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Wood Based Biomass Fuel Consumption in the Upper West Region of Ghana: Implications for Environmental Sustainability

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Abstract

Households' fuel consumption decisions are affected by a number of factors. But the choice of fuel can affect environmental sustainability, especially where wood based biomass fuel is preferred. This paper examines households' fuel consumption decisions with emphasis on biomass and its implications on environmental sustainability. In all, 200 heads of households were selected through a multistage sampling procedure. The binary logit model was used to examine the factors influencing households' decision to use wood based biomass fuel for their cooking needs. The major factors influencing such decisions are years of completed school by household head, household size, price of the fuel and household income. Given that the removal of wood based biomass from the land results in very negative consequences in the form of soil erosion, reduced moisture and soil nutrients, it is recommended that alternative livelihoods be found for the people to both help them move up the energy ladder to cleaner fuels and also increase their incomes.

Keywords: Biomass fuel, deforestation, environmental sustainability, modern fuel, logit model.

1. Introduction

Households depend on various types of fuels for activities, such as cooking, heating (or cooling) and ironing among other things, broadly categorized as traditional (biomass) fuel which includes firewood, charcoal and stocks; and modern (clean) fuel which includes kerosene, LPG and electricity.

It is estimated that about 2.5 billion people in developing countries rely on biomass for their cooking (Njong & Johannes, 2011) and that the phenomenon is quite common among households in Central American countries and sub-Saharan Africa. Studies have shown that the use of firewood, for example, is most common in countries such as Mexico (24.0%), Brazil (52.9%) and Ecuador (63.2%). In Vietnam and Nepal, 60 percent and 32 percent respectively of households use straw and leaves (IARC, 2010; Jingchao & Kotani, 2010; Heltberg, 2003). Similarly, both rural and urban households in sub-Saharan African countries including Ghana, Nigeria, Gabon, Angola and South Africa, use firewood for cooking (Howells et al., 2005; Bailis et al., 2007; Mekonnen & Kohlin, 2008). In Ghana, for example, Amissah-Arthur and Amonoo (2004) found that 84.0% and 13.0% of rural households use firewood and charcoal respectively.

These studies have also acknowledged that households in these regions, especially those in urban areas, do partial switching towards the use of cleaner technologies such as kerosene, LPG and electricity. Indeed, the tendency to use one fuel type over another has been explained by economic, sociological and ecological factors. The energy ladder model for example, views income as the key determinant of fuel choice which seeks to imply that, a move up the ladder to a new fuel is simultaneously a move away from previously used fuels (Mekonnen & Kohlin, 2008) and that households with higher incomes are less likely to choose only solid fuels as their main fuels. Income generally, has a significant positive impact on the per capita consumption of commercial energy (coal, electricity and LPG), but a negative effect on per capita consumption of crop residues (Jingchao & Kotani, 2010).

Even though studies (see for example Amissah-Arthur & Amonoo, 2004; Mekonnen & Kohlin, 2008; ESMAP, 2003; Jingchao & Kotani, 2010; Heltberg, 2003), have been done on the subject, very little is done in the Upper West Region of Ghana. In addition, these studies have failed to draw the link between households' fuel choice and environmental sustainability. This is in spite of the fact that, millions of small scale subsistence farmers struggle to produce food crops in extremely challenging conditions resulting in low yields and general food insecurity

(Di Falco et al., 2011) and the fears that climate change will have serious impacts on all dimensions of food security (availability, accessibility, utilization and system stability), which effects are likely to be significant in rural location where crops fail and yields decline (FAO, 2008). Currently, about 69 percent of the land area in Ghana is affected by soil degradation as against an average of about 43 percent for sub-Saharan Africa (World Bank, 2006). For a country that depends almost entirely on its land resources the situation could have very serious consequences. One way to arrest this looming danger is to educate users of the country's land resources on the possible effects of their activities on the land. But this could be difficult if there is little understanding regarding the consumption pattern of biomass fuel which appears to be one of the major contributors to environmental degradation. In filling this gap, this study, draws on the factors affecting household fuel choice, and outlines the implications of such choices on the environment, using the Wa Municipality in the Upper West Region (UWR) of Ghana as a case.

