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GEOGRAPHY | RESEARCH ARTICLE

Patterns and predictors of household fuel choices in Maswa District, Tanzania

John G. Safari^{1*}, Juliana K. Mwangerezi² and Canute B. Hyandye³

Abstract: This study assessed the spatial and non-spatial patterns of household fuel choice and the factors influencing choices using data from rural and urban areas of Maswa District, Tanzania. Household spatial information was collected using a handheld Garmin Trex Global Positioning System to enable modeling and visualization of energy consumption. The Hot Spot Analysis (Getis-Ord G_i^*) method was used to map the clusters of different types of cooking fuels. The non-spatial data were fitted to a Multinomial Logit model to estimate the significance of the factors that influence the choice of cooking fuels. A transition from traditional to modern fuels as explained in the “energy ladder” model suggests that with increasing affluence, a progression is expected from traditional biomass fuels to more advanced and less polluting fuels. Contrary to this model, however, multiple-fuel use or fuel stacking was more prevalent than fuel switching. Fuel stacking constituted traditional (firewood, 63.9% of the households), transitional (charcoal, 66.6%), and modern (kerosene, liquefied petroleum gas, and electricity, 25.4%) fuels. Demographic and socio-economic factors were essential in household fuel choices. Overall, biofuels are the most common energy sources both in rural and urban areas, albeit at a varying degree of magnitude and significance. These results suggest the need to increase the production of biomass resources and end-use efficiency while promoting the use of clean fuels.

Subjects: Development Studies; Health & Development; Rural Development; Urban Development; Environment & the Developing World

Keywords: Cooking fuel; energy; fuel attributes; fuel choices; spatial patterns

1. Introduction

Energy services are essential inputs to economic and social development. This is because clean, efficient, affordable, and reliable energy services help in reducing poverty, improving the health of people, promoting gender equality, and enhancing sustainable management of natural resources (Monyei et al., 2018). The reliance on biomass is particularly high in sub-Saharan Africa (Mensah & Adu., 2015). However, the use of biomass can lead to high levels of indoor smoke and a complex mix of health-damaging pollutants (de la Sota et al., 2018). Health problems resulting from exposure to the contaminants from firewood may cause difficulties in carrying out economic activities (Stabridis & Van Gameren, 2018). Besides, the energy efficiency is as low as 7–12% for fuelwood and 11–19% for charcoal (Felix and Gheewala, 2011). Nevertheless, empirical evidence shows that modern cooking fuels improve socio-economic and health outcomes, preserve local ecosystems, and reduce green gas emissions (Yiran et al., 2020).

Household energy usage is but dominated by a transition theory in which households gradually ascend an energy ladder. The model underlying the energy ladder assigns differences in energy-

use patterns between households to variations in economic status (Rahut et al., 2014). In this model, non-income factors are thought to have little effect on fuel selection. The ladder begins with a biomass energy source (firewood and charcoal), and as income increases, moves upward to commercial energy sources (kerosene and Liquefied Petroleum Gas-LPG), and ends with electricity (Akpalu et al., 2011). It is assumed that a household faces a choice among alternative fuel types and that the choice maximizes utility. In this regard, the choice made among the alternative fuel types will be a function of the probability that the utility associated with a particular option is higher than that associated with other alternative fuel types (Baiyegunhi & Hassan, 2014).

A growing body of empirical literature on household energy use shows, however, that the energy transition does not occur as a series of simple, discrete steps as predicted by the energy ladder model (Van der Kroon et al., 2014). Instead, multiple-fuel use is more common and is also referred to as fuel stacking. Empirical evidence also suggests that depending on the degree of access to other sources of energy and the specific conditions of households, people decide on the type(s) and amount of energy used (Shamaki & Bucham, 2019). Indeed, social forces such as power, culture, and institutional arrangements shape the scale of production, distribution, and uses of energy (McKague et al., 2016; Uhumamure et al., 2017).

