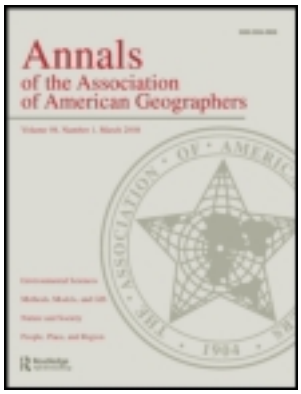

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Burning for Sustainability: Biomass Energy, International Migration, and the Move to Cleaner Fuels and Cookstoves in Guatemala

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Burning for Sustainability: Biomass Energy, International Migration, and the Move to Cleaner Fuels and Cookstoves in Guatemala

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More than a century after the introduction of electric power transmission, almost 3 billion people still rely on biomass fuels to meet their energy needs. Use of this renewable fuel in unvented cooking stoves results in disastrous consequences for human health and global warming. These negative outcomes have led governmental and nongovernmental organizations (NGOs) to push for improved wood-burning stoves and cleaner burning, but nonrenewable, alternatives like liquefied petroleum gas (LPG). The move up the energy ladder to cleaner fuels and improved stoves is thought to be associated with rising income and increased levels of urbanization. Increased income in developing countries often comes in the form of remittances from millions of migrants working abroad. Thus, migrants and their money could arguably be agents of change in the transition to cleaner fuels or the more efficient use of existing renewable energy sources. This article examines the case of Guatemala, where 88 percent of rural households use firewood for cooking, and where almost 15 percent of the country's 14 million population migrates to the United States. A continued preference for firewood, despite increased income, can be explained as a rational decision based on cost, experience, and cooking methods. Additionally, through an analysis of forest cover in firewood source areas, we demonstrate that this energy source is, for the most part, used in a fashion that makes it renewable. Recognizing these patterns of, and reasons for, this resource use permits us to make realistic recommendations for sustainable livelihoods and use of this renewable energy source. *Key Words: cookstoves, energy, firewood, Guatemala, migration.*

电力传输技术的引入已经超过一个世纪，大约 30 亿人仍然依靠生物燃料来满足其能源需求。使用这种可再生燃料的无排气管烹饪炉具对人类健康和全球变暖产生灾难性的后果。这些消极的结果导致政府和非政府组织（NGO）致力于推动改善烧木柴的炉子和清洁燃烧，使用不可再生的能源替代品，例如液化石油气（LPG）。向上移动到更清洁的燃料和改良炉灶的能量阶梯被认为是与收入的增加和城市化水平的提高相关的。发展中国家收入的增加通常具有下述形式：数百万在海外工作的移民汇款。因此，移民和他们的钱也许可以说是过渡到更清洁燃料或者更有效地利用现有再生能源这一改革的推动者。本文考察了危地马拉案例，该国百分之 88 的农村家庭使用木柴做饭，全国 1400 万人口里迁移到美国的几乎有百分之 15。尽管收入增加，对木柴的继续偏好可以被解释为在成本、经验和烹调方法基础上的合理决策。此外，通过对木柴源区森林覆盖的分析，我们证明了这种能量来源在大部分情况下是以可再生的方式使用的。认识到这些资源利用的模式以及这些模式的产生原因，可以使我们对可持续生计和可再生能源利用提出现实的建议。*关键词：锅灶，能源，木柴，危地马拉，迁移。*

Más de un siglo después de que se introdujera la transmisión de energía eléctrica, casi 3 mil millones de personas aun dependen de combustibles de biomasa para satisfacer sus necesidades energéticas. El uso de este combustible renovable en estufas para cocinar sin desfogue termina en desastrosas consecuencias para la salud humana y en calentamiento global. Estos resultados negativos han llevado a organizaciones gubernamentales y no gubernamentales (ONGs) a presionar por el uso de estufas mejoradas a base de la quema de madera y por alternativas de combustión más limpia, aunque no renovables, como el gas de petróleo licuado. El ascenso en la escala de la energía hacia combustibles más limpios y estufas mejoradas se toma como asociada con mejores ingresos y niveles incrementados de urbanización. El aumento del ingreso en los países en desarrollo viene a menudo en la forma de remesas de millones de migrantes que trabajan en el extranjero. Así pues, los migrantes y su dinero podrían ser considerados como agentes de cambio en la transición hacia combustibles más limpios o al uso más eficiente de las fuentes existentes de energía renovable. Este artículo examina el caso de Guatemala, donde el 88 por ciento de los hogares rurales usan leña para cocinar y donde casi el 15 por ciento de los 14 millones