Broadly, the study seeks to analyze the determinants of household fuel choice in the Wa Municipality of UWR. It does so by identifying the different types of fuel used by households, assessing the factors that influence household fuel choice, and then outlining the implications of household fuel choice on environmental sustainability.

2. Methodology

2.1 Study design

The study uses the survey design and employs the multistage sampling procedure to select 200 households in the Wa Municipality. The municipality was first put into clusters based on the 10 recognized suburbs. The simple random sampling procedure (involving the lottery method) was then employed to select 4 suburbs from which data were collected. The sample size of 200 was then distributed equally among the 4 suburbs for final data collection. Data was collected using questionnaire administered by some assistants. This involved reading out the questions to respondents and recording the answers. Where respondents were illiterate the interviewer translated the questions into a language understood by the respondents and then recorded the responses.

2.2 Data Analysis

Methods of data analysis employed are basically descriptive statistics largely involving the use of frequencies and percentages. This method allows for a vivid description of characteristics and fuel types available to households. However, in analyzing the factors affecting household fuel choice, the dependent variable was whether or not a particular household uses biomass (traditional fuel), in which case traditional fuel takes 1 and 0 otherwise. This situates the analysis in the framework of choice analysis. Given that the left hand side variable is dichotomous, one of three models can be applied. These include the linear probability model (LPM), the binary logit model and the binary probit model. However, the last two are usually preferred given that the LPM does not exhibit normality and predicted values of the dependent binary variable can fall outside the [0, 1] interval, among others (Hill et al., 2008).

This study employs the logit model to analyze the probability that a particular household uses biomass for cooking subject to a number of factors. The advantage in using logistic regression is that it does not require any strict adherence to the assumptions of normality, linearity, equal variance and covariance of error terms (Hair et al., 2006). The logistic formula derives from assumptions about the characteristics of the choice probabilities, namely the independence from irrelevant alternatives (IIA) property. This property says that for any two alternatives i and k, the ratio of the logistic probabilities does not depend on any alternatives other than i and k. This is to say that the relative odds of choosing i over k are the same regardless of what other alternatives may be available or what qualities these other alternatives may possess (Train, 2003). Suppose that $(x) = (Y/x)$ represents the conditional mean of Y given x when the logistic regression is used, the specific form of the regression becomes:

$$\pi\,(x) = \frac{e^{\alpha + \beta X}}{1 + e^{\alpha + \beta X}} \ldots \ldots \ldots \ldots \ldots \ldots \ldots (1)$$

The logit transformation of equation (1) defined in terms of x is given as:

$$g\,(x) = ln[\pi(x)/\,1 - \pi(x)\,] = \alpha + \beta X \ldots \ldots \ldots \ldots (2)$$

which ensures that $g(x)$ is linear in parameters and may be continuous (Hosmer & Lemeshow, 1999). Assuming the value of the outcome variable given x is $Y = \Pi(x) + \varepsilon$, then ε may assume one of two possible outcomes. If $Y = 1$, then $\varepsilon = 1 - \Pi(x)$ with probability $\Pi(x)$, and if $Y = 0$ then $\varepsilon = -\Pi(x)$ with probability $1 - \Pi(x)$. In this case Hosmer and Lemershow (*ibid.*) argue that ε has a distribution with mean zero and variance equal to $\Pi(x)\,[1 - \Pi(x)]$, which follows the binomial distribution with probability given by the conditional mean $\Pi(x)$.

The algebraic form of the model is given as follows:

$$FC = b_0 + b_1P_r + b_2Y_h + b_3E_h + b_4X_h - b_5H_s + b_6H_e + b_7X_m + e \ldots \ldots \ldots (3)$$

where FC is fuel choice (in this case biomass fuel), P_r is relative price of fuel; Y_h is household income; E_h is level of education of household head; X_h is sex of household head; H_s is household size; H_e is employment status of household head; and X_m is marital status of household head, b_0 = constant/intercept, b_i = coefficient (where i = *1, 2, 3…8*) and e is stochastic term.

The implications of the use of biomass for household cooking for environmental sustainability is derived from discussion of such relationships between biomass use and environmental degradation, established from literature.

