

The Influence of Socioeconomic Status and Fuelwood Access on Domestic Fuelwood Use in the Brazilian Atlantic Forest

Kellie Wilcox-Moore and Christian Brannstrom

*Department of Geography
Texas A&M University*

Michael G. Sorice

*Department of Forest Resources & Environmental Conservation
Virginia Tech*

Urs P. Kreuter

*Department of Ecosystem Science and Management
Texas A&M University*

Abstract

In the Brazilian state of Minas Gerais, rural households use wood from the endangered Atlantic Forest as a source of domestic energy. Reasons for household fuel choices were explored in four small rural communities in rural Minas Gerais using a survey of 48 households and semi-structured interviews. Socioeconomic status and the interaction between status and access to fuelwood explained significant percentages of the variance in collection effort, our indirect measure of fuelwood use by households. Access to fuelwood is best explained by the circumstances of a household, which we generalize into typologies that may inform future studies in fuelwood use.

Key Words: *Fuelwood, sub-tropical Brazil, energy ladder, rural energy*

Resumo

No estado de Minas Gerais, domicílios rurais usam a lenha da Mata Atlântica como fonte energética doméstica. Pesquisamos as motivações das desições energéticas domiciliares em quatro comunidades rurais mineiras por meio de um questionário aplicado a 48 domicílios e entrevistas semi-estruturadas. O variável para status sócio-econômico e a interação entre status e acesso à lenha explicaram uma porcentagem significativa da variação na coleta da lenha, o variável que usamos para medir, indiretamente, o uso da lenha. O uso domiciliar da lenha pode ser explicado pelas circunstâncias particulares dos domicílios, o que generalizamos em quatro tipologias que podem informar estudos futuros sobre o uso da lenha.

Palavras-chaves: *lenha; Brasil sub-tropical; escada energética; energia rural*

Introduction

The energy ladder, used in the study of energy-use patterns in developing countries since the early 1980's, remains a pervasive framework for describing and inter-

preparing household energy transitions (Hosier 2004). Increasing socioeconomic status is thought to explain changes in household reliance on biomass to higher density fuels such as liquid petroleum gas (LPG). The energy ladder concept is based on the notion that higher density fuels have fewer disadvantages associated with their use and are therefore more desirable, although more expensive, than low-density fuels. Movement up the ladder to high-density fuels is associated with a change in status, often related to income, education, or both (Israel 2002). Movement down the energy ladder may also occur. A recent study conducted in Nigeria found that as the price of kerosene and petroleum-based domestic fuels has risen, low and middle-income households in peri-urban regions have begun to switch back to biomass-based alternatives such as fuelwood (Maconachie *et al.* 2009). Household location (rural or urban) and the proximity to readily available sources of biomass may also play an influential role in domestic energy decisions. For example, a country-wide study in India found that transition up the energy ladder, from fuelwood to LPG, was occurring across nearly all income classes in urban areas, while in rural areas the majority of households continued to rely on fuelwood (DeFries and Pandey 2010). Other factors affecting movement up or down the energy ladder include fuel cleanliness, fuel availability, relative cost of fuel, government subsidies, and the cost of appliances (Israel 2002; Hosier 2004).

Several scholars have found that the energy ladder fails to integrate the multi-dimensional aspect of domestic energy decisions; moreover, evidence from some case studies contradicts assumptions of the energy ladder (Hiemstra-van der Horst and Hovorka 2008). For example, research in South Africa has found that even in areas where electricity is provided by the government it may only have limited use and more traditional forms of energy may be retained for important activities like cooking (Madubansi and Shackleton 2006).

Attempts to amend and even re-theorize energy transition patterns in the developing world include the Masera *et al.* (2000) "multiple fuel" model, which is based on the observation that in rural Mexico most households tend to stack fuel types rather than switch from one to another. This study found fuel types are not perfectly interchangeable, and therefore when households adopt new cooking technologies they rarely abandon traditional fuels, so that even the wealthiest households continue to use fuelwood for cooking particular foods.

Fuelwood is an important source of industrial and domestic energy in Brazil, contributing to 11.4 percent of the national energy budget (Brito 2007). In rural subtropical Brazil, households obtain energy from LPG and wood from remnants of the Atlantic Forest, an umbrella term for a mosaic of forest ecosystems that once dominated the coast of Brazil and still support high biodiversity and endemism (Ribeiro *et al.* 2009; Galindo-Leal and Câmara 2003). The Atlantic Forest is extremely fragmented and by some reports has been reduced to between 11.4 and 16 percent of its original distribution, with only 9 percent of the remaining forest being protected in reserves, and much of the remainder being composed of fragments smaller than 50ha (Ribeiro *et al.* 2009). Although fuelwood harvesting was not the main cause of Atlantic Forest clearing (Dean 1995), it is often assumed that this activity has detrimental impacts on native forests (Hodge *et al.* 1997; Lucon *et al.*, 2004; Tabarelli *et al.* 2005). Native fuelwood harvesting has continued in spite of numerous restrictions, such as the 1965 Forest Code (Sparovek *et al.* 2010) requiring forest set asides of 20 percent of rural properties and prohibiting unlicensed felling of native trees in the Atlantic Forest, effectively making these wood resources legally inaccessible.

We use quantitative data collected from household surveys to statistically test the applicability of the energy ladder model in the study region. We also explore the

extent to which socioeconomic status explains fuelwood use in a rural municipality in the State of Minas Gerais. Additionally, we test the hypothesis that the amount of fuelwood available to a household in this region affects the strength and direction of the relationship between socioeconomic status and fuelwood use. This hypothesis is supported by research reviewed by Hosier (2004), who found that rural fuel use is predicated mainly on fuel availability rather than other economic factors. Finally, in order to explore how fuelwood access might influence fuel decision making we analyze qualitative data collected at the household scale.

Study Area

General Description

This study was conducted in the municipality of Rosário da Limeria, within the region of the Brazilian state of Minas Gerais known as the *Zona da Mata*, or “Forest Zone”. The population of this municipality is about 4,000 inhabitants in an area of 112km². Elevations range from 300m to 1500m and the climate is subtropical (Köppen Cwa) with annual precipitation of 1,000 to 1,200mm occurring mainly in November, December and January (Tomé da Costa Mata 1994; Le Breton 1998). The landscape consists of fragments of primary forest located in inaccessible areas, patches of secondary forest on hilltops and around springs, coffee plantations, eucalyptus groves and pastures. About 75 percent of the municipality is agropastoral land and 12 percent is primary and secondary growth forest (Achinelli 2003). Over 60 percent of agricultural land (1250ha) is devoted to coffee plantations while slightly more than 5,000ha of the municipality is in pasture for milk and beef production (IBGE 2006).

