FUELWOOD COLLECTION IN NORTH-EASTERN ZIMBABWE: VALUATION AND CALORIC EXPENDITURES

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ABSTRACT

The value of forest resources in developing countries has been the focus of considerable research and is significant in developing policies for resource use. In this paper the value of forests in terms of fuelwood provision is examined by constructing a behavioral model of choice of fuelwood collection site for two communal areas in Zimbabwe. In the research areas, fuelwood sales are banned and labour is rarely hired for collecting fuelwood. The impacts of changes to the forest resource base are evaluated by assessing the changes in caloric expenditures made by local people. This measure of value may be relevant to households in developing countries and may provide insights for policy analysis. The results show that the "cost" of losses of fuelwood sites may be a significant percentage of the total caloric intake of the village women.

Keywords: Deforestation, fuelwood, nonmarket valuation, random utility model.

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INTRODUCTION

Wood is the primary source of household energy for the developing world. Fuelwood is used for cooking meals, heating homes (as the season requires), making charcoal, etc. However, there is increasing concern over the state of forests in developing countries, in part because of the depletion of forest resources for use as fuelwood. In addition, the depletion of forest resources is seen as a significant contribution to greenhouse gas emissions and several suggestions for climate change policies include reductions in the use of forest resources for fuelwood (Cline, 1992; National Academy of Sciences, 1991). In analyzing the fuelwood situation, researchers have attempted to assess

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the value of fuelwood resources by employing techniques like contingent valuation (e.g. Gwaai Working Group, 1997). This approach attempts to identify the value of this typically non-market good so that more accurate resource use plans can be made. The value of fuelwood, in addition to the value of various non-timber forest products, and the value of ecosystem services, provides an estimate of the economic importance of forest resources in developing countries. In order to assess more fully land use options, afforestation plans, or options associated with climate change policy, like the reduction of deforestation, accurate assessments of the economic impact of changes in the forest resource base are required. Most previous studies have used some form of hypothetical valuation approach and a number of potential problems have been identified in trying to elicit hypothetical responses in cross-cultural contexts (Adamowicz *et al.*, 1998). Despite these problems, the use of behavioral approaches for resource valuation in developing countries has been almost completely absent. In this paper, we employ a behavioral approach that may be more consistent with the cultural setting in developing economies (see Adamowicz *et al.*, 1997; Gwaii Working Group, 1997).

Choosing to collect and use fuelwood is one of a series of choices that households face in allocating labor effort or cash income. The choice takes on a spatial element if the household chooses to collect wood from the surrounding landscape. The choice of any particular location will involve the opportunity costs of the time and effort required for the journey and the potential benefits of the collection site. Understanding this choice problem is of interest because it identifies the trade-offs that local people make, and identifies the behavior that they would employ in response to changing forest resource stocks and conditions. One could use methods like contingent valuation to ask people their willingness to pay for changes in forest conditions. As an alternative, we observe fuelwood collection behavior, and construct a model that “values” changes in the forest resources in terms of caloric expenditures. Calories may be much more relevant to people in small communities in developing economies than monetary units where cash transactions are rare, and physical labor for subsistence prevalent. Under these circumstances, caloric expenditure may explain more in terms of fuelwood collection behavior than does the value of time or other monetary constraints, even though the latter measures are generally preferred for economic analysis.

The problem of fuelwood use, or more generally energy use, as an economic decision is attracting the attention of applied economists. The standard approach is to extend the agricultural household production model to incorporate domestic fuel decisions. The advantage of this approach is that energy choices are viewed as one choice in the context of a series of consumption and production decisions. A small group of researchers have adapted the household production modeling framework to consider problems such as the adoption of improved stoves using a binary logit model (Amacher *et al.*, 1992), the choice between agricultural residues and fuelwood for domestic use with switching regressions (Amacher *et al.*, 1993), and the decision to purchase or collect fuelwood (Amacher *et al.*, 1996) where the demand and supply equations are estimated. Understanding domestic energy choice is important not only for issues of deforestation in the developing world, but as researchers and policy makers are beginning to realize, for the global environment. The prospects of global warming and the potential importance of carbon sequestration suggests that the economics of fuelwood collection needs to be better understood as part of exploring the potential options to address these problems.

