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Recycling for deforestation reduction in Tanzania: Why are households not using waste charcoal?

NORBERT J. NGOWI[1,♥], ATHANAS A. NGALAWA[2,♥♥]
[1]Institute of Development Studies, Mzumbe University. P. O. Box 83, Mzumbe, Morogoro, Tanzania.
Tel.: +255-23-2604380/1/3/4, Fax.: +255-23-2604382, ♥email: njngowi@mzumbe.ac.tz
[2]Centre for Rural Development, Mzumbe University. P. O. Box 83, Mzumbe, Tanzania. Tel.: +255-23-2604380/1/3/4, Fax.: +255-23-2604382,
♥♥email: aangalawa@mzumbe.ac.tz

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Abstract. *Ngowi NJ, Ngalawa AA. 2023. Recycling for deforestation reduction in Tanzania: Why are households not using waste charcoal?. Asian J For 7: 1-8.* Charcoal making and the subsequent waste charcoal produced contributes to deforestation and the production of greenhouse gases, the major drivers for climate change. Whereas climate change is increasingly becoming a public issue, Africa produces 63% of the total global wood charcoal. Since 2004, the demand for wood charcoal on the continent has risen by 30%, the highest in the world. The low efficiency of locally made earth kilns, between 8% and 36%, reported in Africa has contributed to increased waste charcoal production on the continent. However, more information is needed on the cycling use of waste charcoal in low-income countries. In order to improve forest resource use, we investigated the factors influencing the cycling use of wood waste charcoal in Kilosa District of East-Central Tanzania between 2020 and 2021. A total of 298 randomly selected households were involved in the survey. SPSS version 20 tools were used in the analysis through cross-tab descriptive statistics and the independent sample t-test. Results show that sex, age, expenditure on fuel energy, environment, and technology for cooking significantly affected household use of waste charcoal ($p < 0.05$). The availability of wastes ($v = 0.272$) was the most influential factor in the cycling use of waste charcoal. The paper shows that cycling the use of wood waste charcoal would reduce volumes of trees cleared for firewood and improve sanitation by removing rampantly disposed waste from the environment.

Keywords: Charcoal grates, deforestation, greenhouse, rampant, kiln

INTRODUCTION

The African continent ranks first in wood charcoal production, accounting for 30 million tonnes of global charcoal output (Steierer 2011). This trend has been increasing by 30% (https://www.grida.no/resources/7497). The increase in charcoal demand as the main energy source is attributed to many factors, including reliability, high calorific value, technology, urbanisation, and economic incentives (Steierer 2011), causing a significant increase in the production of the waste charcoal. Public policies, gender, cultural practices, behavior, technology, and cooking methods are among the factors that explain the choice of energy types in many developing countries (Masera et al. 2000; Wilson and Dowlatabadi 2007; Kowsari and Zerriffi 2011; Asada 2019). The changes in income between rural and urban households are associated with a shift in the use of energy type from the traditional to the modern one (Masera et al. 2000; Kowsari and Zerriffi 2011). Barnes and Halpern (2000) show that people maintain both the traditional and the modern energy types irrespective of changes in income or location. On the other hand, studies (Kowsari and Zerriffi 2011; Lewis and Pattanayak 2012; Sander et al. 2013; Tao et al. 2018; Wassie and Adaramola 2019, 2020; Doggart et al. 2020) assert that despite the introduction of various efforts including policy change, energy subsidies to electricity, and the use of alternative energy sources among others, still more than 90% of people in East Africa including Tanzania, prefer wood charcoal as the most favorite fuel energy for cooking, thus escalating pressure to forests and woodland ecosystems in the region (https://www.grida.no/resources/7497).