The majority of landowners in the study region are independent small-scale farmers who mostly cultivate coffee, eucalyptus and subsistence crops, and graze cattle on plots of 9ha or less, often on marginal, sloping lands. Only 10 percent of the rural population occupies farms larger than 30ha, which with current technology is considered the minimum economically viable property size to support a family unit (Le Breton 1998). Sixty percent of the total land area in this region is owned by 20 percent of the population and the most favorable 3 percent of the total land area are large-scale (100ha or more) farms whose owners often live outside the region and employ caretakers to maintain coffee, eucalyptus and cattle on the land (Watson and Achinelli 2008). As in much of Minas Gerais, the communities of Rosário de Limeira are highly reliant on agriculture and the federal conditional cash transfer program known as *Bolsa Família* (Le Breton 1998; Hall 2006).

The Atlantic Forest Policy governs forest use in the region by requiring landowners to set aside 20 percent of their property in native forest as a Legal Reserve (LR) and maintain native vegetation on environmentally sensitive areas (along rivers, around springs, hilltops and steep slopes) as Permanent Protection Areas (PPA). Additionally, this policy prohibits the unlicensed felling of any native tree with a diameter greater than 10cm at chest height.

The illegality of using native species for firewood in Brazil’s *Zona da Mata* contrasts strongly with the characteristics of such use in India as reported by Robbins *et al.* (2009). In both regions illicit use of forest resources is widespread; however, in our study area this has not generated the bribery and corruption reported in India (Robbins *et al.* 2009). Other forms of illegal wood use, such as timber operations and charcoal production, are notorious in Brazil for being plagued with corruption.

Access to Fuelwood and Energy Use in the Zona da Mata Mineira

Households in the Zona da Mata Mineira obtain their fuelwood from three main sources: eucalyptus plantations, coffee fields and native forest. The native forests provided domestic energy to the original inhabitants of the Zona da Mata and have been the principal source of energy in this region until recent times. By the late 1700s, coffee had arrived in the region, and thrived in the nearly optimum growing climate (Watson and Achinelli 2008). For several decades, coffee growers in Brazil have practiced a system of sun-grown coffee that requires the complete clearance of native vegetation from the land (Dean 1995). Over time, the term “forest zone” became increasingly inaccurate to describe the region, as plantations expanded across the Zona da Mata Mineira, replacing the native forests with monocultures of coffee. The resulting depletion of the region’s thin and infertile rainforest soils has been exacerbated by erosion due to the practice of planting coffee vertically across steep hillsides. Soils in this region generally reach exhaustion after fifteen years of cultivation, resulting in a relatively short productive lifespan of coffee trees. Low-yielding bushes may be trimmed or cleared and the wood can be burned as fuel. For households with many hectares of coffee this is a viable source of fuel both for domestic purposes and for roasting coffee beans. However, coffee is not a reliable source of fuel for small landholders or for large industries, which rely on either exotic eucalyptus or native Atlantic forests. In the last decade increased enforcement and inaccessibility of remaining forests have halted large-scale clearing of native forest in the region. The timber and fuelwood that had been supplied by native species is now being replaced by eucalyptus, which is capable of gleaning remaining nutrients from soils exhausted by decades of coffee-growing and cattle grazing.

Eucalyptus was introduced to Brazil from Australia in 1868 (CIB 2008). In the late 1980s the World Bank lent the forestry institute of Minas Gerais (*Instituto Estadual de Florestas*, IEF) over US\$48M for eucalyptus planting programs that aimed to increase industrial wood production (primarily for the purpose of supplying charcoal for steel production) and reduce degradation of the native forests (WB 1987). Additionally, this loan provided funds for the planting of about 40,000ha of eucalyptus woodlots on small and medium-sized farms. Since this time the IEF has provided eucalyptus to landowners but transportation of the seedlings was not provided, creating a bias against less affluent landowners. In the last decade, municipalities have played a more active role in distributing eucalyptus seedlings to landowners who cannot provide their own transportation and eucalyptus plantations have become a widespread feature of the rural landscape (Le Breton 2008). Consequently, the use of eucalyptus as a domestic fuel has become commonplace.

Access to fuelwood is a product of the region’s settlement history and complex land-labor relations. Luso-Brazilian settlement in the Zona da Mata Mineira began in the nineteenth century and, by the twentieth century, demands of the metallurgy industry for charcoal stimulated mass deforestation (Dean 1995). Over time, forest clearing continued for charcoal production and the establishment of coffee plantations and cattle pasture. Gradually, a mosaic of land-cover types emerged, ranging from primary native forest to *capoeira* (secondary growth forest), coffee, pasture, and eucalyptus.

Contemporaneous to these processes, Brazil’s inheritance laws encouraged a steady decrease in farm size. Upon the death of the head of household, the surviving spouse received half of the estate, while surviving children claimed an equal portion of the remaining assets (Triner 2007; Lewin 1992; Brannstrom 1997). In rural Brazil, where small farmers were cash-poor during much of the twentieth century, most assets were held in land, and, therefore, property size decreased over time. Forest fragmentation and land subdivision left most landowners with relatively small parcels of land over which

patches of native forest, capoeira, coffee, pasture, and eucalyptus are unevenly distributed (Figure 1). Most landowning households have access to some type of fuelwood in native forest, coffee, or eucalyptus; however, some households occupy land with no wood reserves. Households without their own land generally have access to any native forest fragments or eucalyptus groves on the property they occupy. The size of these forest patches varies depending on past land-use choices, and access for caretaker workers depends on employment terms with absentee owners.



Figure 1: Patchwork landscape typical of Rosário da Limeira, Minas Gerais, Brazil.