In Tanzania, the energy balance is dominated by biomass-based fuels which account for 94% of the primary energy supply (URT, 2016). However, reports suggest that biomass resources are under severe strain and that unsustainable wood consumption compromises the ability of forests to cater to energy needs (Lusambo, 2016). It has been projected that the demand for charcoal, without supply and demand-side interventions will double by 2030, from approximately 2.3 million tons of charcoal (URT, 2015). This situation is exacerbated by the increasing concentration of the population in urban areas and the lack of alternatives to wood/charcoal. The semi-arid of Maswa District is typical of areas in many parts of Tanzania experiencing challenges in the supply of energy (Wiskerke et al., 2010). Historically, Maswa District was once covered by Miombo woodlands but massive deforestation occurred due to farming and grazing activities. Wood production and other land use activities in the district have increasingly reduced areas of natural woodland (UNDP, 2012), posing risks of energy poverty.

Much of the evidence, however, suggests that users' perspectives of cooking fuels, and the nature and magnitude of the factors that affect household cooking fuel choices vary widely over geographies, socio-economic and environmental conditions (Behera et al., 2016; Ravindra et al., 2019). There is limited information on household choices of cooking fuel and the factors influencing choices, particularly in growing towns of semi-arid areas. Knowledge regarding public preferences on cooking fuels and of the factors that drive household energy consumption patterns is important in developing interventions that seek to secure sustainable energy futures. This paper aims to assess the spatial and non-spatial patterns of different cooking fuel choices and the factors determining household choices of cooking fuel.

2. Methodology

2.1. Study area

This study was conducted in Maswa District, Tanzania. The district is bound between latitude 2° 47'55"S to 3°36'15"S and longitude 33°25'25"E to 34°9'3"E. The area lies at 1272 m above the mean sea level and receives about 750 mm annual mean rainfall with an annual mean temperature of 26°C (Saanane, 2016). Rainfall is unimodal with large variations in patterns and quantities. The major crops grown include maize, sweet potatoes, millet, cassava, sorghum, cotton, and rice. Crop production used to be characterized by shifting cultivation and long fallow periods. Because of the increasing population, this practice has changed to almost permanent cultivation. The native vegetation is composed of shrubs, often thorny and usually deciduous, and trees reaching up to 10–15 m.

2.2. Sample

This study adopted a cross-sectional research design in which a multistage sampling procedure was used to select wards and villages or *Mitaa* which are the smallest units in rural and urban areas, respectively. The term “urban” as used in this study refers to small towns or secondary urban centres. Data were collected from rural wards (Iyogelo and Binza) and urban wards (Sola and Shanwa). Within wards, sample households were identified by systematic random sampling technique based on the official list of households obtained from local offices. The sampling formula $n = (N/N(1 + e))^2$ (Yemane, 1967) was used to determine the sample size of 317 households at a 95% confidence level. Sample households were proportionally distributed among rural and urban areas. Thus, questionnaires were administered to 138 and 179 households in rural and urban areas, respectively.

2.3. Measures

Data were collected through interviews using questionnaires. Informed verbal consent was obtained from each participant before proceeding with interviews. The interviews were conducted in Kiswahili and transcribed into English with comparable responses checked for consistency. The questionnaires sought to obtain households’ information on social demographic characteristics, spatial location, and types and attributes of fuels used. Additional questions of interest included awareness and adoption of improved cookstoves as types of cookstoves are associated with the efficiency of fuel utilization. The spatial data were collected using GPS. Spatial information (latitude, longitude, and altitude) of each household was collected and recorded using a handheld GarminTrex Global Positioning System (GPS). The administrative boundaries were downloaded from the National Bureau of Statistics data portal at <http://www.nbs.go.tz>. The road network and location of Maswa town center were digitized from the Google Earth program. The spatial data, namely household latitude and longitudes, the roads, town centers, and administrative boundaries, were processed in ArcGIS software (ArcMap 10.3). The spatial data were processed to generate the study area map and household distributions.