Studies (Antal and Grønli 2003; Ishengoma et al. 2016; Nweke 2017) report that waste charcoal such as tree barks, residues, and specks of dust are generated mainly due to the low efficiency of locally-made earth kilns during the carbonization process (Figure 1A), means used in the transportation, handling in the warehouses, and handling in the marketing or collection centers. Despite the potential of wood waste charcoal as recycled fuel energy, animal feed supplement Louis et al. (2018), and green manure, waste charcoal is considered useless in many low-income countries and thus disposed off with little or no consideration of its impact on the environment. The practice contravenes with research findings like the one by Eggleston et al. (2006), who report that the sector contributes to about 5% of the global greenhouse budget, with air pollution estimated at US$ 6.0 Billion in low-income countries in 2013 (World Bank and Institute for Health Metrics and Evaluation 2016). Thus, the rampant disposal of waste charcoal, as observed in the study area and illustrated in Figure 1B, may adversely contribute to greenhouse gases leading to increased global temperature and climate change.

Yu et al. (2021) show that the released amount of Carbon Dioxide gas (CO_2) through the energy from forest biomass is used by plants, thus making biomass fuel mainly renewable and carbon-neutral. Waste food, agricultural residues, and forests are among the biomass fuel sources of which the latter (forests) are the most vital biomass carbon producers (Gonçalves et al. 2018). However, Scheer and Moss (2012) report that cutting trees to obtain biomass fuel makes carbon neutrality out of the equation, leading to extra CO_2 in the environment, which contributes to the climate change phenomenon. Studies show that nearly 50% of renewable energy in the EU region is biomass, and the trend is slowly growing by 2030 (Ravilious 2020). In some EU countries, for instance, nearly 70% of renewable energy consumption in Denmark and around 25% in Sweden comes from forest biomass (Titus et al. 2021). In other places like Australia, Yu et al. (2021), biomass fuels alternatively, unlike fossil fuels, cut atmospheric CO_2 by 25 million tonnes per year.

Biomass, in general, and forest biomass, are significant energy sources in most developing and developed countries (Scheer and Moss 2012). However, approximately 15 billion trees are cut down annually, reducing the number of trees by 46% worldwide (Ehrenberg 2015). In Africa, where 93% of rural and 58% of urban households depends on wood biomass for fuel, estimates show that the extraction of wood fuels from trees contributes to 70% of deforestation on the continent (Wassie and Adaramola 2020, 2019). The scenario suggests that the utilization of wood biomass will remain fundamental and increase over time due to population growth and limited options for alternative energy sources in low-income populations (Subedi et al. 2014). It also suggests that more feedstock is required, resulting in bulk extraction of forest biomass for fuel (Titus et al. 2021). In Tanzania, deforestation has been accelerated by wood-fuel extraction, changing land use, and unsustainable extraction methods, among others (Scheer and Moss 2012; Manyanda et al. 2020). In some cases, the destruction is often not observed, as degraded forests often retain a closed canopy (Manyanda et al. 2020).

Different approaches have been implemented to reduce or curb deforestation and woodland degradation. They include: reusing biomass fuels, oil seeds for biodiesel, sugar plants for bioethanol, food waste, and pulp remains for biogas energy production, among others (C and E Advisory Ltd 2020, unpublished data). However, some countries like Djibouti, more prone to aridity than other countries in the region, have completely canceled any utilization of wood biomass at a large scale (C and E Advisory Ltd 2020, unpublished data). Subedi et al. (2014) show that biogas can lessen deforestation from wood fuel demand by 6% to 36% in 2010 and 4% to 26% by 2030. This is equivalent to 10-40% of absolute deforestation in 2010 and 9% to 35% by 2030.

Malimbwi and Zahabu (2008) and Wassie and Adaramola (2019) purport that the predominance use of wood fuel energy in domestic chores is the main cause of forest and woodland degradation in many low-income countries. For example, in Tanzania (https://www.climatelinks.org/resources/greenhouse-gas-emissions-factsheet-tanzania), report show that forests and changes in land use and agriculture are the largest sources of Greenhouse Gas Emissions (GHGs), contributing to 72.7% and 17.3%, respectively. On the other hand, energy and wastes contribute 7.8% and 1.6%, respectively. This situation invites the question of how countries like Tanzania can reduce the annual volume of trees cut, rampant disposal of waste charcoal, GHGs, and household budget on energy by formulating and adopting user-friendly strategies of recycling wood waste charcoal that eventually can contribute to improving community livelihoods and the environment. However, despite the potential of wood waste charcoal in recycled fuel energy, more is needed about the scope of utilization of these resources in Tanzania. Thus, unless the scope and determinants of wood waste charcoal utilization are well established, it is difficult to promote strategies for the use of recycled wood waste charcoal by the local community and integrate this into the local government plans for natural resources and livelihood security in the country.