Together, the combination of historic and current land-use choices, as well as land-labor regimes inherited from the early twentieth century, created a complicated situation in which many households do not control access to fuelwood. Until recently the supply of fuelwood was not a concern as most properties had some type of fuelwood reserve on them. However, as the size of landholdings and forest fragments declined, increasing numbers of households in the study region faced fuelwood scarcity. Legal restrictions that protect the remaining Atlantic Forest fragments and prohibit the felling of any native tree in the region without a permit also restrict fuelwood access. Loss of fuelwood poses little problem for households who can afford to switch to LPG but may impose hardship on low-income households.

Elsewhere in Minas Gerais, landowners produce eucalyptus fuelwood for metallurgy; however, most landowners in the municipality of Rosário de Limeira produce and harvest fuelwood only for routine domestic activities such as lighting, cooking and heating bath water. In this region fuelwood collection for these purposes does not vary seasonally. A small minority of landowners require fuelwood to roast their own coffee beans (a seasonal activity), but most landowners pay for their coffee to be roasted offsite. Trade in fuelwood is not common in this area as the majority of households supply their own wood. The few households that sell fuelwood tend to do so infrequently. All wood harvested for commercial purposes is from eucalyptus plantations and most of this is sold to buyers for local industries.

According to a local official, nearly all households have electricity due to a program, *Luz Para Todos*, implemented in 2003 by the federal government for rural electrification. Households in this region use electricity primarily for lighting and powering electrical appliances. However, electric stoves are not used in this region; instead, wood-burning and gas stoves are used to varying degrees. Nearly all homes in the region have a gas stove as well as an indoor wood-burning stove constructed from brick with a metal chimney (Figure 2). A minority of households use only wood or only gas, while most use both depending on the type of cooking, the amount of time, the availability of fuelwood and the cost of gas (Table 1). Households that do not have electric showers also rely on fuelwood to heat bath water. Although winters in this region can be cold, energy is not used to heat homes. Nevertheless, the heat emitted when cooking with wood is seen as an indirect benefit.



Figure 2: Woodburning stove in a rural home in Rosário da Limeira, Minas Gerais, Brazil.

Table 1: Frequencies of fuel types used among respondents to household survey in Rosário da Limeira, Minas Gerais

Fuel Type	Heating Coffee		Cooking Lunch		Cooking Dinner		Baking		Heating Water	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Wood ^a	10	20.8	43	89.6	32	66.7	3	6.1	12	25
LPG or Electricity	35	72.9	5	10.4	16	33.3	43	91.5	35	72.9
Both ^b	3	6.2	0	0	0	0	1	2.1	1	2.1

^aNative and/or eucalyptus

^bWood and LPG/electricity

Methods

A household survey, semi-structured interviews, participant observation, and focal follows were used to gather field data (Dunn 2005; Klofstad 2005; Wilson 2005). For the purpose of this study, a focal follow was defined as directly observing a respondent in the act of collecting fuelwood. Data for this study were collected in June and July of 2009 from households in four villages in the municipality of Rosário de Limeira in Minas Gerais, Brazil (Figure 3). These villages were purposefully selected with guidance from the Iracambi Atlantic Forest Research Center, an NGO based near the city of Rosário de Limeira, which has assisted with previous studies in the region (Watson and Achinelli 2008; Silveira 2008; Achinelli 2003).

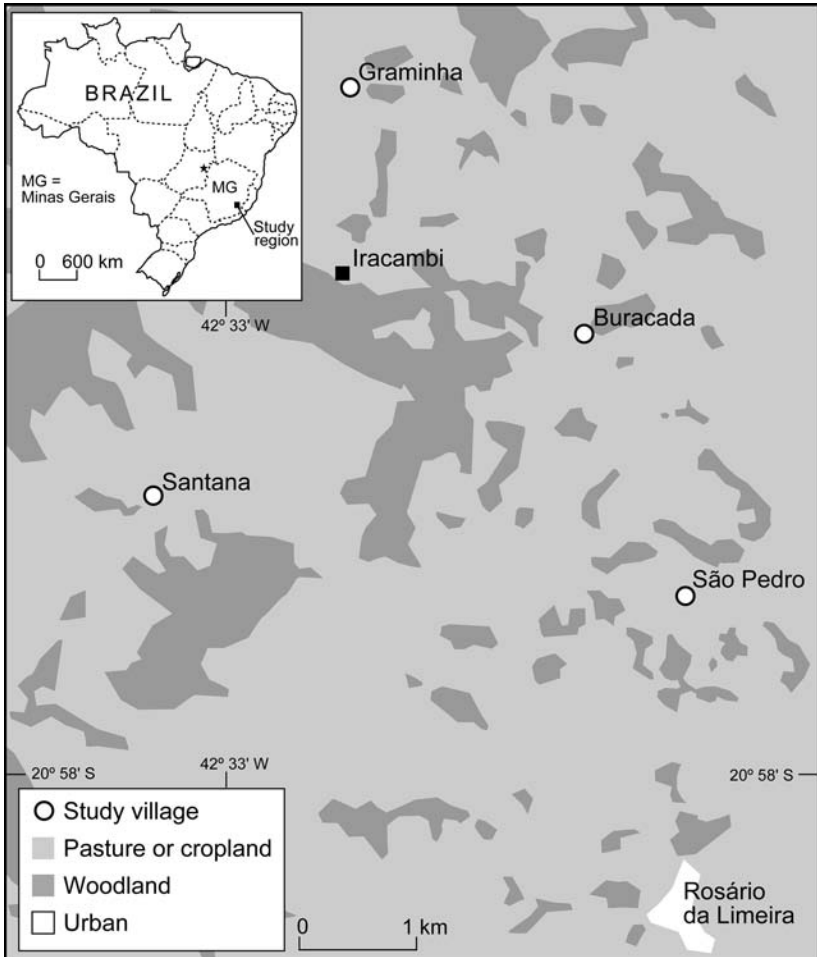


Figure 3: Study villages in Rosário da Limeira municipality in Minas Gerais, Brazil (Land cover data derived from Google Earth imagery. Woodland category includes Atlantic Forest and Eucalyptus. Pasture or cropland area includes coffee fields).

Nine semi-structured interviews were conducted with three types of informants: Iracambi staff, state forestry officials, and municipal officials. Selection of informants was intentional; we identified types of informants prior to the interviews. The precise phrasing of questions varied depending on the informant, but the issues remained constant: (1) Which factors contribute to the use of fuelwood in the rural communities in this region? (2) What are the biggest concerns for agricultural families in this region? (3) How well do small agriculturalists understand Atlantic Forest Policy? (4) Does this policy influence their domestic energy decisions?

