



Women's work is never done: Lifting the gendered burden of firewood collection and household energy use in Kenya

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ABSTRACT

In rural Kenya, firewood is used for cooking and heating by 9 out of every 10 households due to its affordability, availability and convenience. This study was carried out using social and natural science methods to understand women's energy burdens and the reasons for the persistent use of firewood. Firewood remains the main source of energy even when multiple fuels are used ("fuel stacking"). Collecting firewood from forests limits women's earning potential and has a negative impact on their well-being although it is a source of income for some as they sell part of what they gather. In these modern times no one would expect that the prospect of freezing to death due to lack of firewood in the tropical highlands worries aging women, but it does. Women's burden of collecting firewood could be lifted by bringing firewood closer through use of residues from trees on farms and burning it in more efficient cookstoves although there may be gender-specific barriers for some women. Income from sale of two timber trees was adequate to meet the cost of labour for pruning trees on-farm and carrying home a year's supply of firewood for families without members who can do the work. This information is useful towards improving rural women's wellbeing and the sustainability of cooking energy. Knowledge gaps still exist in nature, causes and impacts of energy burdens and solutions that work for the people.

1. Introduction

Energy is an essential commodity in sustaining people's livelihoods. At the most basic level, energy provides cooked food, boiled water, and warmth [1]. About a third of the world's population relies on traditional solid biomass for cooking; 50% being from developing countries [2]. In Kenya, 90% of rural households depend on firewood for cooking and heating energy [3]. Although the use of firewood for cooking is well understood, the role of open fires in keeping rural houses warm during the rainy seasons and cold hours of the day, especially in the highlands, is often undervalued. Houses are not insulated and lack heating systems similar to those used in countries that experience winter. Warming houses is important as cold indoor environments could have adverse consequences on the health of the vulnerable including the elderly, children, and the sick. The World Health Organization (WHO) recommends temperatures of 21 °C in the living room and 18 °C in other occupied rooms, although older and sedentary people may feel cold at those levels [4]. Failure to heat houses adequately results in cold and

dampness which have been linked to illnesses including respiratory infections such as pneumonia and bronchiolitis, asthma, rheumatic fever, and stress on the cardiovascular system [5]. While there is still no data on the novel coronavirus, it is entirely possible that homes that are cold, damp and smoky increase the risk of negative outcomes in this regard as well.

Collecting firewood from forests is a wearisome activity, mainly carried out by women and girls [1]. In Kenya, the national forest regulations restrict firewood collection to branches or trunks that have fallen of their own accord or brush residues that are left over from authorized timber harvesting [6]. Some areas restrict the tools one may bring into the forest, outlawing axes while allowing machetes. These rules protect the forest structure but also makes the shortage of legally-acquired firewood less obvious to outside observers. Populated with extensive firewood use (the Central Highlands, for example) the forests consist of mature trees surrounded by very little brush, young growth or downed deadwood hence firewood collectors must travel into the forest itself for fuel collection. With forest residues receding, more time is spent and

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longer distances are travelled in search of firewood [7]. Carrying wood out of the forest typically involves creating a bundle of branches bound together by twine and then attach that bundle to a carrying band that wraps around the forehead. Carriers are assisted by someone to put the heavy loads on their back. Those involved in this method of firewood collection can suffer serious long-term physical damage on their back-bone, head, hands and legs from the strenuous work [8]. It also has a negative impact on women's capacity and opportunities to pursue productive activities, and takes away time that a girl child could otherwise invest in schoolwork or leisure.

According to the African Development Bank [9], the real rural energy crisis is its gendered nature, with women working longer days than men to provide energy for household survival activities [10]¹. This exposes them to injuries or even attacks by wild animals [11]. The inclusion of access to firewood for cooking and heating in research and development agendas is critical for women's wellbeing [12].

One novel solution is sourcing firewood from trees on farms. This has high potential, as about 50% of agricultural land globally has more than 10% tree-cover [13]. Planting trees purposely for subsistence firewood production might not be attractive to farmers, unless there is a severe firewood shortage or where monetary value is attached to the activity. However, in some areas such as Eastern Uganda, one percent of households have deliberately planted trees on their own farms to ease the problem of firewood shortage [14]. In Murang'a County in Kenya over 90% of households source firewood from multipurpose trees on their farms, while in Thika and Kiambu counties, most families purchase firewood [15].

This paper is based on a research project that was implemented in villages in two counties in the Kenyan highlands. The objective of the work was to understand women's burden. The research questions included: (i) How important is firewood as a domestic fuel and where is it sourced? (ii) What are the effects of firewood collection from forests on women's wellbeing and how is that changing? and, (iii) Despite it being a hard job, why do women continue to collect firewood from forests? This last question is particularly important because a narrative exists which advocates for "cleaner" cooking solutions which have been promoted for several decades but are not being adopted on a large scale in Kenya [16,17]. At first glance it seems counter-intuitive that women would choose to carry heavy burdens on a weekly basis and then cook on open fires in smoky kitchens. While it is tempting to assume that the price of firewood and lack of knowledge of fuel alternatives are the reasons firewood collection and open fire use continues, we wanted to understand from the user's perspective what benefits they derive from their current practices.

Our working assumption is that cultural practices have reasons that make sense within the larger fabric of people's lives and therefore, any systemic improvement in energy access, for example, needs to meet both the technical but also the social/cultural desires if change is to be adopted. The first step in any effective attempts to improve the firewood energy system must therefore document the conditions on the ground and the practices at household level. To that end, we tracked the distances travelled by women collecting firewood, weighed the bundles women actually carried, noted the physical conditions of paths and stream crossings, as well as surveying firewood use at the household level. We then conducted a series of focus group discussions that helped to elaborate the values, preferences, and concerns of women engaged in collecting and using firewood. In some of the study areas, collection of downed wood is being replaced by agroforestry which allowed us to discuss with participants why specific households might adopt growing their own fuel and why others might choose not to. The methodology

that we used is discussed in detail in the following section.