2.4. Analysis

The non-spatial data from the household interview were processed and subjected to descriptive and regression analyses using the Statistical Packages for Social Sciences (SPSS) program. Cooking fuels were categorized as traditional (firewood), transitional (charcoal), or modern (kerosene, LPG, and electricity). Income was reported over 30 days preceding the survey (a proxy for household income). Households were categorized into low (USD<220), middle (USD 221–420), and high (USD >420) income levels. A Multinomial Logit (MNL) model was used to assess the behavior of consumers with a possibility of more than two choices. Kerosene and electricity were dropped in the regression analysis because very few households used them. The MNL model was preferred because of its ability to perform better with discrete choice studies. The analysis is based on conventional consumer choice theory which states that if the utility of a good is greater than that of another good, a consumer will choose the former good (Johnson & Takama, 2012). It is assumed that the choice of a given source of energy depends on household socio-economic characteristics including age, sex, level of formal education, income, type of house, and area of residence. The MNL model is used to assess the behavior of consumers with the possibility of more than two choices. This model assumes that households make fuel choices that maximize their utility (McFadden, 1973). The model is based on the use of a cumulative logistic probability function specified as:

$$\Pr[Y_i = j] = \frac{\exp(\beta_j^i X_t)}{\sum_{j=0}^j \exp(\beta_j^i X_t)} \quad (1)$$

Where: $\Pr[Y_i = j]$ is the probability of choosing charcoal or LPG with firewood as the reference category; j is the number of possible fuel choices (charcoal, LPG); $j = 0$ is firewood; x_i is the vector of the predictor variables; β_j is a vector of the estimated parameters. Because the logit model uses

a logarithmic transformation to assume linearity of the outcome variables on the explanatory variables, the specific logit model to predict the odds of cooking fuel choice is given as:

$$\ln\left(\frac{p}{1-p}\right) = \beta_0 + \sum_{i=1}^n \beta_i x_i + \varepsilon_i \quad (2)$$

Where n is the total number of variables, β_0 is the regression constant, β_i is the logit coefficient for the variable and ε is the error term. From equation 2, the quantity $p/(1-p)$ is the odds ratio which is expressed as a linear function of the independent factors. The set of regressors (independent variables) comprised demographic and socio-economic characteristics with potential influence on household choice for clean cooking fuels. These variables were either continuous or categorical. Responses to categorical variables were denoted as 1 for “yes” or 0 for “no” if the sex of the respondent was male, the main household occupation was farming, the respondent had attained formal education, type of house was traditional (earth floor with roofing materials other than iron sheet), location of the house was urban, and the household had access to electricity. The dependent variable was the cooking fuel choice which could be charcoal or LPG with firewood as the reference choice.

As explained in a previous work (Pundo & Fraser, 2006), the estimated coefficients do measure the change in the logit for a one-unit change in the predictor variable while the other predictor variables are held constant. Independent variables were subjected to a multicollinearity test. All the variables had values less than 10, indicating acceptable levels of multicollinearity. The results of the MNL model are interpreted in terms of the odds ratios which indicate the probability of choosing one outcome category over the reference category. A positive coefficient indicates that the relative probability of choosing the alternative fuel increases (*ceteris paribus*). A negative coefficient implies that a household is less likely to change to alternative fuel. A p -value greater than the accepted confidence level means that there is insufficient evidence that a change in the predictor affects the choice of a response category from the reference category. The Spatial Statistics Tools in ArcMap 10.3 was used to analyze the spatial patterns of energy use. Under these tools, the Hot Spot Analysis (Getis-Ord G_i^*) method was used for mapping the clusters of different types of cooking fuels. During the Hot Spot analysis, the Fixed Distance Band option was adopted for the conceptualization of the spatial relationships while the Euclidean distance was used as a Distance Method. The z -scores in the Hot Spot map of each fuel type were classified into three classes using the Symbology function. The high z -score of a feature indicates a spatial clustering of high values (hot spots), while low to negative z -scores indicate a spatial clustering of low values (cold spots). The higher the z -score, the more the clustering intensity.

3. Results

3.1. Patterns of cooking fuels by household characteristics

Table 1 summarizes the descriptive statistics for demographic and socio-economic variables of the sampled households. Results show that the majority of the respondents were men (78.2%) with formal education (88.1%). Farming was the major economic activity in most households (84.1%) that owned an average of 5.7 acres. Family size ranged from 2 to 14 persons (average, 6.2). Further, results show that over two-thirds (69.4%) of the households belonged to the low-income category while nearly one-third (30.6%) were in the middle- and high-income levels. More than half (55.9%) of the sampled households were located in urban areas. About one-third of the households owned traditional houses and only 0.6% of households had access to electricity.