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de habitantes del país migra a los Estados Unidos. Una preferencia continuada por la leña, a pesar de la mejora del ingreso, puede explicarse como una decisión racional basada en costo, experiencia y métodos de cocinar. Adicionalmente, a través de un análisis de la cubierta de bosque en las áreas de donde procede la leña, demostramos que esta fuente de energía es, en su mayor parte, usada de una manera que la hace renovable. Reconociendo estos patrones del uso de este recurso, y las razones para hacerlo, nos permite hacer recomendaciones realistas de medios de vida sustentables y el uso de esta fuente de energía renovable. *Palabras clave: estufas para cocinar, energía, leña, Guatemala, migración.*

Almost 3 billion people in the developing world rely on biomass fuels to meet their household energy needs, accounting for 10 percent of all human energy use and 78 percent of the global supply of renewable energy. Biomass fuels include firewood, charcoal, dung, and crop residues (Granderson et al. 2009; Jetter and Kariher 2009). Even though many biomass users will transition to fuels like kerosene, liquefied petroleum gas (LPG), and electricity, most analyses predict that the total number of biomass users will increase over the next four decades (Barnes et al. 1994; International Energy Agency 2006; Legros et al. 2009). Biomass burning for cooking results in high levels of indoor and outdoor pollution. These emissions have implications for a number of important and interrelated aspects of development, including human health, natural resource use, climate change, and household economy. We touch on some of these aspects to frame our study.

Results from longitudinal epidemiological studies exploring the relationship between biomass burning and human health demonstrate the causal link between biomass smoke and the deaths of more than 1.6 million people annually and the development of chronic obstructive pulmonary disease, which is responsible for 2 percent of the global burden of disease (Smith-Sivertsen et al. 2009; Northcross et al. 2010). In addition to health impacts, recent studies link biomass cookstoves to global warming. Biomass cookstoves not only emit carbon dioxide (CO_2) but also other products of incomplete combustion, such as carbon monoxide, methane, nonmethane hydrocarbons, nitrous oxide, oxides of nitrogen, particulate matter, organic carbon, organic matter, and black carbon (MacCarty et al. 2008). Black carbon (BC), recent research reveals, is the number two contributor to rising global temperatures after CO_2. Researchers believe that BC from various sources is responsible for 18 percent of global warming, whereas CO_2 is responsible for 40 percent of global warming. CO_2 has a lifetime in the atmosphere on the centuries to millennial timescale, whereas BC's lifetime is less than a few weeks. Thus, because of their shorter life span, reduction in the output of BC and other short-lived climate forcers (SLCF) has the potential to offset CO_2-induced warming for several decades, giving policymakers time to develop and implement effective measures to reduce CO_2 emissions (Bond, Venkataraman, and Masera 2004; Ramanathan and Carmichael 2008; Gustafsson et al. 2009).

