Household's choice of fuelwood source in Malawi:

A multinomial probit analysis

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Abstract

This paper addresses the following question: What determines household's choice of fuelwood collection source? We address this question by estimating the multinomial probit model using survey data for households surrounding Chimaliro and Liwonde forest reserves in Malawi. After controlling for heterogeneity among households, we find strong substitution across fuelwood sources. Attributes of the fuelwood sources (size and species composition) and distance to them are the most important determinants of fuelwood choice. Further results show that customary forests generate environmental benefits by reducing pressure on both plantation forests and forest reserves. These findings support the need to focus more on community forests in national forest policies, and to strengthen community-based institutions to manage these forests.

JEL Classification: C25, Q42

1. Introduction

The principal aim of this paper is to raise and provide empirical evidence to the following question: what determines household's choice of fuelwood collection source, and what are its environmental consequences? This is a pertinent question considering the importance of fuelwood to rural livelihood in Malawi, and the fact that fuelwood extraction is one of the leading causes of deforestation and environmental degradation (Malawi Government, 2001). Biomass energy accounts for more than 90% of the total primary energy consumption, and forests contribute nearly 75% of the total biomass supply. With only 5% of the country's population having access to electricity (IEA, 2002), fuelwood remains the primary source of energy for heating and cooking. Even among households with electricity, much of it is mainly used for lighting due to high cost of appliances and electricity charges. It is estimated that of the total annual wood consumption of 8.5 million cubic meters, rural and urban households accounts for 60% and 10% of the total fuelwood consumption, respectively, and the remaining 30% is used by the commercial sector (Malawi Government, 2001).

In Malawi, there are three main sources of fuelwood: customary forests[1], forest reserves and plantation forests. Customary forests are the most important source of fuelwood contributing 37% of the total fuelwood supply. These consist of natural (tropical) woodlands dominated by *Uapaca*, *Parinari*, *Julbernadia* and *Brachystegia* species. From our sample, 35% of the households collect their fuelwood exclusively from customary forests. Forest reserves are the country's second most important source of fuelwood contributing 26% of the final energy consumption. Like customary forests, these are natural woodlands mainly dominated by *Brachystegia*, *Julbernadia* and *Isoberlinia* species (Ngulube, 1999). Forest reserves are generally not accessible to the local community as these are protected areas.

Plantation forests are the third most important source of fuelwood contributing 11% of the final fuelwood supply. These consist of exotic tree species most of which were established by government in the mid 1970s with support from the donor community and the private sector. The government established 0.5 million ha of softwood plantation (mainly *Pinus patula*) across the country for pulp, paper and timber, and hardwood species (*Eucalyptus* species) for fuelwood and poles. Of the total area under plantation forests (111 000 ha), only 0.8% is owned by the private sector mainly for processing of tea and tobacco (Malawi Government, 2001). Apart from fuelwood, other sources of biomass energy include crop residues and animal dung.

[1] In this paper, customary forests refer to all forest resources mainly natural woodlands on customary land which is held in trust by traditional chiefs who determine how it should be used.

2. Fuelwood problems in Malawi

Although Malawi is relatively endowed with vast forest resources, they are not evenly distributed across the country. Of the total forest area of 2.6 million ha, 42% is in the Northern Region with only 12% of the country's population of 12 million people compared to 28% in the Central Region with 38% of the population, or 30% in the Southern Region where half of the population lives (Kayambazinthu and Lockie, 2002). The scarcity of fuelwood increases the burden of collection as people have to walk long distances to fetch fuelwood. In extreme cases, households resort to cooking with inferior fuels such as crop residues. Estimates indicate that crop residues contribute 10% of the total biomass energy consumption (Malawi Government, 2001). Increased use of crop residues exposes households especially women to air pollution which can have a negative impact on their health. Zhang et al. (1999) estimated that burning crop residues for one hour produces carbon monoxide (CO) concentration of 241 parts per million (ppm), which exceeds the exposure limit of 30 ppm according to the WHO Air Quality Guidelines (WHO, 1999). It is estimated that worldwide, more than 2.5 million people, mostly women and children, die every year from breathing noxious fumes from inferior energy forms[2].

