currently understudied. Articulating which approaches need to be prioritized and the methodologies developed to generate effective policy and development strategies is the next step needed to improve the knowledge base in SSA.

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Author contributions

RM and MN analyzed and interpreted the data. RM and MN contributed resources. RM and MN drafted or revised the manuscript.

Competing interests

The authors have declared that no competing interests exist.

Data accessibility statement

All relevant data are within the paper.

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