3. Results and discussions

3.1 Household characteristics

The study revealed that out of the 200 households, about 13% of them are headed by people aged 61 and above, whilst up to 49.0% of households are headed by people within the age range of 30-45. In addition, only 19.0% of households are headed by females whilst 81.0% of households are headed by males. Similarly, about 79.0% of household heads are married whilst about 21.0% are single. Generally, most household heads attained basic education. Results from the study indicate that about 53.0% of household heads attained basic level of schooling, 7.0% attained secondary level of schooling, whilst 40.0% attained tertiary level of schooling. The average household size in the municipality is about 7 members. The study also shows that 26.5% of the households had monthly incomes below GH¢450.00, 50.5% households had monthly incomes between GH¢451.00 and GH¢999.00 whilst 23.0% of households had GH¢1000.00 and above. Data on households' characteristics are presented in Table 1.

Table 1: Household characteristics

Variable	Frequency	Percent
Age group of household head		
60 and Above	26	13.0
46-60	44	22.0
30-45	98	49.0
Below 30	32	16.0
Sex of household head		
Male	162	81.0
Female	38	19.0
Marital status of household head		
Married	158	79.0
Single	42	21.0
Level of education of household head		
Basic	106	53.0
Secondary	14	7.0
Tertiary	80	40.0
Household size		
1-5	105	52.5

6-10	70	35.0
11 and Above	25	12.5
Monthly income of household		
Below 450	53	26.5
451- 999	101	50.5
1000 and Above	46	23.0

3.2 Fuel choice

Generally, households use biomass (traditional) fuel for cooking. Of the 200 households, only 30.0% of households use modern (clean) fuels, in the form of LPG and electricity. On the whole, however, only 1.0% of households use electricity for cooking purposes whilst 29.0% use LPG as their cooking fuel. These findings agree with a study conducted by Bailis et al. (2007) across several countries of sub-Saharan Africa. In that study, it is reported that a very insignificant number of households depend on modern fuels such as LPG and electricity compared to the other fuel categories, but predicted a higher increase in the usage of LPG in sub-Saharan Africa by 2050.

On the other hand, about 70.0% of the 200 households use traditional fuels. Specifically, about 60.0% of the households use charcoal whereas only 10.0% use firewood. This could be attributed to the fact that charcoal is cleaner than firewood in terms of emission of smoke even though cheaper than modern technologies. Again, these findings are very similar to results reported by Amissah-Arthur and Amonoo (2004) in Ghana, indicating that firewood and charcoal use are the dominant form of energy with about 84.0% and 13.0% of rural households in their sample using fuel wood and charcoal, respectively, and that the use of charcoal tends to dominate the other forms of traditional fuels with about 61.0% of households using it followed by fuel wood which commands 25.0% of urban households (*ibid.*). Ghana`s energy use therefore widely comes from biomass in the form of firewood and charcoal accounting for about 59.0% of the total energy consumption (*ibid.*). Table 2 represents types of fuel used by households in the study area.

Table 2: Types of cooking fuel used by households

Fuel Type	Frequency	Percent
LPG	58	29.0
Electricity	2	1.0
Charcoal	120	60.0
Firewood	20	10.0
Total	200	100.0

Household characteristics affect the decisions households make in terms of fuel use. To see these relationships some cross tabulations between various characteristics and choice between traditional or modern fuels were done. The results generally show significant positive relationship between modern fuel use and level of schooling and household income as well as significant positive results between traditional fuel types and household size.

Household heads who attain only basic level of schooling tend to use more of traditional fuels and those who attain tertiary education are more likely to use modern fuels. In all, about 90.6% of the respondents who attain basic level of schooling use traditional fuels while 9.4% of them use modern fuels. Conversely, those who attain higher education use more of modern fuels than traditional fuels. About 61.2% of household heads who attain higher education use modern fuels while 38.8% of them use traditional fuels. The chi-square value of 64.658 with a p-value of 0.001 shows a statistically significant relationship between respondents' level of schooling and the type of fuel they use at the 0.01 level.