Figure 1. Traditional earth kiln (A) and rampant disposal of waste charcoal at Maguha market (B)

This study aligns with Tanzania's Development Vision 2025 (www.mof.go.tz/mofdocs/overarch/vision2025.htm) and the National Environmental Policy (URT 2021), which emphasize the need for the reduction of waste for environmental sustainability by promoting environmentally - friendly technologies for sustainable development. The study on recycling waste charcoal in Tanzania aimed to understand the determinants of households' use of waste charcoal for reducing the cutting down of forests and woodlands for biomass fuel in east-central Tanzania.

MATERIALS AND METHODS

Description of the study area

This study was carried out in Kilosa District, Tanzania, located at latitude 5°55' and 7°53' South and longitude 36°30' and 37°30' East (Figure 2). The district occupies 14,918 km^2 of land (Ishengoma et al. 2016). Forests and woodlands occupy about 40% of the total land area. Village forest reserves occupy about 88,879 ha, national forests reserves 66,517 ha, district council forests reserves 8,168 ha, reserved village land forests 208,732 ha, and forest plantations are 1,692 ha (Ishengoma et al. 2016). The forest vegetation is characterized by miombo woodland mixed with shrubs and grasslands. The district experiences a semi-arid climate with an average annual rainfall of less than 1000 mm on low plains and a temperature of 25°C. The lowest temperature is 19°C in July, and the highest is 30°C in March. The district falls into three agro-ecological zones. The first is the mountains with an altitude of 2200 m extending along with the Eastern Arc system with pre-Cambrian metamorphic rocks covered with coarse soils. This area is suitable for wheat cultivation. The second zone is an upland plateau, also known as a cultivation steppe featuring an altitude of about 1100 m. Plains and a few hills with clay and loamy soils dominate this zone. The area is suitable for maize production and livestock keeping as the name depicts. The third zone comprises floodplains at a low altitude of 550 m, dominated by the Wami and Ruaha river basins. In 2012, the district had a population of 438,175 people (males 218,378 and females 219,797) (NBS 2013, unpublished data).

Research design, sampling process, and sample size

This study used both secondary and primary data sources. The secondary data were collected through a documentary review of various reports, journals, books, policy documents, and web pages. The sample size of 298 respondents shown in Table 1 was determined through a sampling process (Israel 1992).