Apart from the health hazard of using crop residues, their removal from gardens exposes the soil to erosion and deprives livestock of fodder. It also reduces agricultural productivity, since most farmers who cannot afford chemical fertilizers use these crop residues as compost manure to replenish soil nutrients (Leach and Gowen, 1987; IEA, 2002; Heltberg, 2005). In tobacco growing areas of Malawi, tobacco stems are popularly used for cooking, which can have even more devastating health impacts especially on infants who are carried on their mothers' backs

[2] For a survey of health implications of indoor pollution, see Schirnding et al. (2002) and Bruce et al. (2002).

inside the kitchen when cooking and tending fires. Tobacco smoke contains more than 4000 compounds including 40 human carcinogens and toxic agents (Jantunen et al., 1997).

Another problem is that the fact that the bulk of the forest resources (1.8 million ha) are protected areas consisting of forest reserves, national parks, catchment areas and wildlife reserves. For many years, local people surrounding forest reserves were not allowed to collect fuelwood or any other forest and non-forest products from these reserves. As one way of reducing pressure on customary forests, the Malawi government with financial support from the World Bank and the British Government in 1996 launched the forest co-management (FCM) program in Chimaliro and Liwonde forest reserves located in the Central/Northern and Southern Regions of Malawi, respectively. The aim of the project was to enhance rural livelihood by allowing program participants to collect fuelwood and other forest products from the reserves in exchange for undertaking silvicultural management practices such as boundary marking, firebreak maintenance, pruning, early burning and patrolling to monitor unauthorized forest extraction (Kayambazinthu and Lockie, 2002). Under the project, 210 ha out of 160 000 ha in Chimaliro forest reserve and 1172 ha out of 274 000 ha in Liwonde forest reserve were demarcated for joint management between the government and surrounding communities (see Kayambazinthu and Lockie, 2002). This paper uses original survey data from the two locations to examine factors that influences household choice of fuelwood collection source.

3. Theoretical model and empirical strategy

The theoretical framework for analyzing household's decisions on the choice of fuelwood source can be cast in a random utility model (e.g., Mc Fadden, 1973; 1974; Train, 1998, Ben-Akiva et al., 1993). Consider a household i from a sample of N households who has to choose a fuelwood collection source from a feasible set defined by $j = 1, 2, 3$ alternative collection sources, namely forest reserves (1), customary forests (2), and plantation forests (3). We assume that each household attaches a utility U_{ij} to each source depending on personal perception of source-specific attributes η_{ij}, participation status in the FCM program I_i, and household-specific factors h_i. If η_{ij}, I_i and h_i include all the relevant factors, utility derived by an individual who chooses a fuelwood collection source j can be written as:

$$U_{ij} = U(\eta_{ij}, I_i; h_i) \quad \forall j = 1, 2, 3 \tag{1}$$

In this model, a household chooses the fuelwood collection source that maximizes utility. Let D_{ij} denotes a discrete choice variable taking the value of one (1) if a household collects its fuelwood exclusively from a collection source j and zero (0) otherwise. For exposition, other things being equal, a utility maximizing household will choose the first alternative (forest reserve) only if the following inequality holds:

$$\begin{aligned} &D_{i1} = 1 \quad \text{if} \quad U_{i1} > U_{ij},\ j = 2, 3 \\ &D_{i1} = 0 \quad \text{otherwise} \end{aligned} \tag{2a}$$

and the corresponding probability that a household i collects its fuelwood from the forest reserves can be expressed as:

$$P_{i1} = \Pr(U_{i1} > U_{i2} \text{ and } U_{i1} > U_{i3}) \tag{2b}$$

Although the utility a household derives from choosing a particular collection source is not observable, some of the characteristics of the household and attributes of the collection sources are observable. The utility that a decision maker obtains from alternative j can be represented as:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \quad \forall j = 1, 2, 3. \tag{3}$$