The study found that use of firewood in open fires remains a key practice amidst other sources of energy, and that heating living space with open fire is critical in the highlands. This study also observed that solutions to the current firewood situation may work better for larger households that include both men, women and youth, and not as well for single women. Using existing data and that collected from the study, this paper proposes interventions for lifting women's energy burden. The structure of the paper is as follows: 2.0 materials and methods, 3.0 results and discussions, 4.0 innovations to lift women's energy burdens and 5.0 conclusion and recommendations.

2. Materials and methods

2.1. Study area

The study was carried out in Kibugu and Kereita villages, in Embu and Kiambu counties, respectively in rural Kenya. Kibugu households source firewood from Mt. Kenya Forest; the site was selected so as to work with farmers involved in a project on cleaner cooking with biomass while producing biochar [18]. At Kereita, households source firewood from a local national forest and the authors already had ongoing work with women as researchers in a kitchen laboratory.

Kibugu Village in Embu County is located about 120 km north-east of Nairobi. The county is situated on the slopes of Mt. Kenya, a key water tower in Kenya, and has a population of about 609 thousand [19]. Farming activities include cultivation of commercial crops such as tea (*Camellia sinensis*) and coffee (*Coffea arabica*), and macadamia nuts (*Macadamia* spp.) as well as woody species for timber such as *Grevillea robusta* which is periodically pruned for firewood. Average low temperature in Embu range from 10.4/50.7 (°C/°F) in July and August and 12.1/53.8 (°C/°F) in March [20].

Kereita, which comprises Kambaa and Hilton villages, is located in Lari Constituency, Kiambu County, about 60 km west of Nairobi, and a few kilometres off the Nairobi-Nakuru Highway. Kiambu County has a population of 2.4 million [19]. The main crops cultivated in Kereita include horticultural crops such as *Brassica oleracea* (kale) commonly known as *sukuma wiki* and *Spinacia oleracea* (spinach) which are sold in Nairobi [21]. Kereita area borders Kereita National Forest to the south. The forest forms the southernmost part of the Aberdare Forest, one of the five water towers in Kenya. The two forests from which communities source firewood have an electric fence to prevent human-wildlife conflict resulting from wildlife such as elephants destroying crops and causing human death in the neighbourhood [22]. In both sites, the electric fence has gates that are guarded by Kenya Forest Service (KFS) and entry is allowed between 8am-5 pm. Average low temperatures in Kereita range from 12/53.6 °C/°F in July and 15/59 °C/°F in March, April and October [23].

2.2. Social and natural sciences methods applied

In addition to collecting research data, the purpose of this study was to give firewood-using women a voice in framing the narrative about energy use in their communities [24,25]. For this reason, a community-based research assistant who both collects firewood and farms in the Kereita region was included in the research process and was involved in creation of research questions. We were particularly mindful that the differences in education and life experience between professional researchers and small-scale farmers could lead us to project our preferences and values onto practices that are core to family well-being. This was particularly true as some of us were not Kenyan and therefore were operating across cultural, linguistic and experiential boundaries. For the same reasons, even the data collection methods of physical evidence, involved an experiential element. For example, the research team walked into the forest with a group of women collecting firewood not only to engage in participant observation of research subjects, but also to

¹ In this paper we are discussing cultural contexts in which gender roles are considered to be binary and essential and thus our usage of the term gender reflects that context rather than the more accurate and nuanced definitions outlined by Futhallah and Payakurel.

understand the social and physical context in which heavy loads are carried. In one instance, a severe thunderstorm broke out, allowing the researchers to contemplate the challenge of carrying heavy loads over slippery paths in the cold, hard rain typical of the highland tropics.

(a) household survey and focus group discussions

A household survey was conducted using a semi-structured questionnaire among 80 households (40 in each site). In Kereita the households were randomly selected by picking the 10th household along the roads. In Kibugu they were randomly selected from 50 households involved in the biochar work. Data collected included: tree species on farms and the purpose for which they were grown; types of cooking energy used by households; sources of cooking energy; and time spent on firewood collection.

Focus group discussions (FGDs) were held with 14 women (7 in each site) who were purposively selected based on household survey results to represent different categories of households, such as those that sourced firewood exclusively from trees on farms or forests, the ones with a mix of sources of firewood, and those who collected firewood for sale. In Kibugu, the FGD also included the husband of one of the women who hosted gathering. The discussions were guided by a checklist of open-ended questions on sources and the role of firewood as a domestic fuel, experiences, and gender roles in firewood collection from forests and trees on the farms and firewood preparation before use. FGDs were found to be useful tools in understanding complex issues and producing social realities in energy systems [26]. Participants of the FGDs narrated stories of their experiences. Stories and storytelling have been found to be important devices in helping people from different disciplines and different domains better understand the world and each other in walking outside normal constraints. Thus, a storied framing of the problem of energy could contribute to a wider set of solutions [27].

(b) measuring loads of firewood, distances covered in firewood collection, mapping and establishing tree density on farms

A spring weighing scale with 100 kg capacity was used to weigh the loads of firewood transported by women from the forest (Fig. 1), and recorded to the nearest kg. The measurements were made among seven women randomly selected by picking every 3rd and 2nd individual collecting firewood for household use and sale, respectively from those the team met transporting firewood from the forest in the two sites. To estimate per capita daily use of firewood under normal cooking practices, 34 kg and 43 kg of firewood were measured in Kibugu and Kereita, respectively from a heap ready for use and that women considered as one load. Seven households in each site volunteered and committed to only use firewood from the weighed load and report when it was finished.