$$\mathbf{n = \frac{N}{1 + N \cdot (e)^2}}$$

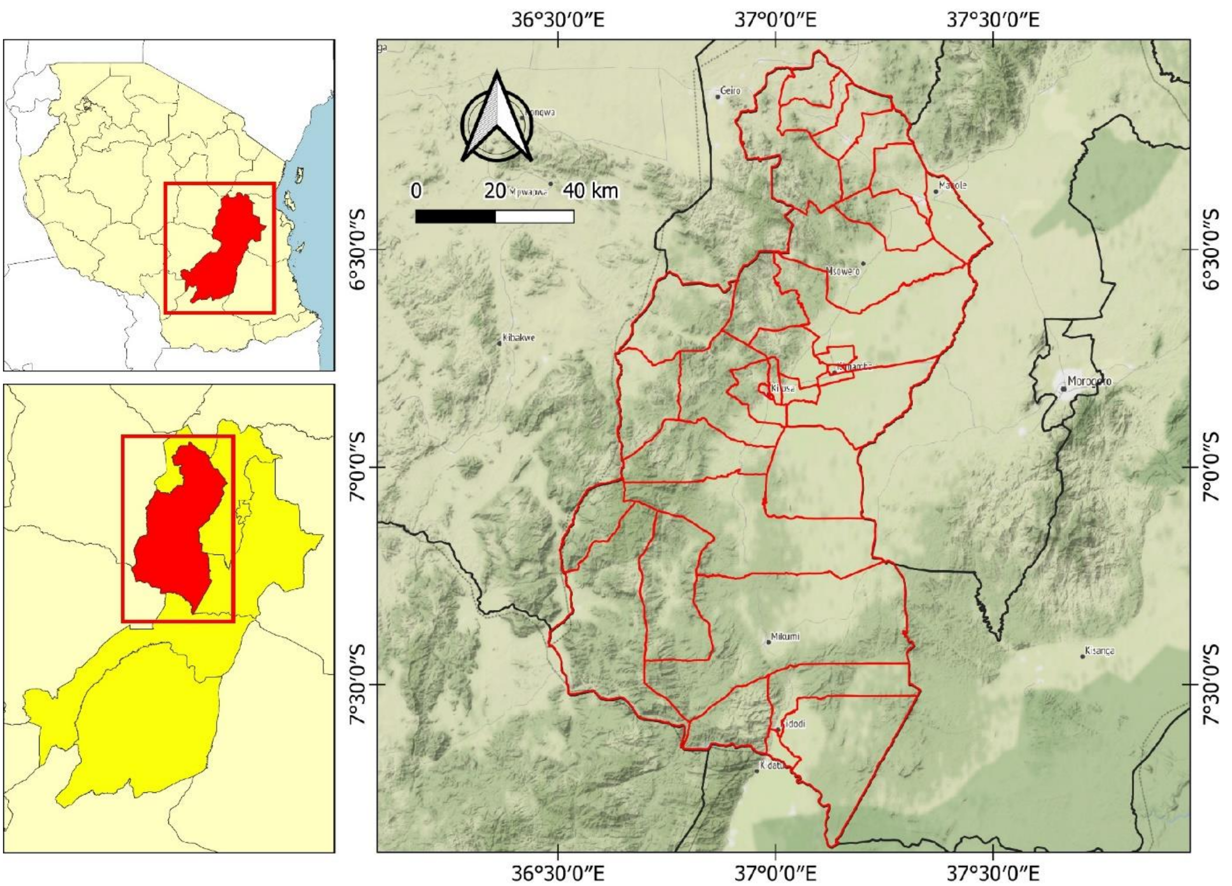

Figure 2. The location of the study area in the Kilosa District, Tanzania (Ishengoma et al. 2016)

In the formula, **n** is the Sample size, **N** is the Number of households, and **e** is the sampling error at 5%. A purposive sampling technique was used to select two study villages. The selection of the two villages was considered, among other factors: annual charcoal production (Ulaya Mbuyuni), marketing centers (Maguha), as well as people involved in the Sustainable Charcoal Project (both villages). This maximized the variability of data on waste charcoal (Ishengoma et al. 2016).

Data collection

Quantitative and qualitative approaches were used in gathering information. This is because a combination of both stories and statistics provided a better understanding of the problem being investigated than using either numbers or stories alone. Primary data were collected using a questionnaire administered to the heads of households. The questionnaire used to collect quantitative information included, among others, thirteen items on household cycling use of waste charcoal. The items were used to assess whether or not households had at least been using cycling waste charcoal a year before the survey period. In addition, qualitative information obtained through interviews with Focus Group Discussions (FGD) and personal observations were used to supplement quantitative information. People aged 18 years and above involved in the charcoal industry were interviewed to provide information on the charcoal-making process, use of waste charcoal, and factors a household considers influencing the cycling use of waste charcoal.

Determination of household cycling use of waste charcoal

The research framework in Figure 3 was used to determine the various features characterizing the cycling use of waste charcoal in Tanzania.