In addition to the semi-structured interviews, a survey of 48 households in the four selected villages was performed in June and July of 2008. These villages were selected because they were representative of small rural communities in the municipality and varied in their access to roads, dominant form of livelihood, and levels of affluence. The number of families in the villages ranged from about 25 to 50 (Achinelli 2003). Given that no formal household data were available for randomized sample selection, Iracambi employees were asked to help identify representative individuals from each community for the survey. These individuals were then asked to identify other residents as potential survey participants or to introduce the first author to village members at community events. Using this snowball sampling approach, approximately 12 households were surveyed in three of the four communities. In the least accessible community the first author made cold calls to households where the inhabitants were present. To avoid a socioeconomic bias, the initial survey participants were asked to recommend potential additional participants who spanned the socioeconomic spectrum in the community. Particular attention was paid to non-landowning residents characterized by lower socioeconomic status; this group is often underrepresented in fuelwood studies (Cooke *et al.* 2008). Households representing the wealthiest strata in each community were also interviewed.

A mixed-method approach was used for the household survey. A standard questionnaire relating to household demographics, income sources, access to land, fuelwood use, and collection habits of family members was used with each household. This information provided location-specific fuelwood-use data important for elucidating household energy decisions (Cooke *et al.* 2008). We also included questions in the survey relating to understanding of Atlantic Forest Policy. Readers may request the full survey instrument from the second author. The quantitative data were supplemented with qualitative information gained opportunistically through more in-depth conversations with many of the survey participants. This mixed method strategy has become common in recent geographical and anthropological research due to the renewed emphasis on finding explanations for behavioral patterns that cannot be easily quantified (Winchester 1999).

The veracity of the data collected relied on the willingness of villagers to participate in the study and to provide honest responses. The main factors that appeared to influence willingness and honesty included participant awareness of the illegality of native fuelwood use and perceptions of the NGO Iracambi. For example, one participant responded as follows when asked about the type of fuelwood she most often used:

When people heard that you were coming to interview me, they told me to tell you that I only use eucalyptus. But you can look in my woodpile and see that it is all native wood. I have no eucalyptus on my land; it's ridiculous to think that you would believe that I use eucalyptus! But people think that you are going to report us to the Forest Police.

Due to the sensitive nature of the research topic, finding participants for the survey proved to be a delicate endeavor. In many situations, the first author unexpectedly found that the presence of her young son facilitated communications with potential participants. The child's presence seemed to encourage villagers to see the first author primarily as a mother, rather than a foreign researcher or a Forest Police informant. The first author never presented herself as a researcher interested in firewood use as an illegal activity; instead the interview protocol emphasized patterns of domestic fuelwood use. Therefore, we believe that the answers we received were, in general, truthful. If respondents were initially skeptical of the first author's intentions, then the relaxed atmosphere created by the presence of the child, or by the friendly tone of the first author, helped to encourage truthfulness.

Results

Household Characteristics

Size of households participating in this study ranged from two to eleven members, with an average of four (Table 2). Seventy-three percent of participants owned land, with size of landholding ranging from three to 64ha (mean =16.6ha). Eleven surveyed households did not own land, but had regular access to plots of land ranging from one to 500ha, with a mean of 154.5ha. These survey participants were employed as caretakers for landowners. Caretakers had access to most of the natural resources on the land to supply daily household needs including water, pasture for animals, and wood for fuel, construction and carpentry. But regular access to large amounts of land was not common. Fifty percent of all households sampled had access to 15ha of land or less (Table 2), and much of this land had been cleared for pasture, so that in some cases households had no access to fuelwood on the land they inhabited.

Table 2: Descriptive Statistics generated from household survey in Rosário da Limeira, Minas Gerais

Item	Mean	Median	STD
No. people per household	3.7	3.0	1.75
Hectares owned or occupied	16.6	9.0	13.0
Hectares available fuelwood*	12.3	4.5	28.48
Socioeconomic status score*	-0.09	-0.6	3.38
Collection effort (min/day/household)*	17.2	12.0	17.2

* Variable used in regression analysis.

Table 3: Type of wood used as fuel among respondents to household survey in Rosário da Limeira, Minas Gerais

Wood	Frequency	Percent
Eucalyptus	19	39.6
Native species	14	29.2
Eucalyptus and Coffee	9	18.8
Coffee	3	6.2
Natives and Coffee	2	4.2
Eucalyptus and Natives	1	2.1
No wood used	1	2.1

Field observations suggested that an important variable in fuelwood use is the amount of fuelwood available to households, which is affected by factors such as land-use choices and forest access rights. When all categories of wood sources were included (native forest, eucalyptus and coffee), the area of potential fuelwood immediately available to participants (by being located on land that they either owned or occupied) ranged from zero to 126.8ha, with a mean of 12ha and a mode of one hectare (Table 2).

Households in the study area obtain their fuelwood from eucalyptus plantations, coffee fields, and native forest (Table 3). Forty percent of respondents reported that they obtained fuelwood primarily from eucalyptus trees, while nearly 30 percent stocked their woodpiles solely from native forests. A further 21 percent used a combination of eucalyptus with either coffee or native species, while approximately 6 percent used only coffee and 4 percent used a combination of coffee and natives. Only 2 percent of respondents (1 household) used no fuelwood at all and supplied all its energy needs with either LPG or electricity.

The most common use of fuelwood was the preparation of lunch, the principal meal in rural Brazil, with more nearly 90 percent of respondents using wood of some type for this purpose (Table 1). The most common use of LPG was for baking cakes, which are commonly taken with coffee as a breakfast or snack. In addition, 72 percent of respondents used LPG for heating coffee while the remaining 28 percent used wood or a combination of wood and LPG for this purpose.