Table 2 shows a portfolio of cooking fuels. The use of these fuels varied with demographic and socio-economic characteristics. Of the modern cooking fuels identified, only LPG has a substantial share (20.6–27.5%) across age and gender, and its users are spatially clustered close to Maswa town center (Figure 1c). Results also show that the use of firewood for cooking tended to concentrate more in rural than urban households (81.2% vs. 47.5%), and the opposite was true

Table 1. Summary statistics

Variable	N	Min	Max	Mean	SD
Age (years)	313	18	77	41.740	14.621
Sex of respondent is male	317	0	1	0.782	0.445
Respondent has formal education	317	0	1	0.881	0.307
Household size	317	2	14	6.220	2.611
Household income is low	220	0	1	0.694	0.461
Household income is middle	68	0	1	0.215	0.411
Household income is high	29	0	1	0.091	0.288
Main occupation is farming	317	0	1	0.840	0.307
Farm size owned (acre)	64	1	16	5.750	4.314
Type of house is traditional	317	0	1	0.306	0.412
Household has access to electricity	317	0	1	0.006	0.445
Residential area is urban	317	0	1	0.559	0.401
Distance to the fuel source (km)	317	0.25	17.5	2.192	3.013

for charcoal (33.3% vs. 83.3%). Firewood use was more common in households primarily engaged in farming (67.6%) compared with employment (36.8%) or business (40.0%). Accessibility (ability to collect or purchase cooking fuels), affordability (ability to acquire fuel at a price that does not impose an unreasonable burden on household incomes), and convenience (low or no smoke emission) were the most frequently mentioned attributes of cooking fuels both in rural and urban areas. The main sources of cooking fuel in rural and urban areas combined were charcoal (66.6% of households) followed by firewood (63.9%) and LPG (22.5%).

The spatial distribution and hot/cold spots of the three cooking fuel sources are shown in Figure 1(a–c). Spatially, a hot spot of high-income earners (high positive ZScore values) is found in the urban center, while a cold spot (low ZScore values) is far from the urban center (Figure 1c). Regarding utilization of firewood, only 2.6% of the households (rural 1%, urban 1.6%) used improved cookstoves while 58.1% of them (rural 35.4%, urban 22.7%) used traditional cooking stoves. The use of charcoal and LPG was more common among those in employment and business. In contrast, participants with formal employment predominantly used charcoal (92.1%) and LPG (68.4%). Although biofuel use for cooking was prevalent across all income groups, the use of firewood tended to concentrate more in low-income households (Figure 1a,d) and among those without formal education (73.7%). A higher proportion of LPG users was recorded among householders with formal education compared with their counterparts (22.9% vs. 15.8%). Small household size and urban residence were associated with increased use of LPG.

LPG was either used as the only cooking fuel or in combination with other sources. As shown in Table 3, a combination of modern and solid fuels, especially, the LPG-charcoal stacking, prevailed

Table 2. Percent of households using traditional, transitional, and modern cooking fuels (n = 317)