The widespread use of biomass and knowledge about its effects on human health and the environment illustrate why the study of biomass is important and also why many institutions around the world attempt to provide biomass users with fuel-efficient and cleaner burning biomass stoves (Ezzati and Kammen 2002; Berrueta, Edwards, and Masera 2008). Simply, more efficient and chimney-vented stoves use less fuel, reduce the amount of time and money spent on fuel acquisition, save lives because the harmful products of combustion are vented outside, and reduce the emission of SLCFs like BC. The scale at which biomass fuel is used around the world also explains why so much research focuses on the factors that determine household fuel and stove choice. Researchers suggest that the ascent of the energy ladder to cleaner fuels and improved stoves is associated with rising income and increased levels of urbanization (Heltberg 2004, 2005; Edwards and Langpap 2005; Madubansi and Shackleton 2007). Increased income often comes from millions of migrants who live and work abroad and inject billions of dollars into their home countries. Thus, migrants and their money could arguably be agents of change in the transition to cleaner fuels or the more efficient use of existing renewable energy sources. This article examines the relationship between fuel use and income in Guatemala, where about 15 percent of the population migrates to the United States and where biomass makes up 52 percent of the national energy budget.

In this article we investigate how migration influences cooking fuel choice in Guatemala. Do migrant households transition to other cooking fuels like LPG, use various fuels, or continue using firewood? Also, we explore the landscapes that result from the annual increase in the use of firewood (although firewood's

contribution to Guatemala's total energy budget declines every year, the amount of firewood used continues to increase). Are these energy landscapes renewable (Zimmerer 2011), or is the increased demand for firewood driving deforestation as suggested in the "fuelwood crisis" literature of the 1970s and 1980s (e.g., Eckholm 1975; Openshaw 1978; Dewess 1989)?

We offer a case study from a Maya community in Guatemala's Western Highlands. Our discussion begins with a review of the literature surrounding the fuel and income ladder theory, the impacts of firewood consumption on forests, and the relationships between migration and the environment. We also reveal the importance of firewood to Guatemala's energy budget and environment. Then, we provide outcomes of the research, and finally discuss the ramifications of the results in terms of renewable energy use in the developing world.

The Move to Cleaner Cooking Fuels and Improved Biomass Stoves

Modern cooking fuels like LPG and improved biomass stoves provide significant health, environmental, and productivity benefits (Boy et al. 2000; MacCarty et al. 2008). Yet understanding the social, cultural, and economic behaviors involved with users making the fuel and stove switches is more complicated. One theory suggests an "energy ladder" where each of the three rungs corresponds with income levels, and the energy rungs rise as income rises. Biomass sits at the bottom; transitional fuels such as kerosene, charcoal, and coal occupy the middle rung; and fuels like LPG and electricity characterize the top rung. The energy ladder implies that moves are made from inferior to superior fuels. Moreover, this theory uncritically places firewood—the most widely used renewable resource in the world—at the bottom of the ladder (Arnold, Kohlin, and Persson 2006). The reality with many households in the developing world, however, is far more complex because they often use multiple fuels at the same time. This is referred to as the *household fuel mix* or *portfolio*. Fuel portfolios depend on multiple factors, including culture, household size and age structure, price, opportunity cost, fuel availability, precipitation regimes, and variations in household economy and labor (Heltberg 2004; Moran-Taylor and Taylor 2010).

Many governmental and nongovernmental organizations (NGOs) recently realized that there is no silver bullet to create a fast transition to modern fuels and thus focused their efforts on the fuel that billions of households already use—biomass. Take the case of India. In 2009, recognizing that a renewable resource was already part of the lifestyles of its citizens, the Indian government launched the National Biomass Cookstove Initiative, which aims to provide an affordable and reliable clean cooking energy option for the poorest households that rely on biomass. The new options revolve around stoves that burn biomass (Venkataraman et al. 2010). At the global scale, the Global Alliance for Clean Cookstoves (GACC), launched in September 2010, intends to provide 100 million households with cleaner biomass-burning stoves by 2020.

Firewood and Forests: Degradation or Sustainable Use of a Renewable Resource?