This paper follows the same tradition of modeling as the Amacher *et al.* papers in that the collection decision is seen as part of the household resource allocation decision. A microeconomic approach is useful for isolating the nature of the trade-offs occurring in the household production process with respect to fuel choices. For rural areas in northeastern Zimbabwe, where the data for this study were collected, energy sources such as bottled gas and electricity for domestic use are not readily available outside urban areas. Further, the sale of fuelwood is largely prohibited on communally held land and the prohibition is well enforced through local social institutions such as the "sabhuku's court". For collecting fuelwood, virtually no hired labor is used. The use of family labour was consistently observed and confirmed in discussions with local women. Therefore, households are dependent on collecting their own fuelwood. Here is where the significant difference lies between this paper and Amacher *et al.*: the decision to collect wood becomes a discrete choice problem concerning whether or not to collect wood at a particular site. This requires a very different approach to modeling the fuelwood collection decision. In this case, a behavioral choice approach is used to model the site choice problem. The fuelwood collector chooses a site, usually at the base of a hill or mountain, from a set of wooded sites. The fuelwood collector is assumed to collect a standard load of wood (i.e. a headload) in terms of weight, and size[1]. Choosing a particular site is likely to be based on the various attributes of the site such as availability of good quality fuelwood, as well as the measure of effort to get to each site.

The specification of the site choice problem is further complicated by the present nature of the labor market. In northeastern Zimbabwe, almost all rural households grow a seasonal crop of maize for subsistence with the surplus sold for cash. Family members residing in the cities (where cash paying jobs are located) may return to the rural areas during peak periods to assist with planting and harvesting. Thus, it is rare for individuals to be hired as workers as there is sufficient family labor. As a result, the wage economy or labor market is almost non-existent.[2] If the opportunity cost of time is not well described by wage rates, the next best alternative may be to use a measure of effort such as time, difficulty ratings or an estimate of caloric expenditures involved in a trip to a fuelwood collection site. If calories are used in the estimation of models of choice, then calories provide an alternative means of expressing the welfare losses that the household or community may

[1] Cavendish (1997) supports this assumption.

[2] Researchers at the University of Zimbabwe, specifically the Institute for Environmental Studies, confirm from their experience that rural labour markets in northeastern Zimbabwe are very thin. Also, very few labour transactions were observed to occur over the six months the researcher, Darla Hatton MacDonald, was present. As further, anecdotal evidence, another one of the authors returned to Zimbabwe in 1999 and, hired ten enumerators (five in two separate locations) from a pool of 20 applicants as part of another study. The applicants were young adults with "O level" or "A level" education. As part of the interview process, the applicants were asked if they had ever held a cash paying job. Only one applicant had, and that job was only available because of previous research that had been carried out in the area.

experience due to closure of the site. Although we believe that using calories is currently an appropriate approach, this could change in the future if labour markets form in rural areas as binding cash and capital constraints ease.

FUELWOOD COLLECTION AS ONE TASK IN THE HOUSEHOLD PRODUCTION PROCESS

In rural Zimbabwe, the rural household is both a producer and consumer of goods and services. Rural households, often headed by women, might grow staple crops for home consumption and sell the surplus on the market. The time of adults and older children will be divided between agricultural production, water and fuelwood collection, child-care, cooking meals and the production of crafts, etc. The standard approach to modeling the rural household is to concentrate on the allocation of time using the basic framework of Becker (1965) and to extend the model to incorporate the salient features of household agricultural production following Singh *et al.* (1986). The basic idea is that the household allocates its labor towards the production of goods, some of which are intended for household consumption and some will be sold to generate cash income.

The household demand for any of these goods will depend on its own price, the price of other goods, the price of inputs into the production process and exogenous income. The demand for fuelwood collected by the household will depend on the purchase price for fuelwood, the price of other fuels, the price of other goods and the wage paid to labor. The market for any one of the inputs to the household production process may be thin or non-existent. As a result, many of the prices that might influence demand cannot be observed. In the case of fuelwood, where the resource is often located on communally held land, property rights are such that the sale of fuelwood is prohibited and strictly enforced through social institutions. In other situations where the sale of fuelwood is possible, the marginal rate of substitution between purchased fuelwood and other purchased goods may exceed the price ratio resulting in a corner solution where no purchase of fuelwood occurs. The household, constrained to the collection of wood, must then consider the problem of where to collect wood and how much wood to collect. The household production model would suggest labor effort and the availability of good fuelwood species might be important factors in the decision. In this paper we focus on the decision regarding the location of fuelwood collection. We assume that the frequency of fuelwood collection visits over the sample period (number of visits per week during this period) and the quantity collected on each visit is fairly constant. Thus, given our focus on the location of fuelwood collection, we employ a random utility framework to explain these choices.