The principal requirements of the Atlantic Forest Policy were not well understood among survey respondents. Although the majority (77 percent) were aware of some sort of restriction on the use of Atlantic Forest resources, many were unclear about the exact nature of these restrictions. For example, the majority of respondents who were aware of restrictions believed (incorrectly) that it was legal to fell dead trees. Another common misconception was that felling trees to supply domestic needs was legal without a license. In addition, the difference between the LR and PPA was unclear. Of the households interviewed, 60 percent understood the term *Reserva Legal* (LR), whereas only 24 percent understood the term *Área de Proteção Permanente* (PPA). Fifty-five percent of respondents said they had land set aside on their property as a “reserve,” although only 13 percent of respondents had a notary-registered LR, which is a requisite for selling the property, obtaining credit from state banks, and for obtaining a permit for the felling of a native tree. Due to poor understanding of the restrictions as well as weak enforcement, the Atlantic Forest Policy seems to have little influence on domestic fuelwood choices.

Collection Effort and Socioeconomic Status

The best measurement of a household's reliance on fuelwood would be the monthly wood-generated energy consumed by each household. However, it was not feasible to obtain such data for three reasons: participants could not provide volumetric estimates of fuelwood collected; participants do not use a standard means to measure or transport fuelwood; and fuelwood collecting systems and time-tables vary between households. Since most households surveyed used a combination of energy sources for cooking and heating water, they also found it difficult to reliably estimate fuelwood usage. Additionally, to calculate wood-generated energy consumption it would be necessary to determine the proportional use of individual species because Atlantic Forest trees vary significantly with respect to energy density. Finally, varying proportions of woodpiles consist of empty space, which further confounds efforts to accurately estimate wood energy consumption (Brannstrom 2005).

As a result of these challenges, we had to create a variable other than fuelwood consumption to compare the importance of fuelwood to the surveyed households. We chose collection effort (CE), defined as the mean number of minutes per day that a household allocated for gathering fuelwood, as the closest approximation of a household's reliance on fuelwood that could be obtained from the collected data. We estimated CE indirectly using several other variables, including average number of people collecting wood, time spent collecting wood and collection frequency. The formula for the calculation is as follows:

$$CE = ((t * 60) / i) / p$$

Where CE = collection effort, t = time spent collecting fuelwood in hours,
i = fuelwood collection interval, and p = number of people collecting.

Nine of the 48 participants were unable to provide estimates of the three variables needed for this calculation. Accordingly, they were excluded from the regression model, leaving a sample size of 39 for the statistical analysis.

The estimated values of CE ranged from zero to more than 60 minutes per household per day with the mean collection effort being 17.18 minutes per household per day (S.D. = 17.23). Due to the positively skewed frequency distribution of collection effort, these estimates were converted to log-normal values for use in the regression analysis.

Table 4: Status Indicators used to create a socioeconomic status score for participating households in Rosário da Limeira, Minas Gerais

Item	Frequency	Percent
Owens home	35	73
Owens none of the surveyed means of transport	3	6
Owens horse-cart	19	40
Owens motorcycle	11	23
Owens car	8	17
Owens car and motorcycle	7	15
Owens cell phone	18	38
No regular income	17	35
One regular income	16	33
Two regular incomes	15	31
Receives <i>Bolsa Família</i>	15	31
No formal education (husband)	14	29
Some elementary school (husband)	31	62
Some high school (husband)	2	4
Graduated high school (husband)	2	4
No formal education (wife)	8	15
Some elementary school (wife)	38	77
Some high school (wife)	1	2
Graduated high school (wife)	3	6

Socioeconomic status (hereafter referred to as status) was one of two independent variables used in the regression. Status was calculated using seven indicators of wealth: home ownership, hectares of land owned, type of transportation, cell phone ownership, number of regular incomes, receipt of conditional cash transfers from the government (*Bolsa Família*), and the level of education attained by both the husband and wife (Table 4). Status estimates were obtained by calculating the z-value for each indicator (standardizing each item based on a mean of 0 and standard deviation of 1) and then

summing these z-values to create a single index. None of the indicators used to estimate status were auto-correlated. Socioeconomic status scores ranged from -5.12 to 10.04, with a mean of -0.09. Positive status scores indicate a household with higher status while negative scores indicate lower status.

Testing the Hypotheses

Both the energy-ladder and the available fuelwood moderator hypotheses were statistically tested using jackknife linear regression analysis with CE as the dependent variable. Table 2 includes descriptive statistics relating to the variables used in the regression, indicated with an asterisk. The jackknife technique internally replicates the data, and was used to offset the limitations of the small sample size for the analysis (Yoon 1995, Thompson 2006). This technique performs the regression analysis multiple times on the same data set, omitting each observation from the regression once, thereby calculating the impact of any outliers on the analysis.

When status was used as the single independent variable to explain changes in CE the resulting status coefficient was marginally significant (Table 5). As status increased, CE decreased (Figure 4). Status alone explained 7 percent of the variance in CE.

Table 5: Regression statistics from quantitative data collected from households in Rosário da Limeira, Minas Gerais

Variable	Model 1 Status Only	Model 2 Fuelwood Only	Model 3 Interaction
Intercept	2.38*	2.54	2.49*
Status	-0.09*	—	-0.11*
Log(Available Fuelwood)	—	-0.10	-0.04
Interaction	—	—	0.07*
F _(df1, df2)	3.95 _(1, 36) *	0.28 _(1, 35)	9.35 _(3, 33) *
R ²	0.07	0.01	0.19

*p≤0.05

Jackknife regression analyses were next used to statistically analyze the power of available fuelwood and the interaction between available fuelwood and status to explain variations in CE. Available fuelwood was not a statistically significant explanatory variable (Table 5). However, the interaction between status and available fuelwood was highly significant and the regression model as a whole explained 19 percent of the variance in CE, more than twice as much as was explained by the status variable alone. This indicates that the relationship between status and CE depends on available fuelwood (Figure 5). This interaction can be illustrated by dividing households into two groups based on fuelwood availability (low ≤ 4.5ha; high > 4.5ha; roughly half of participants in each category). Both groups exhibit a different relationship between CE and status. For households with low access to fuelwood, CE decreases as status increases, whereas the CE of households with high access to fuelwood is unaffected by status (Figure 5). This can be interpreted as indicating that households with little available fuelwood will choose to supplement their domestic energy supply with other sources as economic resources permit and thereby spend less time collecting fuelwood. However, for households with plenty of available fuelwood, socioeconomic status does not influence the amount of time dedicated to collecting fuelwood. For these households the use of fuelwood may be based on factors such as tradition and preference for wood-cooked foods.