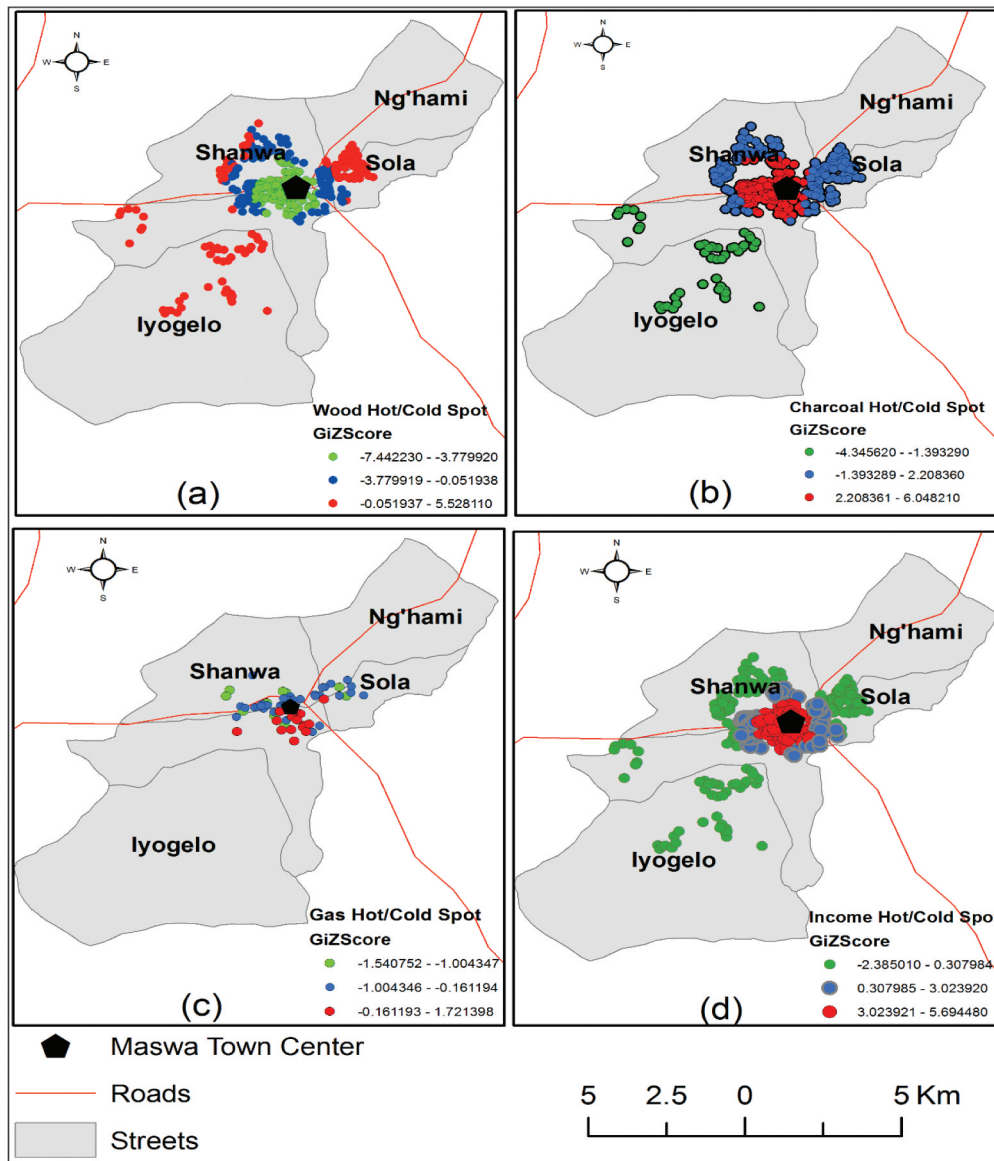
Variable	Traditional	Transitional	Modern		
	Firewood	Charcoal	Kerosene	LPG	Electricity
Age (years)					
18–34	52.6	68.1	2.0	20.6	0.9
36–54	66.7	65.3	2.9	27.5	0.7
55+	71.7	54.7	2.2	22.1	0.0
Sex					
Male	60.9	60.9	2.0	20.6	0.4
Female	66.7	64.4	2.9	27.5	1.4
Education level					
No formal education	73.7	28.9	0.0	15.8	0.0
Formal	60.6	69.2	2.5	22.9	0.7
Household size					
1 to 5	47.4	74.5	1.5	31.4	0.7
6+	73.3	56.7	2.8	15.0	0.6
Income					
Low	70.0	54.3	2.2	10.3	0.0
Middle	47.1	91.2	1.5	50.0	0.4
High	27.3	95.5	4.5	52.9	1.5
Main occupation					
Farmer	67.6	58.3	2.7	14.3	0.0
Employed	36.8	92.1	0.0	68.4	0.8
Business	40.0	90.0	0.0	35.0	0.0
Location					
Rural	81.2	33.3	2.2	6.5	0.0
Urban	47.5	83.3	2.2	34.1	1.1
Overall	63.9	66.6	2.2	22.5	0.7

more in urban households compared with those in rural areas (87.5% vs. 12.5%, $p < 0.001$). The convenience of fuel, which includes less smoke, was frequently cited as one of the main reasons for choosing to use LPG, charcoal, or both. It was intriguing to note that food taste was among the factors behind fuel choice. A common view especially in rural areas was that food prepared using solid fuel has a more appealing taste. Further, analysis of energy use in households with varying incomes shows that modern fuel-only users were insignificant, although nearly one-third of the households were in the middle- and high-income categories. Households using modern fuel only had favourable conditions including small household size (average, 2.2 persons) and a stable occupational structure that guaranteed regular income.