Firewood use in the developing world has often been linked to deforestation. Early research predicted massive energy crises as a result of increased firewood consumption (e.g., Eckholm 1975). More recent research shows that demand for woodfuel is unlikely to result in large-scale deforestation. Case studies and models demonstrate that tropical deforestation and changes in forest cover in general have multiple, rather than single causes (Allen and Barnes 1985; Geist and Lambin 2002; Arnold, Kohlin, and Persson 2006; Hecht and Saatchi 2007). Local demand for firewood, however, can result in changes (degradation and improvement) in local forest composition and extent (McCrary, Walsh, and Hammett 2005; Madubansi and Shackelton 2007). In short, in some cases firewood use results in local or distant forest degradation (depending on local control of forests and the network of improved roads to tap more distant forests) or it can result in the increase of forested areas, especially in the form of energy forests, which are tree plantations specifically for energy purposes (Arnold, Kohlin, and Persson 2006).

International Migration, Development, and the Environment

Around the world, economic remittances (the monies that migrants send to their countries of origin) transform household and national economies. For example, in 2007 the amount of cash remittances reaching developing countries dwarfed official development assistance and were about half as large as both net inflows of foreign direct investment and private debt (Gabriel 2008). In Guatemala, remittances amounted to nearly US$4 billion in 2010. This amount is equivalent to

one fifth of Guatemala's gross domestic product (Banco de Guatemala 2010). Clearly, such funds are key for the economies of sending countries and much scholarly and policy work examines their role in development (e.g., Rhoades 1978; Georges 1990; Grasmuck and Pessar 1991; Rubenstein 1992; Cohen 2001; Jokisch 2002; Taylor, Moran-Taylor, and Rodman 2006; Moran-Taylor 2008; de Haas 2010). Research that examines the linkages between migration and the environment is now gaining momentum. Hugo (1996) reviewed scholarship on the environmental factors (both proximate and distant) that force human migration. Other recent research reveals how droughts, landslides, and hurricanes contribute to outmigration and create environmental refugees (Organización Internacional para las Migraciones 2008). But, we need to pay more attention to how migration feeds back into the environment and land use in the countries of origin of migrants. Aptly, the National Research Council (1999) states:

> There is some agreement that, in the future migration, rather than changes in human fertility and mortality, will be the key demographic link between the two dynamic processes of land use and land cover changes. Causation and feedback will probably move in both directions: environmental changes will likely cause migration, and migration will likely change the environment. . . . Data on migration and other social variables must be linked with biophysical data from remote and land-based sources on soils, climate, and other biophysical factors. (349)

Research examining the relationships between migration and the environment in Latin America shows how return migrants and cash remittances play a pivotal role in sending countries. Bilsborrow (1992) illustrates how return migrants in Ecuador can be linked to lower levels of deforestation. In the Caribbean islands some migrants bring back new notions about ecosystem services and commitments toward environment preservation and invest in the formation of nonprofit organizations for that purpose (Conway and Lorah 1995). Recent studies show how international migration can lead to forest recovery (Rudel, Perez-Lugo, and Zichal 2000; Hecht and Saatchi 2007; Schmook and Radel 2008). The interaction of migration and the environment in sending countries merits continued attention by social and natural scientists because migration makes up, and will continue to make up, an integral part of culture and economies in both the developed and developing world.

Cooking, Fuel Consumption, and Forest Change in Guatemala

Guatemala, with 45 percent of its population living in urban areas, is one of the least urbanized countries in Latin America. Urbanization is on the increase in Guatemala, and recent estimates place the rate of change at 3.4 percent per year (Brunn et al. 2008). Guatemala also has the highest natural rate of increase in population in Latin America at 2.8 percent per year (Population Reference Bureau 2011). Biomass makes up 52 percent of the national energy budget, and 75 percent of households in Guatemala use this renewable fuel as part of their energy portfolio. In rural areas, about 88 percent of households exclusively use wood for cooking and space heating. Moreover, the total amount of firewood consumed every year continues to grow (Elías et al. 1997; Taylor 2005; Programa de Las Naciones Unidas para el Desarollo 2008). LPG is available in Guatemala. From a unit of energy perspective, LPG is cheaper than firewood at current prices. Despite this cost disadvantage, most rural households, and even 46 percent of urban households, continue to use firewood. The continued reliance on firewood can be explained, in part, by the high startup costs (US$110 in 2005) for stoves and cylinders involved in a transition to LPG (Edwards and Langpap 2005). Despite the importance of firewood to the national energy budget and to the households who burn wood, it is not taken into account in national budgets because of the informal nature of the firewood economy. In fact, the true size of the firewood economy is not known in Guatemala. The Guatemalan National Institute of Forestry (INAB) estimated the value of the firewood economy at US$1.5 billion for 2006 (Martínez 2009).