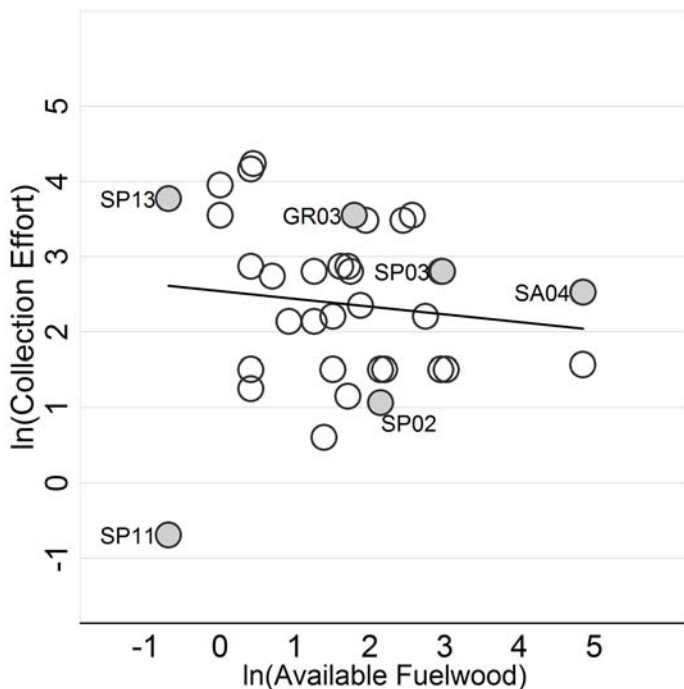


Figure 4: The relationship between the socioeconomic status of households and the effort put into collecting fuelwood in a sample from Rosário da Limeira, Minas Gerais ($p = 0.054$). Shaded circles represent respondents included in the vignettes.

Household Access to Land, Wood, and Income

The energy ladder model explained only a small component of domestic energy decisions made by the surveyed members of rural communities in the Zona da Mata Mineira. However, the interaction between socioeconomic status and access to fuelwood explained a statistically significant percentage of the variance in fuelwood CE among the sample population. This indicates that the relationship between status and CE is dependent, partially, on the amount of fuelwood available to a household.

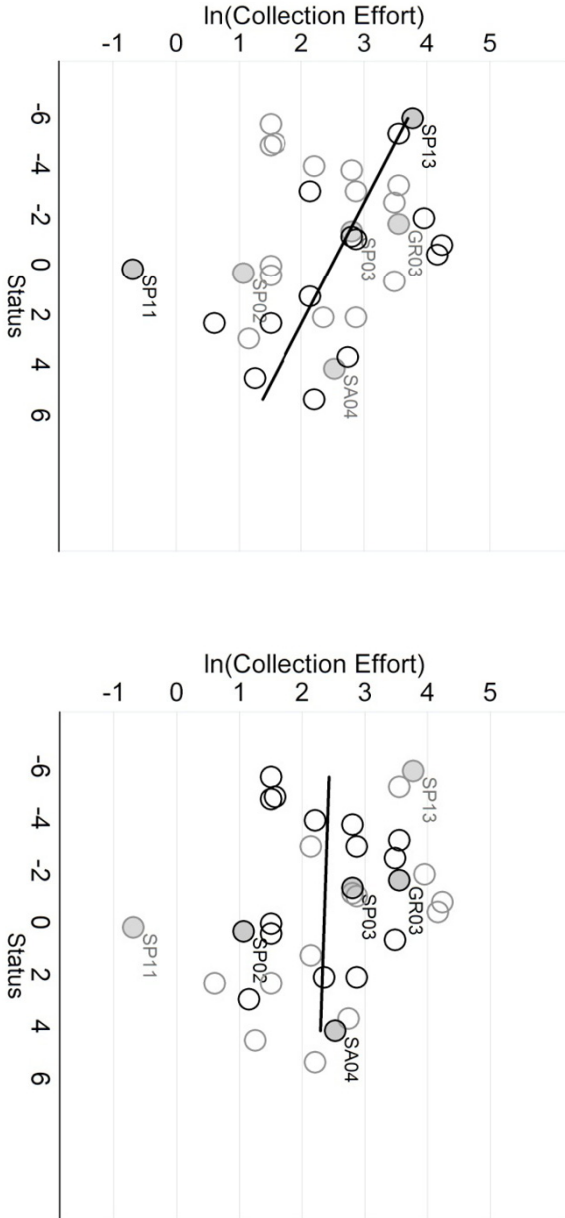


Figure 5: Demonstrating the moderating effect of access to fuelwood on relationship between the socioeconomic status and time spent collecting fuelwood for household in Rosário da Limeira, Minas Gerais. For each chart, circles with black outlines indicate households included in the condition illustrated: a-left) ≤ 4.5 ha of fuelwood and b-right) > 4.5 ha of fuelwood. Shaded circles indicate households discussed in the vignettes.

Table 6: Example households with ranked categories in Rosário da Limeira, Minas Gerais (See Figures 1 and 2 for household location on graphs).

Code	Access to Land	Access to Wood	Regular Income
GR03	Med	Med	Med
SP03	Med	Med	Low
SP02	High	High	High
SP07	Low	Med	High
SA04	High	High	Med
SA10	High	None	Med
SP11	Low	None	Med
SP13	Low	Low	None

To explain the conditions influencing fuelwood availability, we created a typology of households based on a continuum from low to high access to land, wood, and regular income (Table 6). Qualitative information gained in the field suggested that these categories influenced household energy decisions. The vignettes point to the importance of particular circumstances of households, rather than more general variables such as income or socioeconomic status as the determining factor. Moreover, the vignettes demonstrate how uneven access to land, wood, and regular income influence the amount of time households dedicate to fuelwood collection. We follow Birkenholtz's (2009) example in using cases of specific households to argue a more general point.

Landowning households may have high or low access to wood and regular incomes, with no obvious implication for wood use. A common situation is for a household to own a small farm of one to 30ha and to receive one regular income, either as a pension or from employment of at least one member of the family. An example is household SP03 with an average daily wood-collection time of 16 minutes (socioeconomic status = -0.37). This household occupies 21ha of land, of which 15ha are pasture, 3ha are native forest, 1ha is coffee, and one is eucalyptus. The couple is in their early to mid 40s, with four children. Their primary income is from coffee, although two grown sons are employed and contribute to the family income. The household also receives the *Bolsa Família*. The mother uses wood to cook lunch and dinner and LPG to heat coffee and to bake. Usually the father and oldest daughter gather the wood, spending about half a day once a month collecting wood from the coffee fields or eucalyptus plantations on the property. This household uses 13kg of LPG every three months.