APPLYING RANDOM UTILITY THEORY TO FUELWOOD COLLECTION

A body of literature has developed in the transportation, marketing and recreation literature concerning discrete choice situations where the individual (or the household) makes a discrete decision to take the bus or a car to work, to purchase brand A or brand B, etc. The decision to collect fuelwood at a particular collection site fits in this general framework.

The Random Utility Model

The choice of where to collect fuelwood could be modeled in the random utility model (RUM) framework.[3] To illustrate, let us take the example of a fuelwood collector, a rational individual, who chooses a forested site *i* from his / her choice set C_h , where h indexes households or individuals, with probability of choosing site *i* equal to the probability that the utility associated with choice *i* is greater than or equal to the level of utility achieved with any of the other *j* alternatives in the choice set.

$$P\left(i \mid C_h\right) = \Pr\left(U_{ih} \geq U_{jh}\right) \qquad \forall\ j \in C_h. \tag{1}$$

However, utility is not directly observed. Levels of indirect utility, denoted V(·), can be inferred by the choices observed with some random error. The utility from choice *i* of household *h* can be rewritten as:

$$U_{ih} = V\left(M_h - p_i,\ a_{ih}, s_h\right) + \varepsilon\left(a_{ih}, s_h\right), \tag{2}$$

[3] Fletcher *et al.* (1990) served as the basis for this section.

where M_h is household income, p_i is the price of alternative i, a_{ih} is the vector of attributes for alternative i influencing choice of the fuelwood collector h, s_h are the socio-economic characteristics of the fuelwood collectors' household and ε is the random component. Substituting (1) into (2) and rewriting leads to:

$$P(i|C_h) = \Pr\left[\left(V_{ih} + \varepsilon_{ih}\right) \geq \left(V_{jh} + \varepsilon_{jh}\right)\right], \tag{3}$$

which means that the probability that the individual will collect at site i is the probability that the indirect utility from site i (plus some error) is greater than the utility from site j (plus some error).

If the error terms are distributed identically and independently as a Type I extreme value distribution, then the probability of collecting fuelwood at a site i is (McFadden, 1981):

$$\Pr(i) = \frac{e^{V_i}}{\sum_{j \in C_h} e^{V_j}}. \tag{4}$$

Given information on the attributes of the alternatives and a functional form for V_i, the parameters of V_i can be estimated using maximum likelihood techniques (McFadden, 1981).

Choosing to collect wood at any individual site is based on the indirect utility derived from the trip to the site. The RUM framework relies on differences in destination or site attributes. Differences between collectors (i.e. origin variables or individual specific factors) may be captured by interacting (multiplying) the individual specific factor with alternative specific factors. For example, differences in the marginal utility of the "cost" of accessing a site, perhaps due to household size, can be assessed by interacting the "cost" variable with household size. Thus, the independent variables are site attributes and interactions between site attributes and individual or household specific factors. The dependent variable is an indicator variable (0/1) indicating the chosen site from the set of available sites.

Description of the Study Areas and the Collection of Data

A fuelwood collection survey was designed as part of a consultation process with local people in communal area villages in Zimbabwe. The primary purpose of the meetings was to become familiar with the local economy including the major agricultural crops and major activities of men and women. It was discovered through discussions that women were primarily responsible for wood collection activities. Women will tend to walk alone or in small groups to collect wood from the mountains and hills in the area. Sometimes men will engage in fuelwood collection, but men will tend to employ a cart and oxen to carry a large load of wood back to the homestead. Results of a series of village meetings in the Mutoko area are reported in Hatton MacDonald & Weber (1998).