where $V_{ij} = \delta_j X_{ij}$ is the representative utility, X_{ij} is a vector of observed variables relating to the alternatives and the individuals, ε_{ij} captures other unobserved factors that affect utility, and δ_j is a vector of unknown parameters. The probability of choosing the first alternative is:

$$\begin{aligned} P_{i1} &= \Pr(\varepsilon_{i2} - \varepsilon_{i1} < V_{i1} - V_{i2} \text{ and } \varepsilon_{i3} - \varepsilon_{i1} < V_{i1} - V_{i3}). \\ &= \Pr(\varepsilon^*_{i,21} < V^*_{i,12} \text{ and } \varepsilon^*_{i,31} < V^*_{i,13}). \end{aligned} \tag{4}$$

We assume that ε_{ij} has the density function $f(\varepsilon_i)$ where $f(\varepsilon_i) = f(\varepsilon_{i1}, \varepsilon_{i2}, \varepsilon_{i3})$ and has the mean vector equal to zero (0) with the following corresponding variance-covariance matrix:

$$\Omega = \begin{pmatrix} \sigma^2_{i,1} & \sigma_{i,12} & \sigma_{i,13} \\ \sigma_{i,12} & \sigma^2_{i,2} & \sigma_{i,23} \\ \sigma_{i,13} & \sigma_{i,12} & \sigma^2_{i,3} \end{pmatrix} \tag{5}$$

where P_{i1} is the probability of fuelwood collection from the forest reserve, $V^*_{i,12} = V_{i1} - V_{i2}$, $V^*_{i,13} = V_{i1} - V_{i3}$, $\varepsilon^*_{i,21} = \varepsilon_{i2} - \varepsilon_{i1}$ and $\varepsilon^*_{i,31} = \varepsilon_{i3} - \varepsilon_{i1}$.

Equation (4) suggests that the *choice probability* is a cumulative distribution, which is the probability that the difference in the random component of the utility from two alternatives is below the difference in their deterministic components (Train, 2003). We estimate our model as a multinomial probit model following Hausman and Wise (1978), which allows the alternatives to be correlated. From equation (4), the corresponding cumulative probability of fuelwood collection from the first alternative (forest reserve) is expressed as:

$$P_{i1} = \int_{-\infty}^{V^*_{i,12}} \int_{-\infty}^{V^*_{i,13}} f_1(\varepsilon^*_{i,21}, \varepsilon^*_{i,31}) \mathrm{d}\varepsilon^*_{i,21} \mathrm{d}\varepsilon^*_{i,31}. \qquad 6)$$

Similar expressions can be derived from the probabilities of collecting fuelwood from customary and plantation forests. The model is estimated by Monte-Carlo simulations of the choice probabilities and substituting these simulated probabilities into the following loglikelihood function:

$$\ln L(\psi^*) = \sum_{i-1}^{N}\sum_{j=1}^{J} D_{ij} \ln \ (P_{ij} \mid \psi^*, V_{i,kj}^*) \quad \forall j,\ j \neq k \qquad (7)$$

where $(P_{ij} \mid \psi^*, V_{i,kj}^*) = \Pr(\varepsilon_{ij}^* < \varepsilon_{ik}^* \ \forall k \mid \psi^*, V_{ik} - V_{ij})$, ψ^* is a vector of parameters and k represents the chosen alternative. The error terms $\varepsilon_{i,21}^*$ and $\varepsilon_{i,31}^*$ are assumed to have a density function $f_1(\varepsilon_{i,21}^*, \varepsilon_{i,31}^*)$ derived from the density function $f(\varepsilon_i)$, and are bivariate normal with mean vectors zero (0).