Actual measurements of distances travelled by each household to firewood collection locations in the forests were obtained using hand-held Geographical Positioning Systems (GPS). This was done by following the women from their homestead to and from the firewood collection locations inside the forest while saving and recording the coordinates digitally in the GPS machine and manually in a book. These were later used to calculate the distances.

Estimating the density of trees in each farm involved counting any tree above one metre as this was the height when trees were visible above the tea bushes. The counting was carried out by the researchers and members of the households, mostly the respondents, majority of whom were women.

2.3. Data management and analysis

Completeness of the filled hard copies of the household survey questionnaires was cross-checked before the data was entered into a database using SPSS statistics version 24 with the brand name IBM SPSS



Fig. 1. Weighing a load of firewood using a spring scale.

Statistics. The data was then analyzed using Microsoft Excel software for descriptive statistics. The questions used in the FGD were specifically intended to allow participants to articulate their concerns. The primary topic was understanding the experience of collecting and using firewood and ways in which their practices were integrated into other household or employment opportunities. It should be noted that the discussions took place in the local languages (Kikuyu and Kiembu) and were translated for the benefit of the English-speaking researcher. Analysis was done based on the English language notes. The data collected using the GPS were used to indicate the location of households and firewood collection sites on the maps developed using Quantum Geographic Information Systems (QGIS) software and Google Earth at ICRAF's Geo Science Lab.

2.4. Limitations of the methods

This study should be understood as an initial investigation of an under-researched topic in an under-studied region [28]. While a great deal has been written about improved cookstoves and the negative impacts of open fire cooking, only very recently has work started to emerge around the changing firewood collection context, the specific nature of the burdens it places disproportionately on women and girls, and the larger network of needs and preferences that inform women's desire to continue what could seem from the outside, to be a problematic practice [16,24]. All of these issues would benefit from a larger sample and a greater diversity of study sites both in Kenya and across East Africa. It should also be noted that although the farmers in both study sites are economically-deprived, they are relatively well off when compared to farmers and pastoralists in the drylands which comprise the majority of Kenya's landmass.

3. Results and discussions

3.1. Demographic data of the respondents

The household survey results showed that in Kereita, 85% of the households interviewed were male-headed; females formed a majority of the respondents at 82.5%. In Kibugu, 90% of the households interviewed were male-headed, while 80% of the respondents were female.

3.2. The importance of firewood as a domestic fuel

3.2.1. Firewood is key in fuel stacking in rural villages

Data collected in the household survey demonstrated how important firewood is as a domestic fuel. All the households in Kereita and Kibugu used firewood for cooking and heating space. Seventy-five percent and 90%, respectively, used firewood alongside other fuel types (Fig. 2) a practice referred to as fuel stacking [29]. Importantly, when a new fuel is introduced households do not completely switch, but rather continue using the traditional one alongside the new ones [30,31]. Fuel stacking is a common practice in the country as established in the national household cooking sector study carried out in 2018 [3]. These results have been substantiated in other Kenyan studies [32]. In Kereita, charcoal, Liquid Petroleum Gas (LPG) and kerosene were part of the household cooking fuel mix in 70%, 35% and 2.5% of the households, respectively. In Kibugu, charcoal, LPG and kerosene were part of the cooking fuel mix in 90%, 17.5% and 27.5% of the households, respectively (Fig. 2).

The majority of households, 80% and 98% in Kereita and Kibugu respectively, used the three-stone open fire to cook with firewood, often indoors. This was also used to heat the space.

3.2.2. Sources of firewood for household use

Trees on the farm was a lesser source of firewood in Kereita compared to Kibugu, implying a higher dependence on forests for this resource. For instance, Njenga et al. [33] reported that forests were the only and main source of firewood for 25% and 23% of households respectively, in Kereita. The forest is the main source of firewood for 10% of households in Kibugu. More households in Kereita than Kibugu depend on natural government-protected forests for firewood. This could be due to the low tree cover on farms in Kereita (Fig. 5) which could be associated with the small-scale intensive production of vegetables for the Nairobi market and small size of farms, averaging 0.9 acres. Ninety-five percent and 100% of farmers at Kereita and Kibugu had trees on their farms at a density of 64 per farm (71 per acre) and 361 per farm (226 per acre), respectively. During the FGD in Kereita, participants stated that they utilize every space in the farms and, moreover, they possess little knowledge of the benefits of intercropping vegetables with trees. In Kibugu, tea and coffee are the main crops and farmers plant timber trees, mainly *Grevillea robusta*, along the boundaries as a source of shade for these crops. In addition, pieces of land are larger at

an average of 1.6 acres. It is possible that a lot of development work on agroforestry might have been carried out in the area, given the nature of the cash crops and high tree cover on farms visible in Fig. 6.

3.2.3. Distances covered in sourcing firewood from government-protected forests

During the FGD in Kereita, women stated that the distances to firewood collection points in the forest had increased over time as the deadwood near the forest edges had been exhausted following population increase and growing demand from other users such as food kiosks and hotels. A similar scenario was reported in the Ethiopian highlands in 2014 where forests have receded and firewood collectors have to travel longer distances into the interior of forests to access this resource [7].

Measurements on distances travelled by each of the 80 households to firewood collection sites taken during the study indicated that the distance from forest gates to firewood collection points in the forest were longer than those from home to the forest gate (Figs. 5 and 6; Table 1).

The difference in the distances between the forest gate and firewood collection sites could be due to tree density and rate of harvesting of deadwood, among other factors (Figs. 5 and 6).

As mentioned earlier, the authors accompanied the women during the study in a round trip to firewood collection sites and could hardly keep up with them, even though the researchers were not carrying firewood. The terrain through the forest is rough and hilly. At Kereita one needs to cross a river which had no bridge, and women with firewood on their backs had to tip toe on stepping stones (Fig. 7).