The household survey was conducted over the three month period from July through September, 1996 in the Mutoko and Murewa Communal Areas in Zimbabwe. The English translation of the surveys can be found in Hatton MacDonald (1998). The Murewa Communal Area and Mutoko Communal Area are in the same province, Mashonaland East of Zimbabwe. The surveys are specific to each of the research areas in terms of the names of collection sites but the body of the questions is the same for all three study areas. In the Mutoko Communal Area, the two study areas lie in adjacent valleys connected by roads and paths between mountains and hills. These mountains and hills are relatively well forested. The choice sets for households in the two study areas contain a few of the same mountains but usually only one side of the hill or mountain will be accessible to households in a particular study area. These two study areas will be referred to as Nyamakope and Katiyo.[4] In the Murewa Communal Area, Dandara village, was selected for the study. The stock of woodlands has been severely depleted in the immediate vicinity of Dandera, and as a result people have to travel further to collect wood.

The study areas have comparable features in terms of all being Miombo woodlands, some of which have been cleared for agricultural use. These villages were organised

[4] The study areas were chosen in order to obtain a large enough sample to have sufficient degrees of freedom to estimate a model of choice.

on a grid system and each homestead is allocated a field for growing maize, and if available, garden space near a source of water. Cattle are grazed in fields during the dry season, often near the base of the surrounding mountains and hills. The people in these areas generally tend to collect fuelwood in hills and mountains as the immediate area near the homestead is cleared of most trees and shrubs for agriculture.

On three separate occasions four research assistants visited the randomly selected households and queried 200 households concerning site attributes, fuelwood collection trips and socio-economic information about the household.[5] With each weekly visit, the household[6] was asked to recall over the previous seven days how many trips to collect wood had taken place, which fuelwood collection sites were traveled to, how long the trip took and the mode of transportation involved. To avoid respondent fatigue, questions about site attributes and socio-economic status were spread across the first and third visits. Out of the 200 households surveyed, 194 respondents were able to participate in all three visits.

Site Attribute Information

Three species of trees (*Brachystegia glaucescens, Julbernardia globiflora, Brachstegia boehmii*) (or in the local dialects muunze, munhondo, mupfuti) were identified as excellent fuelwood for domestic use. Households were asked to rate how plentiful these species were on each collection site. Since other species are also used as fuelwood, though not as preferred, respondents were asked to rate how plentiful other fuelwood species are at these sites. To summarize the information in the data, effects codes[7] were set up following Louviere (1988). The effects codes used in the econo-

[5] Each research assistant was given a list of 60 randomly selected households and asked to contact 50 of these households. There were no refusals to participate in the household interview.

[6] Often there would be a collaborative effort in responding to the questions with several individuals, even neighbours being present for the interview. The research assistants had been cautioned in training to ensure that the women responsible for wood collection were present and that male voices did not dominate the discussion.

[7] Effects codes translate category-rating scales to a coding system that can be used in econometric analysis.

TABLE 1. EFFECTS CODES FOR MUUNZE.

How Plentiful is Muunze?	$Muunze_1$	$Muunze_2$	$Muunze_3$
Exhausted	1	0	0
Sparse	0	1	0
Moderate	0	0	1
Plentiful	–1	–1	–1

metric analysis for the species Muunze correspond to $Muunze_1$ — exhausted, $Muunze_2$ — sparse, $Muunze_3$ — moderate and the level "plentiful", the negative sum of the other three parameters, is the benchmark for comparison (see Table 1). The coefficients on $Muunze_1$ through $Muunze_3$ provide the "marginal utility" of these levels of the attributes, while –1 times the sum of these coefficients provides the "marginal utility" of the plentiful level of Muunze.

Through group discussions with women, a number of additional factors that would make the trip to collect fuelwood more pleasant were identified. These site attributes included whether there were wild fruits available along the way (variable referred to as fruit), whether useful plants or barks could be found along the way (bark), whether the trip passed by their garden (garden), whether the trip passed by a friend's home (friend), whether there were sources of water for drinking (water), whether wild animals could be found along the way (wild), and whether there were good places to rest (rest). A series of dummy variables were assembled to represent these attributes.