In estimating the model, not all J sets of regression parameters and elements of the variance-covariance matrix are identifiable (Train, 2003). Since our interest is to compare utilities across fuelwood sources, the variance of forest reserve is normalized to one (1) as the base alternative. For identification, we also normalize the variance of customary forests to one (1) as the scale alternative; hence, we have the following variance-covariate matrix:

$$\Omega_1 = \begin{pmatrix} 1 & \sigma_{12} \\ \sigma_{12} & \sigma_{22} \end{pmatrix} \qquad (8)$$

One aspect investigated in this paper is the impact of participation in forest co-management program on household choice of fuelwood source. Since participation in FCM program is potentially endogenous, we first estimate the following probit model of participation:

$$I_i = W_i \varsigma + u_i \qquad (9)$$

where I_i is a binary variable taking the value 1 if the household participates in forest co-management program or 0, otherwise. W_i is a vector of other variables that affect participation (e.g., age, sex, past group experience), ς is a vector of unknown parameters and u_i is a vector of error terms. From equation (9), we obtain predicted values of the probability of participation.

These are included as one of the exogenous variables in the following multinomial probit model of household's choice of fuelwood source:

$$P_{ij} = \alpha + \delta_{1j} w_j + \delta_{2j} x_i + \gamma \hat{I}_i + \varepsilon_{ij} \qquad (10)$$

where w_{ij} is a vector alternative-specific variables (i.e., areas of fuelwood sources (ha), forest collection restrictions, and number fuelwood species)[3], x_i is a vector of household-specific characteristics (e.g., age, education, gender, family size and sex ratio) and $\hat{I}_i$ is the predicted participation from equation (9). $\alpha, \delta_{1j}, \delta_{2j}$ and γ are parameters while ε_{ij} is the error term.

For empirical application, we use pooled data from the household survey conducted in villages surrounding Chimaliro and Liwonde forest reserves in 2002. The survey covered 404 randomly selected households from 31 villages: 205 households were sampled from 20 villages in Chimaliro and 199 households from 11 villages in Liwonde. Summary statistics of all variables used in the analysis are presented in Table 1.

4. Results and discussion

4.1 Descriptive statistics

Before we discuss the empirical results, we briefly discuss features that characterize our data in Table 1 below.

[3] The information on the alternative-specific attributes (sizes of fuelwood source, list of preferred species and existence of fuelwood collection restrictions was solicited through the rapid rural appraisals conducted in each of the sampled village involving traditional leaders and villagers comprising both program participants and non-participants.

Table 1: Summary statistics

	Forest reserve (46%)		Customary forest (35%)		Plantation forest (19%)	
	Mean	SD	Mean	SD	Mean	SD
Age	43.63	14.95	43.99	14.61	42.86	15.46
Gender (Female=1)	0.912	0.416	0.901	0.454	0.818	0.388
Education (Primary education=1)	0.795	0.405	0.845	0.363	0.818	0.389
Family size	5.281	2.199	5.310	2.267	5.506	2.337
Sex ratio (female to male)	1.172	0.935	1.185	0.774	1.120	0.886
Average no. of preferred species	5.720	1.481	2.514	0.878	2.089	0.858
Distance to collection source (km)	1.314	1.318	0.667	0.975	0.582	0.390
Amount collected per trip (kg)	30.21	6.94	30.98	6.53	30.00	6.74
Income poor (earn below US$1.00=1)	0.751	0.433	0.725	0.448	0.403	0.494
Livestock ownership (own=1)	0.357	0.480	0.366	0.483	0.351	0.480
Per capita land size (ha/household)	0.776	0.768	0.895	0.857	0.893	1.011
Availability of access rules	1.000	0.000	0.349	0.477	0.961	0.489
Program participants (N=182)	0.451	0.298	0.368	0.301	0.181	0.108
Size of fuelwood source (ha/person)[a]	13.338	13.772	0.056	0.040	0.064	0.067
Annual fuelwood consumption (ton)	4.631	1.801	4.599	1.649	4.406	1.538
Weekly fuelwood collection (trips)	3.200	1.031	2.972	0.882	3.234	1.012

SD=standard deviation

The above table reveals a number of interesting features. Firstly, despite that area under forest reserve per household is larger compared to the other two fuelwood sources, the annual fuelwood consumption is almost the same across fuelwood sources (approximately 4.5 tons/year and household). This indicates that much of the pressure is on customary and plantation forests for fuelwood since fuelwood collection from the forest reserves follows – at least in theory –

strict guidelines in terms of frequency of collection, type and quantity of fuelwood collected and that households are only allowed to collect fallen and/or dead wood.