3.2.4. Effects of logging bans on access to firewood

Water shortage associated with the degradation of water catchment areas and deforestation led to the country declaring a logging ban in February 2018. The ban aimed at allowing the government to reassess and rationalize the forest sector. However, as this task was being carried out, the limited access to forest has had negative effects on the timber industry and supply of firewood. The FGD held in Kereita in September 2018 which involved the same women who had participated in the one held in 2016, indicated that accessibility and affordability of firewood sourced from government-protected forests can be affected by changes in forest management regulations. The women stated that the ban on logging from forests effected in February 2018 had negatively affected

Table 1

Distances between home and forest gate, and to firewood collection sites in the forest.

Section of the trip	Kereita	Kibugu
Average distance from home to forest gate	0.97 km (1.94 km two-way)	1.76 km (3.52 km two-way)
Average distance from forest gate to firewood collection site in the interior of forest	2.16 km (4.32 km two-way)	2.43 km (4.87 km two-way)

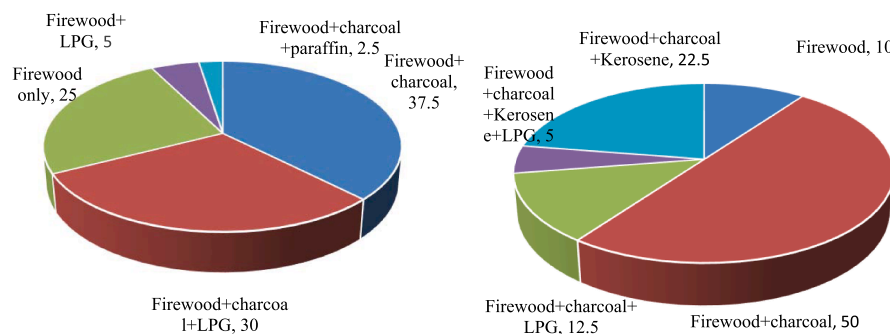


Fig. 2. Percentage of households in each fuel stacking at Kereita (left) and Kibugu (right) counties, Kenya.

firewood sourcing from forests as licensing for firewood by KFS had ceased. A load of firewood weighing 49 kg initially bought at KES 350 (US\$ 3.5) in 2016 cost KES 500 (US\$ 5) after the logging ban. This translates to a price increase of about 43%. In addition, women illegally sneaked into the forests as early as 5.30–8.00 a.m. to collect firewood. If found, they would be arrested by forest guards, taken to the police station and fined. Going to the forest at dawn when it was still dark increased the risk of human and wildlife attacks. The ban had also rendered commercial firewood traders jobless. Some of the women fetching firewood for sale walked very long distances to unfenced plantation forests to collect residues where harvesting of trees had previously been carried out before the ban. Firewood shortage resulted in theft of wooden construction materials from erected fences, further fueling the conflicts.

3.3. Effects of firewood collection on the well-being of women and trends

Having understood the prevalence of firewood use for cooking and heating even in households where other fuels are used, as well as the collection methods used at the two sites to collect sufficient firewood for household use, the question then arises, what is the impact of this energy procurement system on firewood users?

3.3.1. Dangers of firewood collection to women and children

Collecting and carrying firewood from forests is a life-threatening activity as many accidents have resulted in physical injuries. Njenga et al. [11] reported a case where Margaret (a pseudonym) aged above 60 years and a widowed mother of six, suffered a fall while carrying firewood on wet, rough terrain and broke her arm. This left Margaret at the mercy of neighbours and friends who supported her with firewood after she exhausted her stock. She had lost a source of income which she earned from selling vegetables in the market or working in farms. In Kibugu, the women complained of wildlife attacks and going to the forest in the evening was riskier, they stated. They narrated an incident in which some women were attacked by an elephant. As they ran to distract the animal, they dropped a firewood pile and covered it with a piece of cloth. When the elephant saw the firewood, it mistook the load for a human being and stopped to check. When it realized it was not a person it threw the firewood pile into the air. This gave the women time to escape. The potential danger resulted in women developing social networks and collecting firewood in groups. The communities in the two forests where firewood is sourced experienced human-wildlife conflict from wild animals like elephants with some regularity. The KFS has erected an electric fence to keep humans and elephants apart, but this does not apply to firewood collectors. In both focus groups, women discussed how they distracted elephants by throwing the cloth that they use to cushion their backs underneath the bundle of wood. These challenges are common in other rural areas in the country.

3.3.2. Impact of firewood collection on women's income and time left for other chores

The women from Kereita spent three hours every week, between 8.00 a.m. and 1.00p.m., collecting firewood from forests. This results in high opportunity costs as firewood is not collected during weekends according to KFS regulations. In Kereita Village, wage workers are hired between 8.00 a.m. and 1.00p.m., which coincides with the time when firewood is collected. A wage worker earns KES 300 (US\$ 3.0) for five hours of fieldwork. This implies that the time spent by women in collecting firewood from the forests means an opportunity cost of about KES 15,600 (US\$ 156) per annum that would otherwise have been earned working as labourers in the village. Furthermore, morning hours are the main trading time for vegetables in markets in Nairobi City where some of the women sell vegetables that they have produced in their farms or bought for resale. The focus group participants uniformly agreed that it was difficult to do any other work, including cooking, after collecting firewood from forests due to physical exhaustion. This also

affected their leisure time. If the firewood collection day coincided with the day they also had a women's group meeting, they ended up accruing penalties for absence or being late due to exhaustion.