Four types of travel cost data were assembled: estimated time spent walking (time), estimated distance (distance), perceived difficulty of the trip (difficulty) and finally estimated number of calories expended in walking to each collection site. Information was also collected from respondents regarding the perceived difficulty of walking to each of the collection sites. Effects codes were constructed to reflect the perceived difficulty for each trip with $Difficulty_1$ being easiest, $Difficulty_2$ — moderate and the negative sum of these two coefficients reflecting a difficult terrain ($Difficulty_3$). Households were asked to estimate how long, in minutes, it would take to reach each collection site. Distances from the household compound to each of the collection sites were estimated using detailed topographical maps[8]. Calorie expenditures were calculated using the perceived difficulty rating and the estimated time spent walking to derive an estimate of calorie expenditure for each household to each site.[9]

For an easy, moderate and difficult trip, an estimate of 211, 238 and 264 calories per hour respectively, were used. If a trip to collect wood at a collection site is perceived to be easy then the calorie expenditure is estimated to be 211 calories multiplied by the time in hours.[10] More difficult terrain requires greater muscular force but there will be a tendency to conserve energy by adapting the gait (Scott, 1963).

In the case of the fuelwood collection trip, the attributes of the sites and of the trip, as well as measures of the travel cost (measured in terms of calories, time, perceived difficulty, or distance) should be a factor in site choice. For rural households, time is a valuable input in the household production process and time not spent collecting wood could presumably be used for other activities. Thus the further away the site or the more difficult the trip, the less likely it is that the collector will choose that particular site. In this study, time and perceived difficulty are based on the perceptions of the respondents. McLeod (1995) reported that hunters' perceptions of site attributes were often more important variables than the "objective" measures of the site attributes collected by researchers.

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[8] Perceptions of travel costs by local residents were probably more accurate than the researcher's measurement of distance. Local residents utilise foot-paths that were not always visible on maps. Gathering information on the distance from the homestead to the base of a mountain was more of a precautionary step in case there were problems with the surveys questions regarding time since few people seemed to wear a watch.

[9] Caloric expenditures for various effort levels were based on the Calorie Calculator, see http://primusweb.com/fitnesspartner, October 4, 1997. Calorie expenditures were cross-checked using tables on p.98 and p.356 of Katch & McArdle (1979). Models of caloric expenditure are generally based on a North American model and some minor adjustment (up or down) may be required to more accurately reflect metabolic differences, altitudes and climate. Overall, the estimates of welfare should not be affected to any large extent by such changes.

[10] Our thanks to Dr. Robert Hudson, University of Alberta, who pointed out that North American models of fitness are based on ideas of caloric expenditure, but in developing countries there will be a tendency to conserve energy.

The variable $Muunze_1$ ($Muunze_2$, $Muunze_3$, $Muunze_4$) indicates that the site is exhausted of (sparsely stocked with, moderately stocked with, plentiful) this species of wood and the estimated coefficient would be expected to be negative (negative, possibly positive, positive). The site attributes such as fruit, bark, friend, water, wild[11] and rest, are likely to have a positive influences on choosing the site.

The dataset was completed by collecting information on the demographic and socio-economic characteristics of the household. The data on the household provided information on whether there are significant differences between households that might influence behaviour.

RESULTS

Large amounts of data were collected in the household surveys. The models presented below focus on a subset of the information collected that is most directly relevant to fuelwood collection behavior. The probability of going to a fuelwood collection site is modeled as a function of the site's attributes, including the "cost" of accessing the site (in calories) and the attributes of the wood available at the site. Interaction effects that attempted to explain site choice by individual specific factors (household wealth, household composition, ownership of capital such as ox carts, etc.) were also examined. However, in general these interaction effects were not statistically significant, thus they were not included in the models presented below. Estimation results for the study areas considered together and separately are summarized in Table 2.

The choice problem can be summarized as follows:

Probability of taking a trip to site i is = a function of:

travels costs (as measured by time or calories),

difficulty of traveling to the site (difficult, moderate, easy),

availability of the preferred firewood species — muunze,

the presence of Rest area along the route to the site

the presence of Friends' household along the route.

[11] In discussions, some women stated that the children liked to see wild animals while other women stated wild animals were frightening.

TABLE 2. ESTIMATION RESULTS.