Independent variables: Socio-economic factors (gender, age, education, family size, income, house ownership), energy profile (asset holding, expenditure on fuel energy, routines and habits, and environment), and technology (calorific value, waste size, and grates). Together with the enablers (public policies and institutions) would influence household decisions on waste charcoal usage. In this study, cycling use of waste charcoal was applied as the dependent variable where the value of **"0"** was assigned as a non-user, i.e., a household that does not use waste charcoal, and **"1"** for a user. Households who had at least used waste charcoal within one year before the survey was used as the sampling frame because they could remember the information the study sought. Marie et al. (2021) have adopted a similar approach in Ethiopia.

Data analysis

The statistical significance relation between users and non-users of waste charcoal for quantitative data was assessed through IBM SPSS statistics with a p-value of 0.05 as a cut-off for statistical significance. Chi-square and independent sample t-test (Cramer's v value) was used to determine any relationship between predictor variables (independent) and cycling use of waste charcoal (dependent variable) in the study area. A description method was used to present qualitative data collected through FGD and personal observation. To enhance clarity and more understanding of the subject, presentations have been supported by plates and direct statements from participants of the FGD.

The sequence presented in Figure 4 shows that the quantitative information collected first helped to inform the qualitative step and later assisted in the analysis and interpretation of the earlier.

Table 1. Sample size

Study area	Population	Number of households (N)	Respondents (n)
Ulaya Mbuyuni	3,257	581	237 (119)
Maguha	6,735	1,417	312 (179)
Total	9,992	1,998	549 (298)