The situation is different in Kibugu, where women collect firewood in the afternoon after spending the day picking tea and/or coffee in their own farms or as wage workers on other farms. Although the women here did not lose their daily wages, they hardly had time to even take a lunch break and they experience physical exhaustion from collecting and carrying firewood in the evening after having manually picked tea or coffee from 8.00 a.m. to 1.00p.m. and then carried the produce to buying centres (distance of about 1 km) on their backs. Picking tea leaves earned them about KES 300–800 (US\$ 3–8) per day at KES 10 (US\$ 0.1) per kg. Picking coffee earned them about KES 200–400 (US\$ 2–4) per day at KES 6 (US\$ 0.06) per kg.

3.3.3. Role played by children and youth in sourcing cooking energy

During the FGDs, participants stated that young girls and boys join their mothers in collecting firewood from forests, a practice that is common during school holidays. This role is however, linked essentialist and binary conceptions of gender and associated social norms. Boys stop participating at age 13 and girls stop once they reach puberty and/or join high school for fear that the strap across their head would make a permanent depression/mark. They are also shy to be seen carrying firewood by their peers and they consider the work hard, dirty and risky. The girls prefer to stay at home and usually engage in household chores such as cooking and cleaning. Mothers are also reluctant to send their girls to the forests to collect firewood, either on their own or in the company of their peers, due to the risk of being raped. The girls resume collecting once they get married in the village. They are considered fortunate if they get married away from the village or if their husbands can afford to buy firewood for them.

In Kibugu, farmers have developed a biennial pruning regime where they prune *Grevillea robusta*, a timber tree, in January to give firewood time to dry before onset of rains in March. In this area, 40% of farmers are self-reliant as they harvest firewood from trees on their own farm [33]. Pruning is carried again in line with age and sex/gender expectations. Young boys, once circumcised, are considered to be 'men' and expected by society to stop climbing trees to carry out pruning. Families with boys have free labour, while those without hire professional male youth who prune at a fee of about KES 50 (US\$ 0.5) per tree for trees about 3 years old; older trees cost more. Young girls then carry the prunings from the farm to the homestead. Surplus firewood and timber from on-farm trees were also sold for income in Kibugu, while the leaves were used as mulch or animal bedding which turn into manure.

Before the logging ban in Kereita, women were allowed to prune and harvest firewood from Cypress plantations as a management practice for better growth of trees. Households with young boys had free labour to prune; those who didn't, had to hire labour and were charged KES 20 (US\$ 0.2) per tree. Women and young girls then carried the prunings on their backs to the homestead. As reported by some of the women in Kereita, in instances where men assist with firewood collection, they only assist with transportation after the women have gathered the firewood and brought it to the edge of the forest.

3.4. Explanation of persistent use of three-stone open fire and collection of firewood from forests despite the handles

3.4.1. Versatility of three-stone open fire and house-warming particularly for old and sedentary people

Given how hard the work of sourcing firewood is in both of these locations, one might imagine that women are eager to abandon this particular chore. Much to the research team's surprise, this was not the case. During the FGDs in both sites, women were adamant that they did not want to be banned from the forests despite the burden that carrying firewood entailed. They gave several reasons for desiring to continue their current practices. First, the need for warmth during the rainy

season and at night in higher elevations meant that more efficient cooking devices did not completely meet the family's needs. Second, newer cooking devices or centralized fuels such as electricity, require that households have money to buy fuel or devices. Moreover, centralized electricity, for example, is not consistently available, even in Kenya's capital city [34]. The women expressed a certain pride in their capacity to provide for their families even when income was scarce and centralized systems were on the fritz. It may be the case that the poorest households may continue carrying firewood as long as they can to avoid having to pay cash for their energy requirements. A household with an open fire and a pile of firewood can make tea and basic foods under any circumstances. For women living in relatively rigid social circumstances, harvesting firewood allows for a particular kind of autonomy, an independence from employers and extended family. Sourcing firewood from on-farm trees eases women's workload but households need money to pay pruners if one's own sons are grown.

Mornings, evenings and nights are cold at high elevation and people need to heat space as described by women during the FGDs in both sites. The rainy season brings damp air that collects inside houses that are made of either mud or wood that has been nailed together. It was apparent that aging women were afraid that when they grew old they might freeze to death as their ability to collect firewood from the forests would be limited. In the temperate zone the term "freezing" implies a temperature below zero degrees Celsius. In highland Kenya however, when women referred to the fear of freezing they meant the night temperatures commonly found in their area. In other words, fear of freezing, should be understood as the fear of being cold enough that one might fall ill. The temperatures in the two sites are lower than what is recommended by the World Health Organization (WHO) and older and sedentary people feel colder [4]. In both sites, women stated that July is the coldest month characterized by fog and drizzle. This period of the year is commonly referred to as *gathano* (cold) and many deaths occur among the elderly. For the women who sourced firewood from on-farm trees this fear was not as profound, though they stated that they will need money to pay for pruning and carrying services. The fear of not having access to firewood when they grew old was a big problem for those women who had no children with the capacity to support them with income to purchase firewood or collect the firewood for them. Aging women who had no source of income depend on well-wishers who are not always available. The crop residues that they collected from their farms were barely enough to cook food or keep them warm. It should also be noted that the manual labour these women engage in as farmers as well as in other areas of life, meant that an older woman might be one in her mid-50 s.

3.4.2. Firewood collection as a source of income for different gender groups

Though a very tough job, collecting firewood from gazetted forests is a source of income for both men and women, especially in Kereita. There

is firewood scarcity due to lack of agroforestry compared to Kibugu which is visible on the maps (Figs. 5 and 6). A license of KES 100 (US\$1) per month allows collection of one woman load per day during working hours (8 a.m.-5p.m.). Use of axes in the forest is prohibited to control illegal cutting down of trees and only machetes (*panga* in Swahili) are allowed. Women normally collect firewood from dead wood in natural forests or residues after trees have been harvested in government plantations. There are those who also collect firewood as a business and sell to households where women are busy and have no time to go to the forest, or are old, sick or pregnant. These women look for dead logs which they split using wooden chisels and other logs to drive the chisel, then trim firewood into attractive, consistent, sizeable and saleable portions (Fig. 3 left and right).