Small landowners without regular monthly income other than the *Bolsa Família* face different constraints. For example, household GR03 is made up of a middle-aged couple with four children living at home. They live on 27ha with two related families. This household has access to 3ha of native forest, and one and a half of eucalyptus and spends an average of 34 minutes per day, double the sample average, on fuelwood collection (socioeconomic status = -1.61). GR03 relies heavily on fuelwood for cooking; the wife says she generally lights a fire in the stove in the morning and keeps it burning the entire day. She never cooks with gas, although she has a gas stove that she laughingly referred to as a decoration. GR03 has used eucalyptus wood for the last 20 years. Before that they used native species, but switched to eucalyptus as it became the most convenient source when native forest near their home was mostly cleared and eucalyptus was planted nearby. The wife and children in this household are generally the ones who gather the wood, spending about two hours once a week collecting wood from the eucalyptus grove.

More affluent landowners face different wood access issues. Household SP02 (socioeconomic status = 1.99) has access to 64ha, most of which is in pasture, only a couple hectares of coffee, 5ha of native forest and one of eucalyptus. The husband gathers eucalyptus wood every 75 days or so, averaging 2.4 minutes a day on fuelwood collection. Both the husband and wife are in their early 60s and still work on the land and in the home. The major sources of income for this household are cattle, milk, coffee, and eucalyptus. For the last 10 years they have been regularly selling eucalyptus wood to a buyer who sells to a dairy product producer. One indication of their relative affluence is that they were able to pay to have electricity lines from the city extended to their house, allowing them to have access to electricity more than a decade earlier than most families in the region.

Household SP02 uses a combination of wood and gas for their cooking needs. The wife uses wood primarily to cook lunch, while she uses gas to heat water for coffee and cook dinner. One 13kg canister of gas lasts this household three months. When cooking with wood she uses eucalyptus, because it is more convenient to gather than native wood that has become increasingly scarce on their property.

Another type of relatively affluent landholder is younger, and expends very little effort on fuelwood collection, even though they have access to wood. In the example of SP07 (socioeconomic status = 9.13), both the husband and wife are employed in positions in the municipal government. They own only 3ha of land, mostly composed of pasture, upon which they recently constructed a modern home. Owing to the sporadic nature of their wood gathering, this household was unable to estimate collecting frequency but answers to other questions suggest that they spend less than four minutes a day, collecting fuelwood from their parents' eucalyptus grove, as their own property has little forest. This type of household lives an urban lifestyle while maintaining ties to its rural heritage. The members of this household rely on motorized vehicles and cell phones, but also keep some livestock, including a milk cow, and, when time allows, enjoy a meal prepared on a wood-burning stove. The mother of this household explained that she only cooks dinner and reheats the leftovers for lunch the next day at the office. At home, she cooks with both gas and wood, depending on what time she gets home from work, and if there is wood available. She goes through a 13kg can of gas every two months.

Non-landowning households face different opportunities and constraints. Often, these households are employed as caretakers by large landowners on whose property they live and have access to all its resources. One example, household SA04 (socioeconomic status score = 4.99), is the caretaker family on a 360ha ranch. The majority of this property is in pasture, with 9ha in coffee, 1ha in eucalyptus and the remaining 116ha preserved in native forest. The time SA04 spends collecting fuelwood was calculated to be 12 minutes per day. The wife of SA04 uses wood to cook lunch every day but uses gas for other cooking needs. She uses primarily coffee wood, which she and her husband gather from the coffee fields two or three times a month. One 13kg canister of gas lasts them about two months.

The resources available to caretakers vary depending on how owners decide to use the land. On a nearby ranch, in the same community as SA04, the first author interviewed the only household in the data set that regularly purchases fuelwood. Household SA10, situated on a 300ha ranch that the husband is employed to manage, includes six children and receives *Bolsa Familia* (socioeconomic status = -2.31). The property is entirely in pasture, except for 50ha of coffee and lacks any forest. This household does not use the coffee plantation on the property as a source of fuelwood. Instead, they purchase wood monthly from their neighbors. They pay R\$55 per truckload (about US\$30

in July 2008). The wife in this household uses wood to cook both lunch and dinner, and relies on gas to heat water for coffee and to bake. One 13kg canister of gas lasts this household three months.

Not all caretakers interviewed were employed by large landowners. One household, SP11 (socioeconomic status score = 1.02), was employed to care for the cattle of a landowner but did not inhabit a large piece of land. Instead, they lived on a small property composed of three pastured hectares. This was the only household surveyed that used no fuelwood. The husband and wife in this household were both young and had a 2-year old son. They relied exclusively on gas for all cooking needs. The wife explained that she preferred to cook with gas because it was faster and cleaner, and because they had no fuelwood. One 13kg canister of gas lasted them a month and a half.

In this same community, another household had circumstances that differed from SP11 in subtle yet important ways. The members of this household, SP13 (socioeconomic status = -4.98), were not employed by a landowner. Instead, they rented 3ha from a landowner and were responsible for managing a small coffee plantation on the property. Rather than being paid a salary for this work, they received 40 percent of the proceeds, from which they purchased any materials needed for the following year's crop. The remainder of the property was pasture and a very small bit of forest. The wood supply on this land was not nearly enough to furnish the needs of this family, composed of a 45-year-old father, a 37-year-old mother, and five children. In order to collect sufficient fuelwood, members of household SP13 traveled over one hour in their horse-cart to their employer's other property. They made this journey every week, and as a household spent an average of 43 minutes a day, well over twice the mean, collecting fuelwood. Even so, they still relied heavily on gas, using 13kg of LPG every two and a half months. Funds from the *Bolsa Familia* were used to help purchase the LPG.

Discussion

In rural communities of the Brazilian Atlantic Forest, several factors influence household fuel choices. Socioeconomic status, as it was calculated in this study, explains 7 percent of the variation in collection time. The amount of fuelwood available did not explain a significant percentage of the variance in CE, although the interaction between socioeconomic status and available fuelwood explained 19 percent of variance, indicating that the relationship between CE and status is dependent on available fuelwood.