3.2. Factors influencing the household choice of cooking fuel

The estimated coefficients derived from the random parameter MNL model are shown in Table 4. Out of 11 explanatory variables considered, only five had a significant influence on choices of both charcoal and LPG. These include the education level of the household head, the main occupation of the household head, the type of house owned, the distance to the fuel source, and the location of the household. Whereas the household size and access to electricity were significant predictors of LPG, land size significantly predicted the choice of charcoal. Specifically, the lack of formal education among household heads reduced the odds of choosing charcoal and LPG by 90%. Households

Figure 1. Spatial patterns of various cooking energy use by households in the selected urban and rural streets in Maswa District, where the cold/hot spots shown using GiZScore values.



reporting farming as their primary livelihood activity were less likely to choose charcoal or LPG compared with other occupations ($OR = 0.3, p < .05$). Small land size decreased the odds of using charcoal ($OR = 0.1, p < .01$) but not LPG ($OR = 0.3, p > .05$). Indeed, the type of house significantly predicted whether a household chose to use firewood or alternative fuel. Owning a traditional house was associated with reduced odds of using charcoal ($OR = 0.7, p < .01$) and LPG ($OR = 0.1, p < .01$) over firewood. Regarding distance, an extra kilometer to the fuel source predicted a 60% choice reduction of charcoal and LPG use. Unlike LPG for which its use was three times more likely in households with less than six members ($OR = 3.3, p < .05$), household size did not influence the choice of charcoal ($OR = 1.8, p > .05$). The odds of choosing LPG over firewood were six times higher in households with access to electricity compared with households without electricity. Neither charcoal nor LPG choice was dependent on household income ($OR = 1, p > .05$). It was further observed that place of residence had a significant influence on the choice of cooking fuel. Living in urban areas increased the likelihood of using charcoal ($OR = 15.2, p < .01$) and LPG ($OR = 21.6, p < .01$) over firewood.

Table 3. Distribution of cooking fuels and cookstoves in rural and urban households

Fuel/ cookstove	Counts		Percent (yes)		p-value
	No	Yes	Rural	Urban	
Single fuel users	152	165	58.2	41.8	0.000
Multiple fuel users	165	152	27.6	72.4	0.000
Firewood only	223	94	83.3	11.7	0.000
Charcoal only	249	68	19.1	80.9	0.000
Firewood-charcoal	220	97	27.8	72.2	0.000
LPG-firewood	289	28	10.7	89.3	0.000
LPG-charcoal	253	64	12.5	87.5	0.000
LPG-firewood-charcoal	292	25	8.0	92.0	0.000
Traditional cookstove	129	179	35.4	22.7	0.000
Improved cookstove	304	8	1.0	1.6	0.470

P-value is for the Pearson Chi-square test. Counts for LPG only and modern fuels only were too few (<5 households) for the statistical test.

4. Discussion

4.1. Patterns of utilization of cooking fuels

The results of this study have shown that wood fuels constitute the greatest source of cooking fuels across rural and urban areas albeit at varying degrees of magnitude and significance. There are various reasons for this pattern. First, firewood is cheaper and affordable, making it an easy choice, especially among the low-income households whose distribution was disproportionately high in the rural areas. In addition, household cash incomes are often more uncertain and variable than in urban households such that regular consumption of modern fuels is more difficult (Masera et al., 2000). Second, the observed high preference for charcoal in urban areas could be associated with several characteristics of charcoal including easy transportation, less space for storage, and higher calorific value per unit weight (Bustamante-García et al., 2013). The results have also shown that charcoal is not displaced to the same extent as kerosene, suggesting limited accessibility and affordability of alternatives to charcoal as a major cooking fuel. However, the extensive use of biofuels may affect time availability, particularly for women in rural areas given their role in searching for cooking fuels. Previous works have shown that the time required to collect firewood reduces household productivity due to lost work hours (Burke & Dundas, 2015; Mosa et al., 2020). For example, research in Maswa reported that interventions involving natural tree regeneration meant that women reduced up to 6 hours per day collecting firewood and the overall dependence on rangeland resources (Safari et al., 2019). Thus, without such interventions, women in this district may spend a significant proportion of the daytime searching for firewood at the expense of more productive work and welfare services.