Secondly, one would expect program participants to rely on forest reserves for their fuelwood. However, we note that only 45% of those who participate in the FCM program collect their fuelwood from the forest reserves. This indicates a weak correlation between participation and fuelwood source. In other words, household's choice of fuelwood source appear to be independent of program participation.

Lastly, the table shows that 75% and 72% of households who collect their fuelwood from forest reserves (N=185) and customary forests (N=142) are poor households (i.e., households who earn less than US$1.00 a day). In contrast, only 40% of those who collect from plantation forests (N=77) are poor households. This seems to suggest that poverty compels households to rely on forest reserves and customary forests for fuelwood while plantation forests are fuelwood sources for the rich.

4.2 Empirical results

We present the marginal effects from the multinomial probit model of the determinants of household choice of fuelwood source in Table 2. The estimated probabilities of household fuelwood collection from forest reserves, customary and plantation forests are 47%, 35% and 18%, respectively, which is close to the actual distribution shown in Table 1.

Table 1: Marginal Effects at Means from Alternative-Specific Multinomial Probit Estimates

	Pr(choice =FR) = 0.4704		Pr(choice = CF) = 0.3531		Pr(choice = PF = 0.1765	
	dP/dx	S.E.	*dP/dx*	S.E.	*dP/dx*	S.E.
A. Household-specific variables						
Age	0.0050	0.0841	0.0197	0.0820	-0.0248	0.0642
Gender	0.0220	0.0620	-0.0546	0.0620	0.0326	0.0477
Sex ratio (female to male)	0.0281	0.0308	-0.0291	0.0302	0.0010	0.0241
Education (Primary=1)+	-0.0272	0.0717	0.0214	0.0696	0.0059	0.0562
Family size	-0.0194*	0.0104	0.0026	0.0129	0.0168*	0.0099
Income poverty(below US$1.00=1)	0.0770	0.0625	0.0629	0.0610	-0.1399**	0.0560
Assets: Land holding (ha/person)	-0.0961	0.0935	0.0379	0.0877	0.0582	0.0631
: Livestock (own=1)	0.0238	0.0578	0.0078	0.0567	-0.0316	0.0434
Distance to fuelwood source(km)	-0.0374**	0.0184	0.0715***	0.0184	-0.0341**	0.0147
Predicted participation	-0.0362	0.0249	0.0519**	0.0247	-0.0157	0.0199
B. Alternative-specific factors						
Access fuelwood collection restrictions+						
Forest reserve	0.0852	0.0539	-0.0653	0.0399	-0.0199	0.0241
Customary forest	-0.0663	0.0411	0.0931*	0.0496	-0.0268	0.0170
Plantation forests	-0.0203	0.0237	-0.0262*	0.0157	0.0465	0.0293
Area of fuelwood source (ha)						
Forest reserve	0.0790*	0.0442	-0.0600**	0.0297	-0.0190	0.0217
Customary forest	-0.0600*	0.0297	0.0843**	0.0393	-0.0243**	0.0133
Plantation forests	-0.0190	0.0217	-0.0243*	0.0183	0.0434**	0.0213
Availability of preferred species						
Forest reserve	0.1214***	0.0433	-0.0922**	0.0419	-0.0292	0.0236
Customary forest	-0.0922**	0.0419	0.1296**	0.0542	-0.0374*	0.0208
Plantation forests	-0.0292	0.0236	-0.0374*	0.0168	0.0666***	0.0251
Location dummy (Chimaliro=1)+	0.3596***	0.1294	-0.2967**	0.1371	-0.0628	0.0811

From the Table above, household characteristics such as age, gender and sex ratio do not have a significant influence on the choice of fuelwood source. Family size is, however, significant suggesting that an increase in the family size by one unit reduces the probability of fuelwood collection from the forest reserves by 1.9 percentage points, and correspondingly increases the probability of fuelwood collection from plantation forests and customary forests by 1.6 percentage points and 0.3 percentage points, although the latter is not statistically significant. Thus, larger households prefer plantation forests, which is the most convenient source of fuelwood. Since land and labor are required for establishing woodlots, these results also indicate that availability of labor (large households) is important.