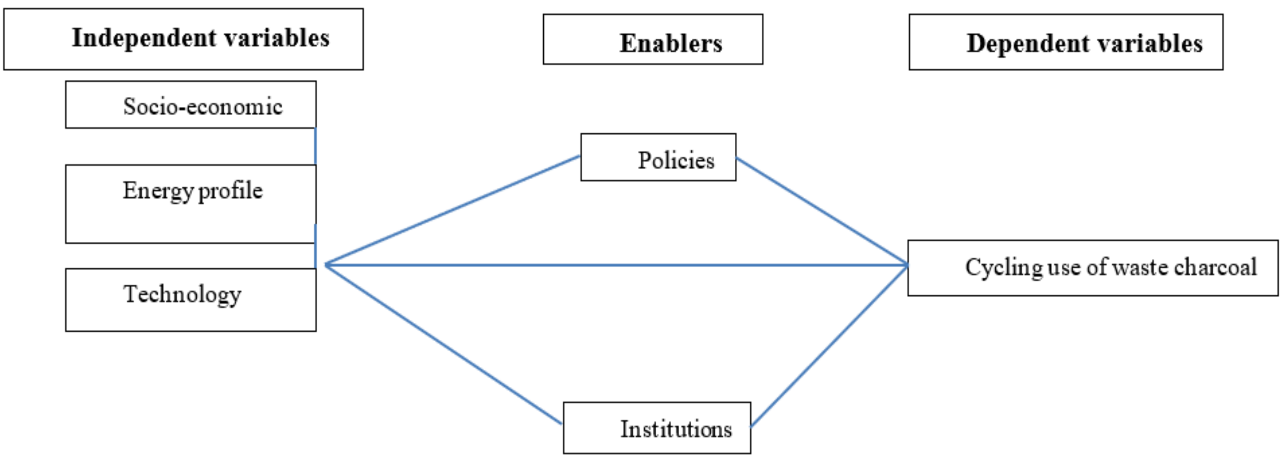

Figure 3. A research framework

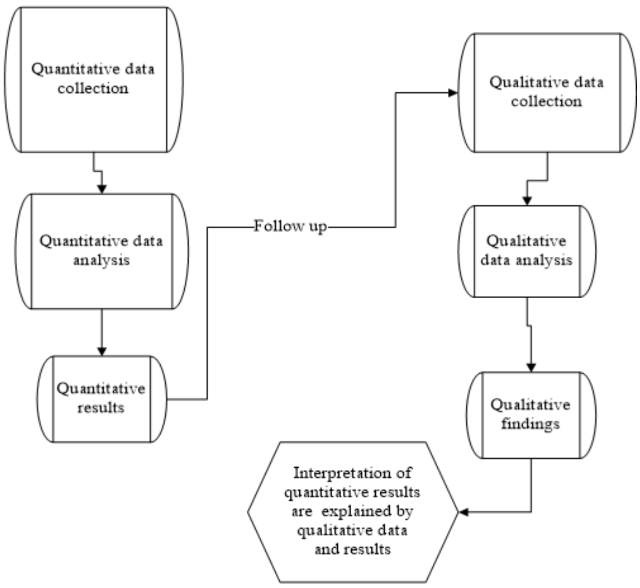

Figure 4. Processes adopted for quantitative and qualitative data collection and analysis

RESULTS AND DISCUSSION

Results

The results in Tables 2 and 3 show that a total of 298 respondents, determined by the sampling process, male-led households formed a large proportion of 164 respondents and 134 female respondents. Among waste-charcoal users, 129 (43.3%) females were leading in using waste charcoal by 23.5% to 19.8% for males (Table 3). The rest, 169 (56.7%), did not recycle waste charcoal. Results in Table 3 show that 30.2% of households used less than 50 kg of waste charcoal in a year. This was followed by 6.4% who used between 51 and 150 kg of waste charcoal. Only 3% were using 151 kg and above. The remaining 3.7% needed to learn how much waste charcoal they recycled.

The t-test results (Table 4) reveal that the mean age for non-waste charcoal users was higher (M = 3.20) than for waste users (M = 2.70). Age, sex, and expenditure of household head on fuel energy (see Table 4) show that age was the strongest factor determining the use of waste charcoal among household-socioeconomic factors ($v = 0.257$) followed by sex ($v = 0.163$) and expenditure on fuel energy ($v = 0.123$) and the relationship are significant ($p < 0.05$). Further, the results revealed that the mean age, education, family size, and house ownership for waste charcoal users were smaller than non-waste users' by 0.47 from 0.66 for waste users. Results show that the availability of waste charcoal ($p = 0.68$) was the most influential factor impacting the use of waste charcoal ($v = 0.272$), although it was not significant ($p > 0.05$) when compared to the environment and technology for cooking. Independent t-test results show that the difference in means for public policies and institutions-related factors was higher for waste charcoal users (M = 1.52) than non-user households (M = 1.43).

Table 2. Household cycling use of waste charcoal

Variable	Category		Total	χ2	df	p-value	Cramer's V
	Non-user	user					
Male	105	59	164	7.945	1	0.005**	0.163
Female	64	70	134				
Age	169	129	298	19.704	1	0.000***	0.257
Expenditure	86	212	298	4.508	1	0.034**	0.123
Policies and institutions	169	129	298	0.993	2	0.321	0.058
Wastes availability	169	129	298	22.114	3	0.68	0.272
Technology	169	129	298	7.034	1	0.008**	0.154
Education	169	129	298	1.164	3	0.818	0.062
Family size	169	129	298	3.782	3	0.189	0.113
House ownership	169	129	298	0.112	1	0.739	0.019
Income	169	129	298	11.613	3	0.922	0.197
Environment	169	129	298	19.916	4	0.020**	0.259
Access to recyclables	169	129	298	4.285	2	0.953	0.120
Asset holding	169	129	298	10.964	3	0.701	0.192

Note: **, *** are significant at 0.05 and 0.01 levels of significance, respectively

Table 3. Quantity of waste charcoal used per household in a year

Response			Quantity of waste used per household per year				Total
			Did not know	50 kg and below	51 - 150 kg	151 kg and above	
	No	Count (%)	26(8.7%)	84(28.2%)	30(10.1%)	29(9.7%)	169(56.7%)
	Yes	Count (%)	11(3.7%)	90(30.2%)	19(6.4%)	9(3.0%)	129(43.3%)
Total		Count (%)	37(12.4%)	174(58.4%)	49(16.4%)	38(12.8%)	298100.0%)