The findings that households in the high-income categories used traditional, transitional, and modern cooking fuels suggest that high income does not always result in linear fuel switching as depicted in the energy ladder model. The use of multiple cooking fuels provides further evidence of the tendency to add fuel without abandoning those traditionally used. Further, the availability and accessibility of cooking energy and the purpose for which energy is used have been shown to influence fuel choice (Ifegbesan et al., 2016). Traditional cooking techniques and taste preferences, for example, have been reported to determine the choice of wood fuel even if it were an expensive

Table 4. Multinomial logit estimation of household fuel choice for cooking

Variable	Charcoal			LPG		
	B	p	OR	B	p	OR
Age of household head exceeds 55 yrs	0.94	0.17	2.6	0.80	0.32	2.2
Household head is female	-0.57	0.47	0.6	-1.23	0.15	0.3
Household head has no formal education	-2.86	0.00	0.1	-2.19	0.03	0.1
Household has less than six persons	0.61	0.17	1.8	1.18	0.02	3.3
Household income is low	-0.01	0.99	1.0	0.25	0.99	1.0
Main occupation is farming	-1.10	0.04	0.3	-1.13	0.04	0.3
Land size is less than three acres	-1.93	0.00	0.1	-1.22	0.12	0.3
Household owns a traditional house	-0.37	0.00	0.7	-1.91	0.00	0.1
Household has access to electricity	0.86	0.12	2.4	1.85	0.01	6.4
Distance to fuel source	-0.82	0.00	0.4	-0.97	0.00	0.4
Residential area is urban	2.72	0.00	15.2	3.08	0.00	21.6

The reference category is firewood; Number of obs (317); Wald Chi2 = 264; df = 22; p = 0.000; Nagelkerke = 0.715; -2Log likelihood = 336; p < 0.05

alternative fuel (Heltberg, 2005; Saad & Bugaje, 2016). In general, these variations mean that households' choices are heterogeneous. This heterogeneity could result from differences in preferences and perceived value of cooking fuels. The limited use of commercialized energy especially in rural areas is most likely due to liquidity constraints. LPG-charcoal stacking is an important feature of the current energy use patterns in urban areas. The findings accord with those of Pires (2003), which describe LPG as “convenience” for making hot drinks, quick breakfasts, and reheating leftover food while biomass fuels are used to prepare major meals.

Considering the end-use efficiency of biomass energy sources and the adoption of improved cookstoves, in particular, the current rate of 2.6% is much lower than the national figure of 25% recorded previously (GACC, 2012). It has been pointed out that sustaining the use of these stoves is often lower than the adoption rate despite the social, economic, and health benefits (Pachauri & Rao, 2013). In an experimental study conducted in Morogoro, Tanzania, for example, the efficiency of traditional cookstoves was as low as 5–10% (Kulindwa et al., 2018). It is worth noting that heavy reliance on wood-based biomass coupled with the use of inefficient wood energy technologies is an important cause of deforestation and poor indoor air quality leading to negative health, socio-economic and environmental outcomes. In this regard, rural-based livelihood is particularly at

stake because the urban demand for wood fuel results in further degradation of natural resources in rural areas. Countrywide, it has been reported that the forest cover is declining at an annual rate of 1.16% with a recovery rate of only 0.32% (World Bank, 2013). Thus, there is a need for supply-side intervention such as agroforestry which can reduce pressure on harvesting wood from natural tree stands.