Similarly, 72.0% of those who are married use traditional fuels whilst 28.0% of them use modern fuels for cooking. Also, about 64.3% of those who are single use traditional fuels whereas 35.7% of them use modern fuels. The chi-square value of

27.520 with a p-value of 0.002 indicates a statistically significant relationship between marital status and type of fuel used at the 0.01 level.

In terms of gender effect, 78.9% of the female headed households used traditional fuels whilst the remaining 21.1% in this group used modern fuels. Among the male headed households, 67.9% of them used traditional fuels while the remaining 32.1% of them used modern fuels. This has a chi-square value of 1.906 and p-value 0.386 showing that, the relationship is not statistically significant even at the 0.10 level. Table 3 contains the relationships between household characteristics and fuel types.

Table 3: Household's characteristics and fuel choice

Variable	Type of fuel	
	Biomass (traditional)	Modern
Level of schooling of household head (chi-square = 64.66; p-value = 0.001)		
Basic	90.6%	9.4%
Secondary	92.9%	7.1%
Tertiary	38.75%	61.25%
Marital status of household head (chi-square = 27.52; p-value = 0.002		
Married single	72.0%	28.0%
Single	64.29%	35.71%
Sex of household head (chi-square = 1.906; p-value = 0.386)		
Female	78.9%	21.1%
Male	67.9%	32.1%
Household income in GHc (chi-square = 20.85; p-value = 0.001)		
Below 450	94.33%	5.66%
451 – 999	59.41%	40.59%
1,000 +	65.20%	34.78%
Household size (chi-square = 14.20; p-value = 0.001)		
0 – 5	59.04%	40.96%

6 – 10	78.57%	21.43%
11 – 15	92.0%	8.0%

3.3 Determinants of household fuel choice

From the model summary in Table 4, it is clear that the goodness of fit of the model is fairly good given a pseudo R^2 value of 0.501. Also, the LR chi-square value of 130.52 is significant at the 0.01 level, which suggests that the variables included in the model together predict significantly variations in households' decision to use biomass fuel for cooking.

Sex of household head, marital status of household head, employment status of household head as well as age of household head do not significantly explain households' cooking fuel choice in the study area. However, educational attainment of the head of household, income of the household and size, and relative price are significant determinants of households' decision to use biomass fuel for cooking (see Table 4).

Table 4: Estimated results

Variable	Coefficients	Marginal effects
Sex of HH	-0.457 (0.555)	0.200 (0.272)
Marital status of HH	0.121 (0.865)	0.049 (0.649)
Employment status of HH	0.714 (0.588)	0.154 (0.617)
Educational attainment	-0.164 (0.001)***	-0.031(0.001)***
HH size	0242 (0.089)*	0.058 (0.001)***
HH income	-0.004 (0.001)***	-0.001 (0.001)***
Age of HH	0.006 (0.816)	0.002 (0.495)
Relative price	-0.006 (0.007)***	-0.0132 (0.190)
Constant	2.869 (0.022)**	

Log likelihood = -64.97	LR chi^2 (8) = 130.52	Prob>chi^2 = 0.001
Pseudo R^2 = 0.501		

Figures in parentheses are probability values.

The number of years of completed schooling by the household head negatively affects the possibility of the particular household to decide on using biomass (traditional) fuel. Indeed, the marginal effects show for every additional year of schooling attained by household heads, households are 0.031 less likely to use biomass fuel for cooking and this was found to be statistically significant at the 0.01 level. These findings corroborate findings in the literature. For example Heltberg (2003) confirmed that increasing levels of education are associated with a higher probability of using modern fuels particularly in urban India and rural Brazil. Also, Mekonnen and Kohlin (2008) reported similar evidence in Ethiopia where households with a more educated member were more likely to use modern fuels. Furthermore, Beaudelaire (2009) asserted lower levels of education remains a barrier to the choice of modern fuels in Cote d'Ivoire, just as findings of Njong and Johannes (2011), Jingchao and Kotani (2010) in rural Beijing, and ESMAP (2003) show similar results.