In Guatemala, firewood consumption is on the increase and forested areas are decreasing. Early research by the Food and Agricultural Organization placed forest cover at 53 percent of the total area of the country in 1988. A later study conducted by the Ministry of Agriculture in 1999 placed forest cover at 40 percent. In 2001, a group of institutions produced a forest-change map comparing images of three years (1991, 1996, and 2001). They reported a deforestation rate of 1.4 percent, equivalent to 73,000 hectares of forest lost per year. Two thirds of that deforestation happened in Petén (the northern one third of the country) where there is a rapid expansion of the agricultural frontier and the establishment of large cattle ranches (Universidad del Valle Guatemala [UVG], Instituto Nacional de Bosques [INAB], and Consejo Nacional de Areas Protegidas

[CONAP] 2006). If, in countries like Guatemala, we are at the incipient stages of understanding the value and impacts of the fuel used for cooking by three quarters of households in the country, it is important to interrogate how other critical issues, like migration and subsequent changes in household income, have the potential to alter firewood consumption patterns.

Study Site: San Cristóbal Totonicapán

The municipality of San Cristóbal Totonicapán (hereinafter San Cristóbal), with a population of almost 30,000 inhabitants, lies in the heartland of the Maya K'iche' indigenous culture in Guatemala's Western Highlands (Figure 1). San Cristóbal is located in the department of Totonicapán, which is recognized for its forested areas and for local control of those forested areas (Veblen 1978; Elías et al. 1997). In the last three decades, the municipality gradually moved away from subsistence agriculture, local furniture manufacturing, and weaving of textiles to a more diverse economy that includes intensive vegetable production for local and international markets (Moran-Taylor and Taylor 2010). Like many other rural towns in Guatemala, at