Women collecting firewood for sale went to the forest almost daily and carried heavier loads of 59 kg compared to those collecting firewood for home use who went to the forest once each week and carried loads of 52 kg [33]. Once they hauled the firewood home, they repacked each load into smaller bundles weighing 49 kg for sale at KES 350 (US\$ 3.5); they earned a monthly income of KES 8400 (US\$ 84) in 2016. Prices rose following the logging ban passed in Kenya in February 2018.

Men collect firewood for commercial purposes and mostly use donkeys for transportation (Fig. 4 left). A cartful of firewood of approximately 260 kg (5 loads of 49 kg each traded at KES 350 {US\$ 3.5} by women) fetched about KES 1500 (US\$ 15) in 2016. Male traders mainly sell their firewood to commercial enterprises such as schools and hotels. Purchasing firewood for home use from men is not common as majority of the households cannot afford to pay the amount of money required to buy a cartful upfront and prefer to buy smaller quantities from women, which in the end is more expensive by 17%. During school holidays children assist their mothers to collect firewood for home use; boys prefer to transport the load using wheelbarrows (Fig. 4 right).

Collecting firewood is an activity guided by some socio-cultural norms where, for example, carrying firewood on the back is considered feminine while pushing a wheelbarrow and guiding donkeys is considered masculine. The mothers of teenage girls reported in the FGD that their daughters consider having to put a strap on their head to carry firewood on the back unappealing and only resume if they get married in the village.

3.5. Innovations to lift women's energy burdens

This section synthesizes existing literature combined with results from the FGD to illustrate two innovations that could contribute towards easing women's burden in firewood collection.

3.5.1. Potential of sourcing firewood from trees on farms

There is potential in sourcing household cooking energy from agroforestry, a practice defined as agriculture with trees [35]. As reported by



Fig. 3. A woman firewood trader from Kereita splits wood into small pieces using a wooden chisel (left) and a load of firewood for sale (right).



Fig. 4. A man transports firewood using a donkey cart (left) Women carry loads of firewood on their backs (middle) and A boy carries firewood on a wheelbarrow (right) in Kereita.

Njenga et al. [33], sourcing firewood exclusively from trees on farms is practiced by 5% and 40% of households, and it is the main source for 5% and 65% of households in Kereita and Kibugu, respectively. This is supported by the higher tree cover on farms in Kibugu compared to Kereita as shown in Figs. 5 and 6. The potential of sourcing firewood from trees on farms requires knowledge about amounts, for example, what one tree can produce and the per capita consumption so farmers can calculate workloads and potential profit effectively. Data from the use of firewood showed that per capita consumption per day was 1 kg equivalent of 5 kg per day per standard household and 0.8 kg equivalent of 4 kg per day per household in Kereita and Kibugu, respectively [19,33]. The estimated 1 kg per capita per day of firewood consumption was the amount estimated in another study carried out in rural Tanzania [36].

A study in Kwale, a coastal region in Kenya, revealed that *Casuarina equisetifolia* trees aged 3–6 years and those above 6 years produce 72.5 kg and 28.4 kg of firewood from prunings, respectively, per year [37]. *Azadirachta indica* (Neem) trees aged 3–6 years and those above 6 years produce 40.3 kg and 15 kg of firewood, respectively. Both trees are mainly produced for timber and medicine in the case of Neem, and are pruned around January before the long rains in March so as to reduce shading effects on crops and allow firewood to dry well. This annual biomass production from prunings from trees on farms, combined with the household firewood requirement, is an illustration of estimation of the number of trees a household needs to be self-sufficient. Calculation

on number of trees required for self-sufficiency in firewood for a standard household was not possible as quantitative data on biomass from prunings from tree species in the two villages was missing. It is important to note that different species yield different amount of biomass at different age and therefore local species needs to be used in this kind of calculations. However Njenga et al., [11] used qualitative information and made a rough estimate that about 76 trees of *Grevillea robusta* at a biannual (after every 2 years) pruning regime were required for self-sufficiency in firewood supply for a standard household in Kibugu. Farmers had developed a rotational pruning regime that ensured that some pruning took place every year.

The FGD showed that sourcing firewood from on-farm trees however, requires that farmers have money to pay for hired labour in homes without family members who could do the work. Farmers met this cost by selling two trunks of mature trees on their farms. In Kibugu, for example, labour for the amount of firewood that supplied cooking fuel to a household for a year includes 21 young-man-days to prune and size the wood and 15 woman-days to carry the firewood home from farms. This work was carried out in one week and cost about KES 10,800 (US\$ 108) at a 5-hour day rate of KES 300 (US\$ 3) per person. Farmers generated the money to pay for this labour from sale of two mature trees at about KES 6000 (US\$ 60) each and the residues were left for farmers to use as firewood. The firewood is cheaper compared to the opportunity cost of sourcing firewood from forests, and the pruned trunk of trees are sold for timber when mature. For farmers and extension staff the practical