Table 4. Determinants of use of waste charcoal

Variables	Non-user (n = 169)		User (n = 129)		t-value	p-value
	Mean	SD	Mean	SD		
Sex	0.38	0.487	0.54	0.500	- 2.847	0.005**
Age	3.20	0.917	2.70	1.115	4.275	0.000***
Education	1.02	0.607	1.01	0.566	0.231	0.818
Family size	1.56	0.596	1.47	0.586	1.316	0.189
House ownership	0.80	0.402	0.78	0.414	0.333	0.739
Income	1.54	1.029	1.55	1.046	- 0.098	0.922
Expenditure on energy	0.66	0.474	0.78	0.419	- 2.132	0.034**
Asset holding	2.87	0.791	2.91	0.870	- 0.385	0.701
Environment	2.05	1.017	2.33	1.085	- 2.337	0.020**
Policies and Institutions	1.43	0.730	1.52	0.782	- 0.994	0.321
Technology for cooking	0.73	0.446	0.58	0.495	2.675	0.008**
Access to recycles	0.03	0.23	0.03	0.174	- 0.059	0.953
Availability of wastes	1.60	0.701	1.46	0.586	1.834	0.68

Note: **, *** are significant at 0.05 and 0.01 levels of significance, respectively

Discussion

The findings suggest that people do not use waste charcoal as a source of energy at the household level because they need more knowledge about how to use it. This study found that fewer households used waste charcoal than those that did not. This was supported by qualitative information from participants of the FGD, who noted that "waste charcoal is thrown away." They have no use". This was evidenced through observation in transect walk where waste piles were poured at different places (see Figure 1 B). When asked why waste charcoal was not used, they gave three reasons: (i) the incompatibility of the sizes of particles that constitutes the waste with the sizes of the grates of the cooking stoves, thus passing easily through grates within the cooking stoves, (ii) people do not have appropriate knowledge and skills of making the small particles big enough to fit in their cooking stoves, and (iii) waste charcoal they produce little energy, therefore, a limiting factor to its use. This study shows that people do not use it because their knowledge is restricted to using the waste in the form it exists without any modification. For example, waste charcoal was found as small particles used to light charcoal stoves in some households. This suggests that the people are aware of the possibilities of using the waste should they be trained on how to modify the small particles and make it big enough and thus compatible with the grates of their cooking stoves along with the capacity of the modified sizes of the wastes in generating enough energy for household use.

These results are supported by a study by Ma et al. (2013) in 28 OECD countries, which show that one factor might have a positive effect in one case and a negative one in others. Furthermore, these results are consistent with findings in Uganda by Asada (2019) and in Thailand by Dunn et al. (1982) that low calorific value for waste charcoal was suitable in rice cooking and steaming banana, respectively. Participants of the focus group discussion explained that: Waste charcoal was not used because they did not generate enough energy for household use. In their own words, they said, "Heat produced from waste charcoal is of low quality, and they burn for a short while. Who is to use such a source of energy, particularly when you come from farm "shamba" work, tired and hungry?". (Ulaya Mbuyuni, December 2020).

This quotation implies that people cannot modify the waste charcoal particles and make them feel like normal charcoal particles. Further, it suggests that the dominant economic activity of the people (agriculture) needs to give them more time to research how to modify the waste charcoal. The hand-to-mouth scenario that characterizes their agriculture has made them think that charcoal for household use should always be in a form that is ready for consumption.

Although household behavior was not among the 13 factors investigated, this study revealed that nearly 1% of respondents were unaware that fuel energy could be tapped by cycling waste charcoal. This has impacted the overall results from other factors investigated by showing that households that discovered the usefulness of charcoal wastes reused them. This study found that 3.7% of households using waste charcoal did not know the quantity of waste charcoal recycled because the very little waste generated by households was used by mixing with other charcoal of larger particle sizes and not cumulatively added to the total amount of waste produced.