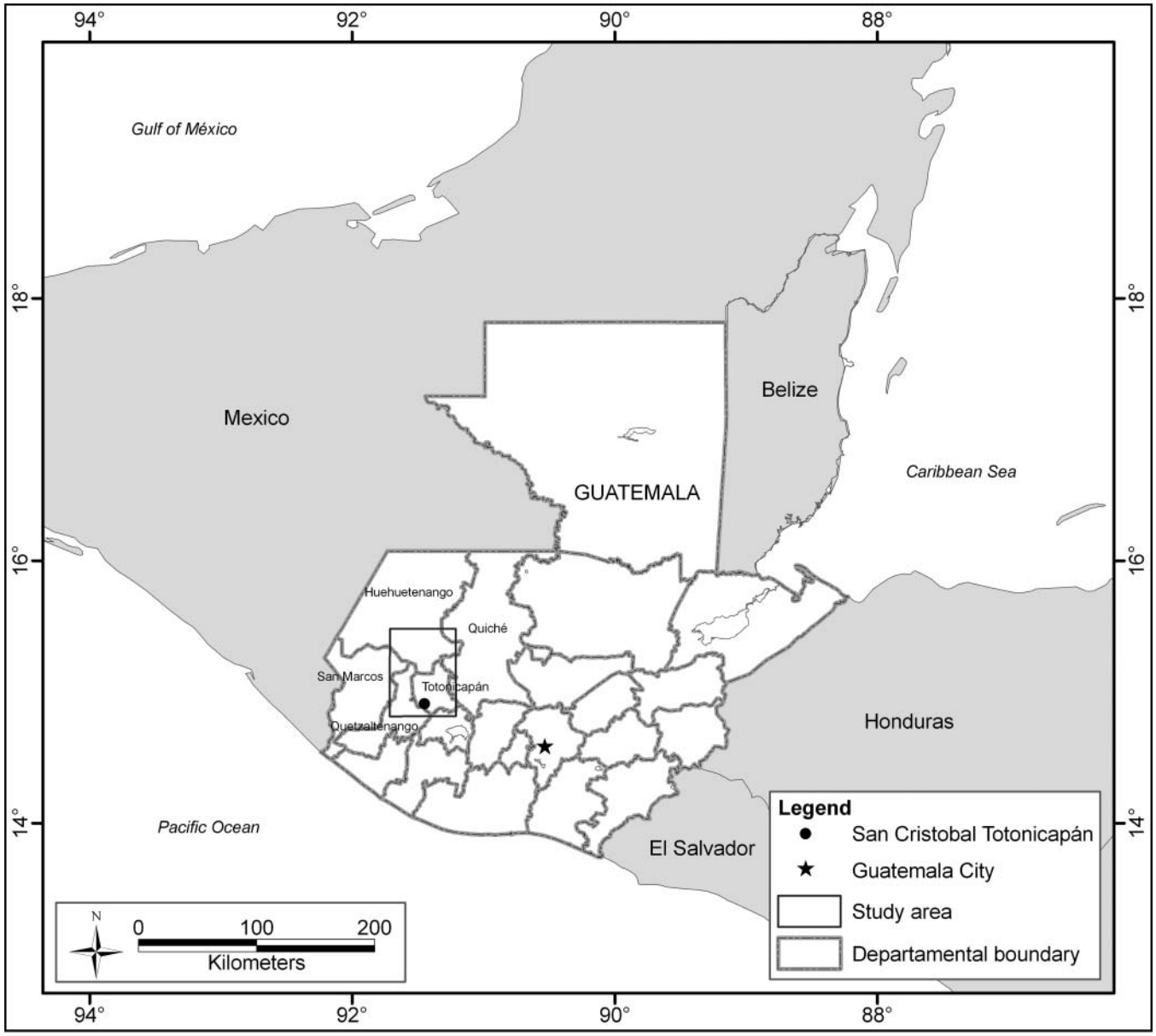

Figure 1. Location of the study area in Guatemala.

least 15 percent of San Cristobal's residents reside and work in the Unites States. Most migrants remit part of their earnings back home on a regular basis (US$200–$300 per month), and many return home after several years of work abroad. Migrants' achievements are clearly evident in their building of large houses (Moran-Taylor 2008, 2009), yet these monuments to success do not tell us anything about the fuel used in migrant kitchens.

Methods

This article relies on ethnographic work and survey data among male and female migrants, return migrants, and nonmigrants conducted in 2001, 2006, and 2010. The ethnographic material includes participant observation, field notes, multiple informal interviews, and thirty-seven in-depth, tape-recorded, semistructured interviews. Interviewees ranged in age from twenty to eight-two. Study participants' occupations included weavers, artisans, seamstresses, tailors, nurses, students, entrepreneurs, and NGO workers. The topics covered in interviews included migration and employment history, transnational flows (e.g., tangible and intangible and their frequency, density, and types), and migration-related changes in home communities. A team made up of the authors (three of whom are Guatemalan) and two local Maya women conducted 102 household surveys in 2006 (77 migrant household and 25 nonmigrant households). We selected migrant households that had at least one family member abroad or a member who returned within the year prior to the survey.

Changes in forest cover in the areas around San Cristóbal were assessed for the period from 1991 to 2006. We also analyzed changes in forest cover in source areas for much of San Cristobal's purchased firewood. The land cover change analysis was conducted using Landsat data obtained by the Center for Environmental Studies (CEA) at the Universidad del Valle in Guatemala City. CEA produces the official forest cover change maps for Guatemala (UVG, INAB, and CONAP 2006). Accuracy assessments of the classifications were performed using ninety-seven randomly generated control points collected from high-resolution aerial photographs. The control points were classified as forest, nonforest, and secondary or brush forest. This classification was then compared with the classified satellite image. The points coincided 85 percent of the time. The points classified as forest and nonforest coincided 95 percent and 100 percent of the time, respectively. Secondary brush or forest had a lower coincidence (60 percent), which lowered the overall accuracy.