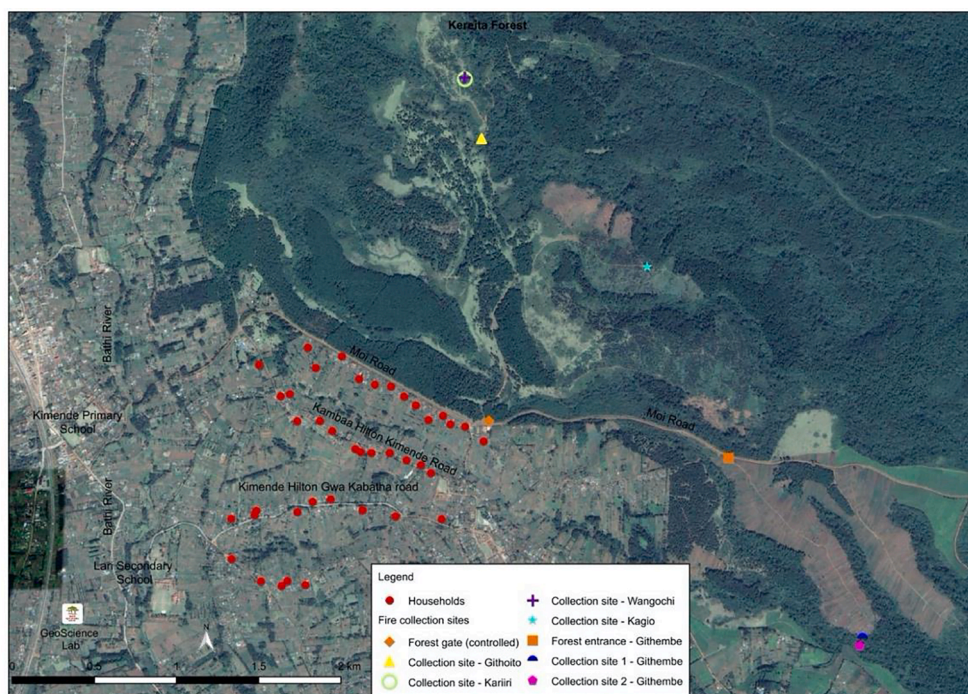


Fig. 5. Location of firewood collection sites in Kereita (Map by Jane Wanjara, ICRAF Geo Science Lab).

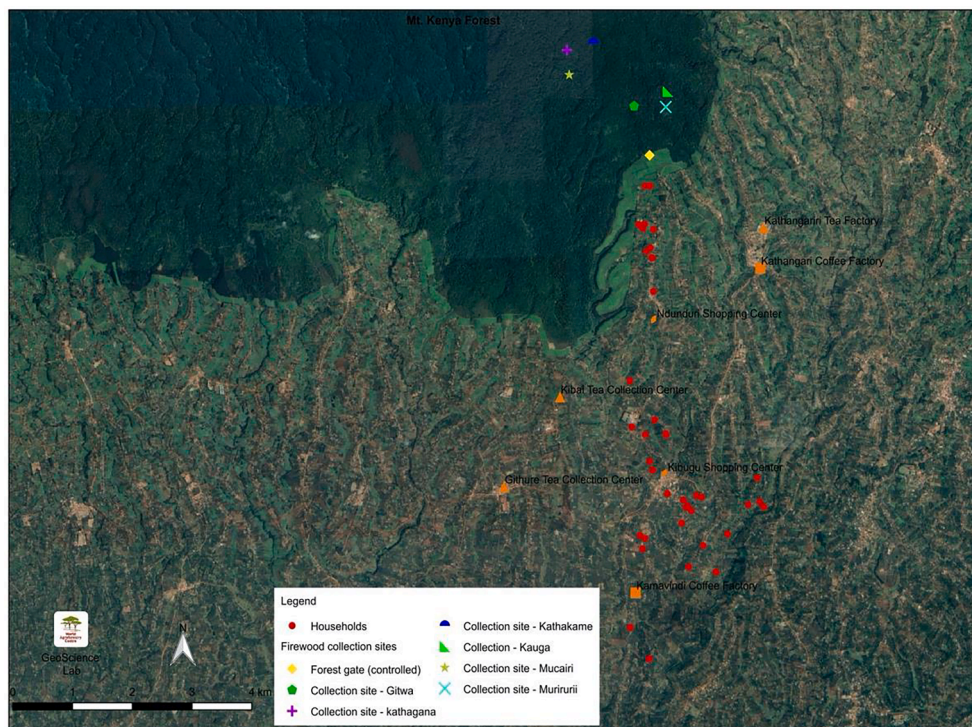


Fig. 6. Location of firewood collection sites in Kibugu (Map by Jane Wanjara, ICRAF Geo Science Lab).



Fig. 7. Women cross a river after collecting firewood in Kereita Forest.

manuals by Moir et al. [38] and Wanjira et al. [39] provides training resources on how to develop quality planting materials, grow and manage trees on farm including pruning for firewood.

3.5.2. Cooking with traditional open fire emits smoke that creates a double tragedy for women, but can be improved with cleaner cooking systems

Women and children spend a lot of time in the kitchen and are the most exposed to smoke from cooking with biomass using open fires in poorly ventilated spaces; a double tragedy in women's lives as sourcing and cooking with biomass are considered health risks [40,41]. When the firewood is brought home, for the majority of households, it is used in

open fires for cooking and heating, resulting in high fuel use and smoke in the kitchen. This is of concern as it is estimated that, globally, over 3.8 million people die every year from household air pollution [42]. A bibliometric study in USA revealed a similar trend, though of different nature in persistent in energy burden and its relationship with health [43]. A solution to this could be use of improved cooking systems which have lower fuel consumption and emissions. For instance, use of improved cookstoves by rural households in Ethiopia, Kenya, Tanzania and India saved 18–56% of firewood compared to the three-stone open fire and other traditional stoves [18,44,45,7,36,46]. Njenga et al. [18] reported that the use of galvanized top lit updraft (TLUD) gasifier by households in rural Kenya reduced concentrations of CO and PM_{2.5} in the kitchen by 45% and 90%, respectively, when compared to the three-stone open fire. Through the use of a TLUD gasifier branded “GASTOV” by households at Kwale County in Kenya, concentrations of CO, CO₂ and PM_{2.5} in the kitchens were reduced by 57%, 41% and 79%, respectively, compared to the three-stone open fire [44]. The benefits of improved stoves would be optimized if they are used and hence the need to ensure that they fit well into the cooking culture and meet people's needs and preferences, barriers that have been noted to limit adoption [47,48,32].