The findings also suggest that the youth are more innovative than the elders. The youth had innovations of increasing their income by making use of the waste charcoal, as evidenced by the results showing that households that used waste charcoal were of relatively younger mean age (M = 2.7) compared to (M = 3.4) for non-user - households. The explanation for this is that households of younger age were more involved in charcoal making and transportation processes, so they had greater chances of accessing waste left in kins in the wild, during packing and transportation of charcoal or selling centers, and bringing them home for use compared to the elderly one. This study's results corroborate previous findings from Peša (2017) study, which found that behavior rendered large quantities of waste from sawdust in wood processing industries to remain unutilized in the Copper belt of Zambia. In addition, Brown et al. (2017), in a study conducted in South Africa, found that behavior was one of the limiting factors to adopting electric cooking from traditional energy sources.

Figure 5. Charcoal sacks found in the study sites, each weighing beyond 50 kg

Concerning the environment and health, findings suggest that people were aware of environmental and health hazards caused by mishandling and poor disposal of waste charcoal. Most charcoal makers and dealers did not use masks in undertaking their respective activities. This research shows the negative impacts of the increased waste from wood charcoal on the environment. According to Nyundo, one of the participants in the FGD said: "Waste charcoal contributes to human diseases by increasing health risks. When you inhale dust from waste charcoal, it can destroy the functioning of your lungs. However, if you work in the charcoal industry and stay without a shower, you will likely suffer from skin diseases. This is because the skin will be rough and dry. This dryness is likely to cause skin diseases as charcoal dust can penetrate your body through the small openings on the skin". (Maguha, December 2020). This quotation reflects that people know the health hazards associated with poor handling of waste charcoal.

The environment variable shows a p-value of 0.020 and technology for a cooking p-value of 0.008, indicating a significant effect on waste charcoal cycling. For instance, the rain was found to have influenced the use of waste charcoal and household choice of energy type. Households with outdoor kitchens preferred using firewood over any other type of energy because it tended to cook faster, saving time for other activities at home, including farming. The results of this study are similar to the findings of the study conducted by Brown et al. (2017) in South Africa, which show that the environment has both direct and indirect influence on the use of types of energy sources. This research shows that waste availability ranked first, followed by environmental variables in influencing the cycling use of wood waste charcoal.

This research revealed that public policies and institutions did not impact waste charcoal utilization (p = 0.321) and Cramer's v value (v = 0.058. These findings contradict those from Ma et al. (2013), Malimbwi and Zahabu (2008), and Doggart et al. (2020), which showed that government policies were the most important factor in improving the utilization of energy in low-income countries. The contradiction is mainly due to the enforcement of rules and guidelines according to the Government Notice (Forest Royalty Collection). The rules set a maximum of 50 kilograms (kg) per sack of charcoal as the basis for calculating royalty of Tanzanian Shillings 250/= per Kg of charcoal (equivalent to US $ 0.114/kg. Calculated at an exchange rate of 1.00 US $ = 2200/=Tanzanian Shillings). However, most sacks weigh beyond 50 kg, contrary to the guidelines. This uncontrolled weight is based on various factors, including the area where charcoal is being processed and tree species used. For instance, in *Brachystegia*, *Commiphora*, *Combretum*, and *Albizia* species-dominated woodlands, charcoal makers were found parking the charcoal bags beyond the recommended weight in order to ease the exercise of transporting the charcoal bags from the point of production, but also the practice provided an opportunity for charcoal traders to avoid payment of appropriate royalty to the respective authorities during transportation of the bags to the final destination where charcoal was sold (Figure 5).

In conclusion, this research shows that the waste availability variable ranked first, followed by environment, and age, in influencing the use of wood waste charcoal. Most households' waste charcoal users used at least one bag of 50 kg or less in a year. This paper shows that cycling the use of waste charcoal would reduce volumes of trees cleared for firewood and rampant disposed of wastes from the environment. This study recommends that people be trained in appropriate knowledge and skills to make the small waste particles big enough to fit in their cooking stoves.

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