Results and Discussion: Migration and Firewood Use in Guatemala

San Cristobaleños report that migrants use remittances to build new homes, buy more land, send their children to better schools, start businesses, buy vehicles, and invest in agriculture. This behavior is common in Guatemala (e.g., Camus 2007; Falla 2008). Whole neighborhoods that in the past were one-level adobe homes interspersed with forest patches and maize plots have now been transformed into densely packed zones of two- and three-story, cinderblock houses with little or no green space. Inside these new house compounds we documented the use of three-stone fires (open-fire cooking), improved wood-burning stoves, and new LPG stoves (Table 1).

Results from the household survey show that 98 percent of migrant households have LPG stoves. Results also reveal that 31 percent of nonmigrant households have LPG stoves, suggesting that many migrant households possessed LPG stoves prior to migrating.

Table 1. Household survey outcomes related to migration and firewood

Select results from household survey[a]	Migrant households[b]	Nonmigrant households[c]
% of households with liquefied petroleum gas stoves	98	31
% of households with improved wood-burning stoves	81	22
% of households with a three-stone open fire	12	67
% of households with a three-stone open fire that is used at least once a month	12	36
% of households that cook with wood "most of the time"	77	94
% of households purchasing wood	94	88
Municipality origin of purchased wood		
a. Malacatancito	35%	
b. The coastal coffee farms	21%	
c. Momostenango	3%	
d. San Carlos Sija	5%	
e. Don't know	27%	

[a] $n = 102$.
[b] $n = 77$.
[c] $n = 25$.

Although almost all migrant households have LPG stoves, 77 percent of migrant households continue to do most of their cooking with wood (Table 1). Why? In 2009 and 2010 a simple three-burner LPG stovetop and 25-lb. gas cylinder sold for US$110. Filling a 25-lb. tank cost $13 and the cost to fill a 100-lb. tank was $52. Most households purchase 25-lb. tanks. A *tarea* of wood (one tarea of firewood measures 1 m high × 5 m long × 35 cm wide) costs between US$25 and $30 depending on the type of wood and delivery options. Although LPG is a more economical choice on paper and in terms of energy efficiency per unit of energy than wood (Edwards and Langpap 2005), most migrant households continue to use wood as their primary fuel. Our survey results indicate that more migrant households purchase firewood (94 percent vs. 88 percent) versus collecting their own wood, which is an onerous task. Overall, more so than nonmigrant households, migrant households use multiple fuels and cooking methods. This points to fuel stacking or mixing, rather than a clean transition from one fuel to another. We also found that 81 percent of migrant households build and use improved wood-burning stoves (Table 1). These stoves are better for human health because they channel smoke out of the cooking area using a chimney. If used properly, these stoves are also more fuel efficient and reduce emissions (Granderson et al. 2009). Thus, even if migrants are not making a quick transition to LPG, their use of improved wood-burning stoves bodes well for human and environmental health. The responses we received about the types of energy use and cooking methods mask the complexity of the energy mix that households employ. The amount of each fuel used depends on household factors that include economy, time, and cooking preference.

The greater ease with which migrant households can purchase firewood does not explain why they do not make a complete switch to LPG. Like Heltberg (2005), we realized that we needed to look beyond cost factors to understand why so many people continue to use firewood. Indeed, culture often proves a wonderful confounding variable. But, good anthropological field work and years of participant observation often help solve the conundrum of what seems like nonrational behavior from a purely economic perspective (i.e., examining the cost per calorie of different fuels). San Cristobaleños explain that they continue to cook with wood for several reasons. Many offer comments such as, "The food tastes better when cooked on firewood and for longer periods slowly," or, "You can always keep hot water boiling/warm" when using firewood. Additionally, because Guatemala's two staple foods, beans and corn, require many hours of cooking, gas becomes more expensive (e.g., corn is cooked twice: once for boiling and again after taking it to the mill to make tortillas or tamales). Many locals also say that using propane gas for these long processes is too expensive, so they prefer to rely on firewood. Moreover, the burners on conventional gas stoves cannot generate enough power to handle the quantity of food cooked and the size of the pots used for cooking corn, beans, and tortillas. Also, interviews reveal that the rising price of LPG makes wood a much more attractive alternative as a domestic fuel choice.