Variable	Coefficient	T statistic (Asymptotic)
Model 1: All Study Areas		
Time	−0.0017*	−2.588
Difficulty$_1$	1.7599*	25.903
Difficulty$_2$	0.2000*	2.545
Muunze$_1$	−1.0638*	−6.669
Muunze$_2$	0.13562	1.425
Muunze$_3$	0.1597	1.581
McFadden R^2	0.410	
Model 2: All Study Areas		
Calories	−0.0015*	−10.733
Muunze$_1$	−1.1634*	−7.917
Muunze$_2$	0.0160	0.184
Muunze$_3$	0.3406*	3.732
Friends	0.8950*	7.483
Rest	1.3408*	10.923
McFadden R^2	0.198	
Model 3: Nyamakope		
Calories	−0.0067*	−8.961
Muunze$_1$	−0.5820	−0.832
Muunze$_2$	−0.2105	−0.644
Muunze$_3$	−0.13562	−0.455
Friends	0.9951*	4.865
Rest	1.3662*	5.708
McFadden R^2	0.278	
Model 4: Katiyo		
Calories	−0.0161*	−10.918
Muunze$_1$	−0.9047*	−2.679
Muunze$_2$	−0.2478	−1.221
Muunze$_3$	0.5949*	3.553
Friends	0.3731	1.670
Rest	0.6664*	3.510
McFadden R^2	0.492	
Model 5: Dandara		
Calories	−0.00005	−0.393
Muunze$_1$	−0.89906*	−4.429
Muunze$_2$	0.23635	1.557
Muunze$_3$	0.21869	1.238
Friends	0.58914*	2.583
Rest	−0.10387	−0.459
McFadden R^2	0.034	

* Significant at a=5%

Final models were selected for presentation based on identifying the significant variables common across study areas. Not all insignificant variables were dropped from the models so that the differences across study areas could be highlighted.

Travel costs, measured in terms of calories, were a very important variable for the study areas pooled together and two of the three study areas when sites are considered separately. Calories being insignificant in the choice of site in the Dandara site are an unexpected result. Households in Dandara have to walk long distances or take a cart to get to the few sites[12] that are not severely depleted. Travel costs being insignificant suggest that the fuelwood situation in the Dandara research area is more complicated than might first appear.

One might expect that limited availability of good quality firewood such as muunze is a deterrent to households at a particular site in the Dandara study area. This expectation is supported by the empirical results where the effects code on limited availability of muunze was negative and highly significant. This suggests that afforestation efforts in the area could be beneficial to households. To date many of the afforestation efforts have concentrated on introducing fruit trees such as mango or fast growing, non-indigenous species such as eucalyptus.

Other site attributes, such as the trip going past the homes of friends, would usually be thought to have a positive effect on choosing a particular site.[13] The estimated coefficient on the variable friend was positive and significant for most of the models. Similarly, having a place to rest along the trip was also considered a benefit in the Nyamakope and Katiyo sites, though not in Dandara where the estimated coefficient on the variable rest was negative though insignificant. Factors such as the journey taking the individual by their garden or the presence of wild animals

[12] Taking a cart does not imply insignificant caloric expenditures as it is often necessary for the collector to walk beside the cart or be jostled about on the cart and considerable energy will be expended hanging onto the cart or the yolk and oxen.

[13] Site attribute variables were used judiciously because some of the variables are somewhat collinear, such as gardens and water.

were not very important, and for this reason these variables were dropped from the logistic regression and only the final set of selected variables were reported.

The results are quite robust in the sense that the estimated coefficients did not change significantly and certainly did not change signs when other variables were included or excluded.

WELFARE MEASURES

Welfare measures in economic theory place a value on the effect of a change in quantity, quality or price of the good. Small & Rosen (1981) report that the compensating variation for a random utility model of the form employed in this paper can be calculated as follows:

$$\text{Compensating Variation} = \frac{-1}{\mu}\left[\left(\ln \sum_{i=1}^{N} e^{V_{io}}\right) - \left(\ln \sum_{i=1}^{N} e^{V_{i1}}\right)\right] \quad (5)$$

where

μ is the marginal utility of income,

N is the number of sites,

V_{i0} is the indirect utility for site i before a price (or quality) change and

V_{i1} is the indirect utility for site i after the price (or quality) change.