Since modern fuel usually does not meet the cooking needs of large household sizes, it was expected that these households will more likely choose traditional fuel. For example, studies by Heltberg (2003), found household size to be inversely related to the use of LPG and kerosene such that smaller households were more likely to depend largely on LPG and kerosene whereas larger households tended to use more of traditional fuels in urban India and rural Brazil. The current study confirms findings by these studies, with a coefficient of 0.242, which shows that there is a positive relationship between household size and the possibility of using traditional fuel. Indeed, Beaudelaire (2009) also found that larger household size increases the probability of biomass fuels consumption. In the view of Njong and Johannes (2011), larger households will prefer to use traditional fuels as they are comparatively cheaper to cook with for many people and reduce the consumption rate per unit of time relative to other alternatives.

The energy ladder model hypothesis has generally supported the notion that the choice of modern fuels has a significant positive relationship with income. It therefore suggests that income is the main determinant of household fuel choice. The model estimate of -0.004, in this study, indicates that as household's monthly income increases, the probability that they will choose traditional fuel decreases. Studies by Mekonnen and Kohlin (2008), in major cities of Ethiopia support recent arguments in the literature that households do not switch to modern fuels as their incomes rise. Households, even in urban areas - such as those in major cities of Ethiopia - tend to increase the number of fuels they use as their incomes rise instead of completely switching from the use of traditional fuels to modern ones. It also found that fuel types such as wood are not inferior, as opposed to the energy-ladder hypothesis.

The study model estimates the coefficient of the age of household head to be 0.006. This implies that as the age of household head increases, the probability of choosing modern fuel also increases. Younger household heads therefore have higher probability of choosing modern fuel than older household heads. Even though the current study could not establish any significant relationship, the fact has been established in the literature including the study of Njong and Johannes (2011) that an increase in the average age of the household head increases the probability of household's choice of traditional fuel compared with modern fuel alternatives. A study by Mekonnen and Kohlin (2008) has also explained that older household heads were more likely to choose traditional fuels, perhaps from habit, because non-solid fuels are relatively recent and more likely to be adopted by younger household heads.

The coefficient on the price of traditional fuel relative to the price of modern fuel is -0.006. This implies that an increase in the price of traditional fuel relative to the price of modern fuel decreases the probability of choosing traditional fuel. Studies by Jingchao and Kotani (2010) found that higher kerosene prices have impacted negatively on the choice of modern fuels. Energy prices have an indirect effect on energy demand. LPG prices therefore have a negative effect on per capita consumption of LPG in rural Beijing (*ibid*.). Beaudelaire (2009) also showed that an increase in the price of charcoal relative to LPG increases the probability of adoption of LPG by urban households by approximately 4.4%.

3.4 Challenges of households fuel categories

The survey identified a number of challenges confronting the use of both traditional and modern fuels. The study identified time consumption as the most challenging factor to the use of traditional fuel as stated by 46.4% followed by indoor air pollution with (for 30.7% of the sample) which reflects the findings of Mekonnen and Kohlin (2008) that developing countries experience severe indoor air pollution which is directly attributable to the use of biomass fuels. Other challenges identified include deforestation, inconvenience and scarcity with 8.6%, 10.0% and 4.3% of the sample, respectively, stating these as challenges (see Table 5).

Table 5: Challenges of fuel use

Challenges	Frequency	Percent
Traditional fuel		
Indoor Air Pollution	43	30.7
Deforestation	12	8.7
Time consuming	65	46.4
Inconvenience	14	10.0
Scarcity	6	4.2
Modern fuel		
Expensive	11	18.3
High risk of fire accident	30	50.0
Scarce	19	31.7

The study also reveals the most common problem associated with the use of modern fuel is high risk of fire accident as this was mentioned by 50.0% of the respondents. Other challenges identified include scarcity and the notion that modern fuel is expensive, with 31.7%, and 18.3% of the respondents, respectively, stating these as challenges. These results are also shown in Table 5. The consumption of LPG, in other studies, has also been found to be relatively expensive compared to wood fuel; this explains why its usage is not yet fully achieved in rural communities, of course, coupled with shortages of the product (Amissah-Arthur and Amonoo, 2004). Another challenge associated with the use of LPG, identified by Amissah-Arthur and Amonoo (2004), is its cost and the extension of the LPG distribution network. The usage of modern fuels has also been found to be highly associated with greater levels of risks of property destruction and loss of lives in cases of misapplication.