Descriptive statistics collected from the household survey offer weak support to the energy ladder hypothesis. Despite the majority of households having access to alternative sources of energy, such as electricity and LPG, most households continued to use wood for at least one purpose, suggesting that in this region most households stack fuel types, rather than make a complete switch, because fuels are not perfectly interchangeable. For example, most households in the survey preferred to cook beans for lunch on the wood stove, but always baked their cakes in the gas oven. This type of fuel use pattern suggests that domestic energy use in the this region may be better described by a model like the Masera *et al.* multiple fuel model developed in rural Mexico than by the energy ladder (Masera *et al.* 2000).

Our analysis of household survey data weakly supported the applicability of the energy ladder model in the region. Socioeconomic status alone is only a modestly significant predictor of the variation in the importance of fuelwood to each household, measured by collection time. Figure 5 shows that for households with low access to fuelwood (< 4.5ha) CE decreases steadily as socioeconomic status increases. This is in accordance with the energy ladder; moreover, we observed that households with low access to fuelwood used LPG as the most convenient source of domestic energy. For these

fuelwood- and income-poor households, increasing socioeconomic status will result in more use of LPG. However, the trend for CE among households with high access to fuelwood did not vary with respect to changing socioeconomic status. For households with more than 4.5ha of fuelwood access, CE was similar regardless of socioeconomic status, indicating that fuelwood has similar importance for households with relatively plentiful fuelwood supplies across the socioeconomic status spectrum. For these households, a strong disincentive, such as increased enforcement of the Forest Code might dissuade fuelwood use, although cultural preferences for wood fuel might be difficult to overcome.

Our research suggests that access to fuelwood is an important factor in explaining collection time variation among some but not all households. The findings support the idea that socioeconomic improvement can reduce the reliance on fuelwood among households with less than approximately 4.5ha of forested land. These households are relevant as they are *de facto* land managers for much of the remaining fragments of Brazilian Atlantic Forest.

The qualitative information included in the vignettes supports the findings from the quantitative analysis and helps to explain the influence of fuelwood access on the power of socioeconomic status to drive decisions regarding household energy. The vignettes also elucidate the multiple reasons for varying degrees of access to fuelwood in the region. This type of information assists in explaining behavioral patterns uncovered through statistical analysis and is best achieved through mixed method household-level studies such as this one.

Much of the information comprising our understanding of fuelwood issues has come from studies covering large areas, such as the gap and balance models of the 1970s and 80s. In a recent review, Cooke *et al.* (2008) acknowledge the perceived failures of these models that tend to leave unanswered questions due to the location specific nature of fuelwood issues. These authors emphasize that due to the critical importance of fuelwood to millions of rural households in developing nations there is a strong need for more localized fuelwood data sets, particularly household-level studies which can be used to thoroughly investigate all aspects of fuelwood consumption including its uses and substitutes and information on the households consuming it. This study specifically addresses these points, thus contributing to the body of knowledge on fuelwood use among rural households.

Additionally, our research highlights the challenges of applying the Atlantic Forest Policy in the Zona da Mata Mineira. To some extent, the poor understanding of resource use, especially wood fuel, among rural households has contributed to the difficulty of applying Atlantic Forest Policy. In addition to this limitation, the topography of the region makes it very difficult for a small landowner to avoid utilizing hilltops, slopes and riparian zones for either agriculture or grazing. An official with the Minas Gerais extension service admitted that “the way the law currently is, it is impossible for small agriculturalists to abide by. There are places where the entire property should be a PPA according to the law.” Moreover, a municipal official with deep knowledge of the study region reported that, “many people cut trees without getting authorization. They know that they need to but they don’t because it takes too long. And the Forest Police almost never come out here”. In summary, the Atlantic Forest Policy is not well understood by all rural wood-users, and even those who do understand it may find it difficult or have little incentive to abide by it knowing that discreet use of forest resources is likely to go unnoticed and unpunished. As a result, the policy does not have a strong influence on household energy decisions and is not effective at preventing those who wish to from harvesting fuelwood from the local forest fragments.

The villages chosen for the survey are representative of rural villages throughout the Zona da Mata Mineira in terms of demographics, access to roads and labor opportunities and size of nearby native forest fragments. For these reasons, the findings of this study should be applicable throughout the region. The specific findings from the study cannot be generalized beyond the study region, although they may inform studies conducted in similar areas worldwide. Particularly, we believe that creating typologies for households based on variables that influence domestic energy choices in the region (such as access to land, access to fuelwood and income) can help researchers to organize household surveys on rural domestic fuelwood use and to better understand the interactions influencing a household's reliance on fuelwood for domestic energy.

Due to the limited scope of this study, several important topics related to fuelwood use in the region were not investigated. The expansion of eucalyptus plantations in Minas Gerais, the extent of forest degradation related to fuelwood harvesting in the Zona da Mata Mineira, and the role of economic scarcity of fuelwood in household energy decisions are all topics for follow-on studies that could be informed by the information revealed by this study.

Conclusions

Fuelwood plays an important role as a source of domestic energy for rural residents of the *Zona da Mata Mineira* in Brazil. The most commonly used type of fuelwood among survey participants was eucalyptus, which is exotic to the region. Many households also continue to rely on native species for fuel, despite the illegality of felling trees, living or non-living, without a permit.

Socioeconomic status, the most common predictor for reliance on fuelwood based on the energy ladder model, explained 7 percent of the variance in the importance of fuelwood to a household, measured by CE. The household's proximity to available fuelwood was also not a strong predictor of fuelwood use in this particular region. However, the interaction between socioeconomic status and access explained nearly twenty percent of the variance in fuelwood use. This finding indicates that access to fuelwood is an important factor in household energy decisions by influencing the degree to which socioeconomic status drives fuel decision-making.

Access to fuelwood, in turn, is best explained by the circumstances of each household, which we categorized into typologies based on access to land, access to wood, and regular income. Some of these factors may be addressed by policies, but mostly they are the product of land subdivision and previous economic cycles. Policies that impose severe restrictions on fuelwood use, such as strict enforcement of the Forest Code, may put many households into the impossible position of being cut off from meager wood lots and unable to afford LPG. These typologies have the potential to be useful in organizing household surveys on domestic fuelwood use in rural households in Brazil and elsewhere in Latin America.

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