To simplify the welfare calculations, it is generally assumed that the marginal utility of income is constant.

$$V_i = \beta\left(M - TC_i\right) + \alpha\, Q_i, \quad (6)$$

where

V_i is the indirect utility associated with site i,

M is the household's income,

TC_i is the travel cost incurred in terms to get to the site i, and

Q_i is a vector of quality attributes at site i.

The marginal utility of income in Equation (6) is:

$$\frac{\partial\, V_i}{\partial\, M} = \beta = \mu. \quad (7)$$

The travel cost TC_i in Equation (6) might be thought of as time multiplied by the rural wage or fraction of the rural wage. However, the market for labor in rural Zimbabwe is thin so the rural wage may be a poor indicator of the value of time. Alternatively, we may wish to think of the household having a total caloric budget that can be allocated towards the activities of the household that result in goods that yield household utility. In this case, the indirect household utility function, which is a function of the caloric cost of activities (everything other than fuelwood collection being suppressed), will be:

$$V_i = B(C - c_i) + \alpha Q_i, \tag{8}$$

where

V_i is the indirect utility associated with site i,

C is the household caloric budget,

c_i is the calories required to get to the site i, and

Q_i is a vector of quality attributes.

The marginal utility of calories (B) reflects the fact that saving caloric expenditure is beneficial to the individual or household since these calories can be allocated to the next best alternative use (cooking, sewing, etc.).

$$\frac{\partial V_i}{\partial C} = B. \tag{9}$$

Thus, it is assumed that calories in this context play the same role as income in traditional economic models. Calories become the constraint in the activity allocation problem. Differences in indirect utility between sites will be related to changes in caloric expenditures. Similarly differences in indirect utility will be related to differences in site attributes such as the changes in the availability of fuelwood or the closure of a rest spot.

Welfare measures in caloric terms can be calculated using the estimated parameters in Table 2. In each of the study areas, the welfare effects were simulated by closing one site at a time and removing it from the choice set. This is a realistic policy simulation since access to sites is becoming an issue in these areas due to granite mining (Katiyo study site), property right disputes (Dandara study site) and ecological concerns.

TABLE 3. WELFARE MEASURES FOR NYAMAKOPE STUDY SITE, MUTOKO COMMUNAL AREA (CALORIES PER TRIP).

Site	Average Welfare Loss	Largest Welfare Loss
Gonye Mountain	4.58	61.50
Mashayamvura Mountain	3.48	44.72
Ndigamarombe Mountain	17.34	47.03
Vhumbika Mountain	24.94	165.20
Nyatsanza Mountain	5.98	15.81
Chidziro Mountain	10.73	50.08
Karunzviru Mountain	3.34	25.35
Chidzanya Hill	2.28	4.75
Mukangiranyemba Mountain	7.2	29.29
Hova Hill	5.21	63.40
Umba Mountain	13.26	56.70
Suswe Mountain	13.29	55.25
Ruchera Area	2.2	57.34
Marirangwe Mountain	28.77	172.98
Mudenyika Hill	13.55	105.09
Hova Area	1.25	208.77

Removing collection sites may result in households having to travel further to collect wood. Tables 3 and 4 present the average cost per trip in caloric terms for Nyamakope and Katiyo. Welfare results for Dandara are not reported as the calculation would be based on an insignificant coefficient for the calorie variable. For many of the households in Nyamakope and Katiyo, closing a particular site has a negligible caloric costs while for other households, site closure has large welfare implications. To illustrate the variation in welfare implications, the largest losses, as well as the average welfare effects, are presented in Tables 3 and 4.

On average the welfare losses are less than 30 calories per trip but closing a mountain such as Vhumbika or the Hova Area in Nyamakope could result in increased level of effort of 165 to 200 calories a trip for some households. If the average daily consumption of a Zimbabwean woman is 2000 calories a day, these latter magnitudes of impact on caloric expenditure are significant. Also, given that women are often observed to be the last to eat from the pot, it is

TABLE 4. WELFARE MEASURE FOR KATIYO STUDY SITE, MUTOKO STUDY (CALORIES PER TRIP).