3.5 Implications for environmental sustainability

Biomass production in the form of removal of wood for fuel has far-reaching negative outcomes; including soil erosion, reduction in the content of soil moisture and decrease in soil nutrients through leaching; for the functioning of the ecosystem (World Bank, 2006). In the long run, such changes to the structure of the land can be very severe in the form of flooding, water shortages and ultimately culminating in changes in weather patterns, drier regions and desertification (*ibid.*).

Per the findings in the current study, about 70.0% of households depend on biomass fuel in the form of charcoal and firewood for their cooking needs and this undoubtedly is produced by removal of wood cover. The reason this situation should be a source of concern emanates from the fact that Ghana currently depends directly or indirectly on its land resources, with crop land representing almost two thirds of the natural capital. In addition, the country's agricultural sector contributes about 29.9% to GDP (ISSER, 2011), employs about 45.0% of the active population (and about 60.0% of the rural labour force) and contributes to meeting over 90.0% of the country's food needs (Oppong-Anane, 2006).

It is therefore not too strange to find that the incidence of poverty in the country is concentrated more in areas (such as Upper East and West Regions as well as the Northern Region) most vulnerable to land degradation (World Bank, 2005, 2006). The situation could become more precarious for the future if alternative energy sources as well as livelihood sources are not found for people in these three regions. This is because the very presence of poverty makes it difficult for people to move up the energy ladder since that presents more cost. Per the results of this study, the income effect on the consumption of biomass (traditional) fuel is negative. This implies that one way to ensuring environmental sustainability is to work at increasing household income to help them move unto cleaner energy sources and reduce their dependence on the environment for everything including cooking fuel.

4. Conclusions

The study reveals that household income, relative price of traditional fuel to modern fuel, years of completed schooling by household head and household size are significant determinants of household traditional fuel choice. Sex of the household head, marital status of the household head, whether or not the household head is employed, number of females in a household and age of household head are not significant factors in determining the probability of switching from traditional fuel to modern fuel. The study also shows that charcoal and LPG in particular are by far the cooking fuels for a majority of households in Wa Municipality. Other household cooking fuels found include firewood, which is usually purchased from the market but other times gathered from the forest, and electricity. The study reveals a number of challenges associated with the use of the various household cooking fuels. Some challenges reported by households on the use of traditional fuel include indoor air pollution, inconvenience, deforestation, time consuming nature, and scarcity, whereas that of modern fuel include cost, higher risk of fire accident, and scarcity.

The results of this study have important policy implications. For example, the findings of the study are important for implementation of the United Nations Millennium Project, which recommends halving the number of households that use traditional biomass for cooking by 2015, which involves about 1.3 billion people switching to other fuels.

Though firewood is a renewable resource, its overuse can lead quickly and easily to shortages especially in the rural areas of the municipality. As many households continue to use firewood, especially in the rural areas of the municipality, this will negatively impact the economy of the municipality, for example, through deforestation, and a declining agricultural productivity. The implications of this on the environment are obvious: deforestation, soil erosion and declining agricultural productivity, and destruction of the ecological system leading to loss in the natural habitat for the country's wildlife.

An answer to these environmental costs requires that modern cooking fuels be made more accessible and reasonably priced, and firewood collection and use be made sustainable. Firewood use can be made sustainable by the cultivation of fast maturing tree varieties and encouraging local communities to have woodlots. The family woodlots will offer needed firewood and at the same time be a useful source of improving soil fertility.

Based on the determinants highlighted by the study, it is recommended that appropriate measures be taken by government agencies, NGOs and development partners to bring the urban households to the use of clean cooking fuels. These measures may include encouraging education and campaigns on the harmful effects of the overuse of traditional fuels, promoting the dissemination of LPG stoves through affordable prices for all, supporting the availability of LPG by accelerating the geographical distribution of the retailers in order to bring it closer to the consumers and maintaining the relative price of gas to charcoal in favour of LPG by the implementation of a socially effective tax on wood resource.

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