The use of GIS spatial analysis and maps as applied in this study enables the modeling and visualization of energy consumption. Statistically significant hot spots for various energies in this study indicate high energy use. As Lee (2013) argued, the use of fuelwood falls sharply with an increase in income; indeed, spatial maps of income hot spots (Figure 1d) show a similar spatial pattern as the charcoal and gas hot spots (Figure 1b,c). Low spots for charcoal and LPG as well as the hot spot for wood fuel are located out of urban areas where Figure 1d indicates income cold spots (low income). The spatial maps can be used for planning and spatial areas for interventions. For example, it has been used in Anambra state in Nigeria to locate the abattoir and poultry bio-energy (Chukwuma et al., 2016). In Mexico, the WISDOM approach (Woodfuel Integrated Supply/Demand Overview Mapping) helped to identify the fuelwood hot spots in residential areas and determine carbon dioxide emissions associated with the non-renewable use of fuelwood (Ghilardi et al., 2007). Maps can also be used to provide structured information about the distribution of energy use and greenhouse gas emissions to local administrative areas (Mattinen et al., 2014).

4.2. Predictors of household fuel choices

The empirical findings from the MNL model in Table 4 provide insights into factors that influence household choices of cooking fuel. Consistent with the earlier observation (Zhang & Hassen, 2017), the MNL results reveal that household characteristics are important determinants of a household's choice of cooking fuel. A low level of education was the demographic factor most strongly associated with low uptake of clean energy possibly due to low awareness of the effects of using biofuels and the advantages of modern fuels. Education is also positively related to labour force participation which could potentially increase household income. These findings underscore the importance of education as a long-term strategy to increase the demand for clean fuels. Further, the increased likelihood of using LPG among small household sizes is consistent with the idea that the relative labour scarcity of these households translates into a high opportunity cost of wood collection. As indicated earlier, the independence between the choice of LPG and household income especially among the medium- and high-income groups shows that households with improved income did not ascend the energy ladder. A lack of a clear-cut linkage between income level and fuel type implies that non-income factors can have a strong influence on fuel choice which suggests that the energy ladder model is not universal.

The negative coefficient for “distance to the energy source” implies that the supply of modern cooking fuels decreased with distance from urban centres, resulting in reduced odds of using clean fuels. Thus, attention needs to be given to the challenges of the distribution of clean energy sources. In general, urbanization is associated with greater use of modern fuels and a fall in the share of traditional biomass because of improved household income, lifestyle, and the availability of convenient and sophisticated energy sources such as kerosene, LPG, and electricity (Alem et al., 2016). The observed variations in the choice of cooking fuel between rural and urban households could be associated with perceived differences in fuel attributes and how these fit into the lifestyles of the two settings. For instance, while firewood is a common source of cooking fuel in rural areas, this fuel is particularly inconvenient in densely populated areas for reasons such as bulkiness, high transport cost, and high levels of smoke emission. These and other significant predictors such as type of house and place of residence as established in this study give an idea of the factors worthy of consideration in interventions that aim to promote the use of clean fuels.

5. Conclusion

This study analysed patterns and factors influencing energy choices for cooking. Empirical findings have shown that households in rural areas frequently use firewood while households in urban

areas use charcoal as the main source of cooking fuels. These two forms of energy, however, are characterized by low conversion and end-use efficiency which contribute to accelerated deforestation. In this study, the use of spatial statistics Hot Spot Analysis (Getis-Ord G_i^*) has enabled the analysis of spatial income distributions along with various energy hot/cold spots. These hot/cold spots represent techniques for energy use visualization which can provide useful information in designing energy-related interventions. Findings from this study have also indicated that a significant relationship exists between socio-economic variables and the type of fuel used for cooking. Lack of formal education, farming as the household's primary occupation, large household size, and long distance to the town centre are important factors associated with reduced odds of clean energy use. Because wood fuel is still the main choice of cooking fuel, efforts are needed to increase the stock of wood resources through natural tree regeneration and reforestation strategies. In this perspective, it is necessary to reduce fuel demand by enhancing the efficiency of wood fuel consumption. This would involve promoting the use of energy-efficient cookstoves with an emphasis on energy services for rural residents. The promotion of clean fuels is indeed critical in addressing health, productivity, and environmental challenges associated with the use of biomass fuels.

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