Site	Average Welfare Loss	Largest Welfare Loss
Tawani Mountain	10.22	65.63
Chijakata Mountain	4.67	38.19
Chindinye Tsvimbo Hill	1.80	12.97
Garireremakoso Mountain	8.78	42.42
Mashayamvura Mountain	6.19	37.24
Mbudziyatume Mountain	2.69	18.71
Rukwiza Mountain	9.74	70.50
Chipangare Mountain	1.23	20.42
Marirangwe Mountain	21.62	107.34
Chidziro Mountain	4.69	37.76
Chitupwana Mountain	8.69	118.44
Gonye Mountain	2.56	36.46

unlikely that their intake of calories will be increased to accommodate their increase in effort and over the long term there may be significant health consequences.[14]

SUMMARY AND CONCLUSIONS

The results of this study suggest that standard economic models of choice can be adapted to model the decision making processes of the subsistence agricultural household. Historically, the tendency in estimating non-market values has been to use hypothetical valuation methods in developing economy contexts, despite potential problems of cross-cultural use of these methods. The behavioral approach employed in this study appears to have worked well in a subsistence economy setting, and provides information not generally derived from hypothetical approaches. The empirical results suggest that calories (reflecting distance and difficulty of the journey), and attributes of the site such as the availability of good quality fuelwood, are

[14] See Dasgupta (1993) for an extensive listing of studies which document the allocation rules used by households concerning access to food and resources of the household. Sen (1981) summarises the controversy concerning caloric expenditures and changes in metabolism.

important factors in the choice of sites in the Mutoko Communal Area. However, the choice behavior in the Dandara study site in the Murewa Communal area is probably more complex because of the nature of the surrounding sites and the characteristics of the people.

There are some significant differences between the Communal Areas. As noted previously, households tend to make fewer trips to collect firewood in the Dandara study site. This may be due to a number of different strategies being employed by these households such as conserving fuelwood, using alternative fuels, or using carts to collect wood. The latter strategies involve substituting other fuels for wood or using a labor saving capital good to collect fuelwood. If this is in fact the case, there may be some potential for using nested models of choice to explain the choice between walking and taking a cart and the choice of fuels.

The welfare simulations reinforce the importance of the spatial context of fuelwood shortages. Closing sites may have a relatively small effect on the community but a large effect on the well-being of particular households. For example, the household collecting wood two or three times a week at Chitupwana Mountain in the Katiyo study site, the closure of this site would cost one household 118 calories per trip. When households in this area are making two to three trips a week, caloric expenditures on a day to day basis are of fundamental importance.

The welfare effects have broad policy implications. For governments considering site closure to protect forested areas, the increased caloric expenditures by women will be a significant but less visible cost for the local population. A government or non-governmental agency which is mindful of these welfare implications has a number of options available to redress the situation. For instance, compensation might be provided through deliveries of staple commodities (or cash equivalents) to increase caloric consumption. However, agencies must be cognizant that careful targeting may be required because the customary allocation of food within the household may not benefit those most affected by the site closure.

Another way the welfare effects could have been simulated would be to change the availability of specific species of fuelwood. By making muunze more plentiful at particular sites, it would be possible to calculate whether there would be significant reductions in the energy women expend in fuelwood collection. This would provide insights into the welfare effects of an afforestation program targeted towards specific species.

The estimation results and the welfare effects may also be of interest to governments from the industrialized world. With recent attention to global warming, governments and industries are interested in the potential for carbon sequestration in the developing world. This research suggests the nature of the costs that would be borne by local populations if stocks of carbon in the form of forested areas were set aside for protection.

If policy makers wish to assess the impacts of global warming policy changes, or the impact of afforestation programs, the decision making behavior of households concerning energy needs to be investigated. Much of the developing world, including the area of concern for this study, Zimbabwe, is dependent on wood as the primary source of fuel. Much of the existing literature concerning fuelwood is broad in scope and does not provide insights into the dynamic, spatial relationships that have evolved with fuelwood shortages. To date, the literature is largely motivated by a concern over the rate of deforestation that is occurring in many parts of the world. Often the spatial nature of the problem is ignored. Fuelwood shortages can be very local in nature and thus large scale projects may not address local needs. Further, as wood scarcity increases, wood may be used more carefully and/or substitutions might occur. Assessing the responses by local people to these scarcities, through behavioral models, will help policy makers in making effective choices of policy instruments.

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