Distance to the forest reserves is another important determinant of households' fuelwood choice. An extra kilometer from the forest reserve reduces the propensity of fuelwood collection from both forest reserves by 3.7 percentage points, while exerting pressure on community forests by increasing the probability of fuelwood collection from this source by 7.2 percentage points. This demonstrates the importance of proximity of the fuelwood source to homesteads, suggesting that the value attached to the time spent on fuelwood collection is important factors in influencing household's choice of fuelwood source.

How does poverty affect household choice of fuelwood source? In general, income poverty increases the propensity of fuelwood collection from the forest reserves and customary forests although the effects are not significant. Results indicate that poverty reduces the propensity of fuelwood collection from plantation forests by 14 percentage points. These results are consistent with descriptive data in Table 1. Most income-poor households cannot afford fuelwood from plantation forests and are too land-poor to invest in tree planting due to land shortage. Their average land size is only 0.42 ha/person compared to 1.2 ha/person among income-rich households. Our data show that only 23% of the income-poor households (compared to 70% of the income-rich households) have private woodlots. Another poverty indicator used in the analysis is the lack of household assets (i.e. land size and livestock ownership). Using these indicators, however, we find that household asset-poverty does not have a significant impact influence household's choice of fuelwood source.

What impact does participation in the FCM program have on household choice of fuelwood source? Our results show that participation in forest co-management program has a small negative and statistically insignificant influence on household's propensity of fuelwood collection from forest reserves and plantation forests. Participation in the program significantly increases the propensity of fuelwood collection from customary forests by 5.2 percentage points. These results are surprising, as we expected that program participation would increase the likelihood of collection from forest reserves, one of the intentions of the program. This is nevertheless an indicator that the program does not work in line with the intentions of providing benefits from the forest reserve *exclusively* to the participants. This suggests that households are motivated to participate in forest co-management program by other factors rather than the need to gain access to the forest reserves for fuelwood (See Jumbe and Angelsen 2005, forthcoming).

To assess the impact of forest regulations on household's choice of fuelwood source, villagers were asked during the participatory rural appraisals whether there were restrictions on the types or species of fuelwood collected, frequency of fuelwood collection or amount of fuelwood collected from different fuelwood sources. Our data show that forest reserves and almost all plantation forests have restrictions on use compared to only 34% for customary forests. Our econometric results indicate, however, that fuelwood collection restrictions on both forest reserves and plantation forests do not have any significant impact on household fuelwood collection decisions. These findings may reflect weak enforcement of forest regulations, especially on forest reserves under the FCM program and the inability of forest co-management structures to exclude non-participants due to lack of legal mandate (Kayambazinthu, 2000).

We note that fuelwood collection restrictions on customary forests significantly increase the propensity of fuelwood collection from customary forests by 9.3 percentage points. While this result may appear contradictory, one explanation may be that restrictions on customary forests help to restore degraded forests and enhance their productivity, thereby making them to be more attractive. This suggests that instituting regulations on customary forests can generate long-term benefits to the rural communities by ensuring sustainable fuelwood supply to households while conserving the forests.

Would expanding area under co-management reduce pressure on customary forests? We address this question by examining the impact of: (a) expanding the area under the FCM program, and (b) increasing the number of fuelwood species that can be legally collected from the forest reserves. In Malawi, certain fuelwood species are regarded as endangered species and are prohibited from collection. These include *Terminalia sericea*, *Adina microcephala*, *Cordyla african* and *Khaya anthotheca* (Ngulube, 1999).

From the results, we find that increasing the area under the FCM program by 1.0 ha/household increases the propensity of fuelwood collection from the forest reserves by 7.9 percentage points, but reduces pressure on customary forests by 6 percentage points, and with no statistically significant effect on plantation forests. Thus, one might argue that expansion of forest co-management is a possible route to reduce the degradation of customary forests.