Health benefits have been reported from the use of improved stoves. For instance, in the brackish water area of south-western Bangladesh, 98% of women had better health and lifestyle improvements by using an improved earthen stove [49]. In Nicaragua, a shift from cooking with open fire to using eco-stove (PROLENA, Managua, Nicaragua) for a year reduced blood pressure by 5.9 mmHg and 4.6 mmHg for women aged 40 and obese women, respectively [50]. Drying firewood well enhances combustion by reaching high temperatures, consequently reducing smoke in the kitchen and wastage of wood [51]. The FGD showed that drying of firewood was done through air drying under a shed next to the kitchen. Traditionally, this is carried out through use of gaseous energy from cooking in an open fire where firewood is placed on a rafter just below the roof. Drying of firewood before use was common when it was sourced from trees on farms following the pruning regime. Firewood sourced from forests, on the other hand, was mainly used in its form as there was no opportunity to dry it as only little amounts were fetched per

trip that met the immediate need, implying a higher chance of smoke in the kitchen

4. Conclusion and recommendations

At first glance it would appear to be more efficient to switch from cooking with firewood to an alternative that produces less or no smoke, and does not require the heavy, physical labour of collecting firewood from forests. This has not happened as cooking and heating space with wood burning in a three-stone open fire is a key component of energy stacking. Other types of stoves are designed to be efficient and conserve ambient heat, which in highland areas would mean that critical home heating needs are not met.

Collecting firewood from forests takes away women's opportunity for involvement in other productive or leisure activities, while reducing their capacity to perform their duties optimally due to physical body exhaustion. Further, women face the risks of physical injuries and attacks by wild animals or human beings in the forest. In addition, collecting firewood from forests is another role among the many physically demanding productive and domestic chores women carry out, thus rendering their work 'never done'.

With depletion of residues near forest edges, firewood collection is becoming increasingly difficult as women have to walk longer distances into the forests.

Nonetheless, women for whom cash incomes involve manual farm labour, picking tea leaves or coffee berries or travelling with heavy loads of vegetables to a market, seem to view the trade-off between firewood collection and paying for energy differently.

Cultural norms in regard to masculine and feminine roles influence the tasks performed in firewood sourcing by men and women including the young and youth where, for example, the mode of transportation has a negative impact on women's wellbeing. There is need for a cultural shift on the need to use transportation methods that remove women's burden of carrying firewood on their back.

Government regulation on forest management, such as effecting bans on logging, affected the community's access to firewood a key cooking fuel in rural Kenya, where the supply goes down and cost goes up with negative effects on livelihoods. The government should, at the same time, support plans that allow communities to continue accessing forest residues for firewood.

That said, a shift towards growing trees on farms, effective drying of wood, and perhaps targeted use of improved cook stoves during the day or dry seasons and improving on the three-stone open fire, could reduce women's burdens. Sourcing firewood from trees on farms saves time, reduces drudgery and promotes income generation through sale of surplus firewood, creates job opportunities for youth and women, and allows wood to dry well, hence reducing fuel consumption and emissions during cooking. Pruning trees on farms and carrying the load home takes a shorter time; for families without members to provide labour, sale of a few trees for construction material financed payment of hired labour while leaving prunings for farmers' use.

It should be noted however, that single women, women without children or women whose children have left home, can collect firewood together with a group of friends from the area who also need fuel. On-farm production requires crossing a gender line either in the form of boys who prune or possibly farm management negotiations if the farm is jointly owned as most are. In rural areas the roles for men and women were clear and inflexible. According to the FGD participants, it would not be at all acceptable to have a young girl climb a tree because people on the ground could look underneath her skirts. The idea that a girl could put on a pair of pants and climb anyway was simply inconceivable. From this perspective, on-farm agroforestry worked better if the farm was larger, the relations between men and women, women and boys were relatively cooperative, and the cash crops benefited from shade. If any of these factors were missing, agroforestry seemed less possible. At the end of the day, land-poor, older, widowed or divorced women,

childless women or women whose children had left home were more likely to be carrying firewood from the forest. This is because agroforestry demanded a resource or access to male human capital. At the same time, because of the physical wear and tear of a lifetime of manual labour, these women were most likely to be unable to carry the necessary heavy loads.

There is need for better ways to provide for injured, ill or elderly women who are living alone and have no one to pay for their cooking and heating fuel. Most importantly perhaps, this is a circumstance where the seemingly obvious problem; inefficient, unhealthy biomass use and burdensome collecting practices, must be understood as a more complex socially informed phenomenon. An improved stove or stronger electricity grid that require consistent cash incomes and reliable maintenance schemes, may actually displace the central role some women play in their households and deprive them of the critical human need for self-determination. The three-stone open fire could be improved so as to continue providing the multiple benefits it does, while reducing the negative effects on health and the high fuel consumption.

On-farm sourcing of firewood and use of improved stoves need to be combined with improved housing conditions and increased sources of income to effectively address energy poverty. Stakeholders working on cooking energy should carry out capacity development on growing trees on farm while matching suitability of the systems to agricultural activities and land sizes, as well as development of cleaner cooking technologies that meet people's needs to ensure that no one is left behind. The Kenya's National Gender and Equality Commission should ensure that gender and inclusion are implemented under government plans on improving access to domestic energy. There is need for further research on causes and impacts of the energy burden and solutions that work for the people.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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