Another possible policy measure for addressing fuelwood shortage in rural areas is to promote establishment of plantation forests. Interestingly, expanding the area of plantation forests by 1.0 ha/household does not significantly affect fuelwood collection from forest reserves, while it significantly reduces pressure on customary forests (2 percentage points), and increases the propensity for fuelwood collection from plantation forests by 4.3 percentage points.

A similar pattern is observed for the impact of increasing fuelwood species collected from the different fuelwood sources on households' choices. Our results indicate that removing restrictions on fuelwood species collected from the forest reserves would lead to a 12 percentage points increase in the propensity of fuelwood collection from forest reserves, while significantly reduces pressure on both customary and plantation forests by 9.2 percentage points and 2.9 percentage points, respectively (although the latter is not statistically significant). Similarly, removing restrictions of fuelwood species collected from customary forests increases propensity of fuelwood collection from customary forests by 13 percentage points, and significantly reduces pressure on both forest reserves and plantation forests by 9.2 percentage points and 3.7 percentage points, respectively. In most cases, plantation forests have one or two species. Our results suggest that increasing the number of fuelwood species on plantation forests (e.g., by planting different species) significantly reduces the propensity of fuelwood collection from customary forests by 3.7 percentage points and leads to a 6.7 percentage points increase in the propensity of fuelwood collection from plantation forests, with no significant effect on forest reserves.

Taken together, the above results indicate strong substitution opportunities between customary forests and forest reserves, and between customary forests and plantation forests, but limited substitution between plantation forests and the forest reserves. From a policy perspective, efforts to reduce pressure on forest reserves can be addressed by strengthening community-based institutions for managing community forests (and not just forest reserves). In addition, encouraging individuals, households and communities to establish woodlots can be an effective measure to reduce pressure on customary forests, which currently is under the most severe pressure of overexploitation and degradation.

We include a location dummy variable to capture differences in fuelwood collection choices among households from the two locations. The coefficient for the location dummy is positive and significant under forest reserves, while it is negative and significant under customary forests. The coefficient is negative but not significant under plantation forests. The results imply that households in Chimaliro depend relatively more on forest reserves, while households in Liwonde depend relatively more on customary or plantation forests for domestic fuelwood consumption. It must be pointed out that Liwonde is located along the busy main road connecting two large cities of Blantyre and Lilongwe and that most households are involved in the selling of fuelwood and other forest-based products by the roadside to the traveling public. These findings suggest that fuelwood collected from customary forests is mainly for domestic use while that collected from the forest reserves is for sustaining their businesses (which corresponds well with field observation, but is not in line with the purpose of the forest reserve). In contrast, Chimaliro is located in a remote area where markets for forest products are underdeveloped such that fuelwood that is collected from the forest reserves is predominantly for domestic use.

5. Conclusions

This study highlights several important findings. Firstly, we find a strong correlation between specific attributes of fuelwood collection sources and household's choice of collection source. Specifically, area of the fuelwood source (ha), fuelwood species and distance to the fuelwood source are important determinants of household choice of fuelwood collection source. Further, we find that customary forests and forest reserves are substitutes, as is customary forests and plantation forests, while substitution is more limited between plantation forests and forest reserves.

Secondly, although fuelwood collection from the forest reserves under the FCM program is subjected to regulations and restrictions, we find no evidence that these restrictions deter households from collecting fuelwood from the forest reserves. This highlights weak enforcement of rules since co-management structures do not have the legal mandate to prosecute violators (Kayambazinthu, 2000). Since our results indicate that location of forest reserves also matters greatly, a policy intervention to expand area under forest co-management program may not help to reduce pressure on customary forests if homesteads are situated away from the forest reserves.

Thirdly, empirical results indicate that increasing area under the FCM program can help to reduce pressure on customary forests. However, we contend that this policy will be limited by the importance given to proximity of the fuelwood source in household's choice, and the fact that most households are located away from the forest reserves. Since customary forests are an important source of fuelwood to most rural households support the need to expand and strengthen community-based institutions to manage local forest resources and design complementary interventions to encourage individuals, households and communities to establish their own woodlots or forest plantations to reduce pressure on customary forests.

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