In our surveys we also asked residents to name the source of their firewood. Large trucks trundle through San Cristóbal on a weekly basis selling firewood from various nearby municipalities and distant coffee and rubber plantations (Table 1). Foresters in Totonicapán (which surrounds San Cristóbal) are famous for their management of their high pine, fir, and mixed pine and oak forests. Indeed, while the rest of Guatemala undergoes rapid deforestation, the forests of Totonicapán survive because local laws and indigenous forest managers closely regulate use of these forests (Veblen 1978; Elías and Wittman 2005). Firewood is collected from the local forests, but it is done within the norms, rules, supervision, and sanctions established by the users themselves and the local government. Thus, families can only collect firewood if they are members of that community, if they have completed their community service and forest maintenance obligations, and if the firewood is not for sale and is used for domestic purposes only. Added to this regulation of forests, which varies in strictness from community to community, there is also an increase in conservation discourse among forest managers. This has led community leaders to ban firewood collection from older forests in protected areas and establish some forest areas for carbon fixation projects. This new regulation has impacted the poorest of families who relied on the now-protected forest for the collection of dry wood from the forest floor (Elías and Wittman 2005; Elías 2011).

Because use of these forests is restricted, residents of San Cristóbal and other Totonicapán communities must purchase their fuel from more distant or private forest sources (Table 1). For example, about 35 percent of respondents say that the firewood they buy comes from Malacatancito, about 50 km to the north of San Cristóbal via the Pan-American Highway. The purchase of fuelwood, studies from around the world state, often reflects local fuelwood scarcities (Madubansi and Shackleton 2007). Analysis of satellite data from 1991 to 2006 reveals that in all studied municipalities, forest

Table 2. Forest cover for the years 1991, 2001, and 2006 in hectares for seven municipalities of the Western Highlands in Guatemala

Municipality	Area in hectares (ha.)	Forest 1991 ha.	Forest 2001 ha.	Forest 2006 ha.
Huehuetenango	18,953	8,170	8,359	8,135
Malacatancito	41,193	19,529	18,721	18,267
Momostenango	35,915	17,366	17,062	17,164
San Andrés Xecul	1,649	320	338	337
San Bartolo Ag Ca	5,636	3,468	3,301	3,366
San Carlos Sija	22,651	10,402	10,689	10,624
San Cristóbal Toto	4,425	737	792	783

cover is roughly 50 percent of the municipal land except for the two smallest municipalities of San Andrés Xecul and San Cristóbal Totonicapán, where forest cover is less than 20 percent (Table 2). The national average for forest cover is around 40 percent, so these two municipalities are considerably more deforested than the rest of the country. Malacatancito is the only municipality that shows a steady decline in its forest cover over the fifteen years that the data span (Table 2). The analysis also revealed that most of the change within Malacatancito is found in the northern part of the municipality on the border with Huehuetenango (Figure 1). The rest of the municipalities show a smaller change in direction, increase, or decrease of forest cover for the period studied; but in many cases, the changes are relatively small and within our range of error, indicating a fairly stable forest cover. This stability in forest areas outside of the municipality of Malacatancito can be attributed to the fact that these forests do not serve as principal firewood source areas.

Firewood for the stoves of San Cristóbal must come from somewhere. Much of the firewood comes from the forests of Malacatancito. Malacatancito is a community that has a long tradition of harvesting trees for firewood sale, thus the decline in forest coverage around Malacatancito is not a direct result of increased regulation of Totonicapán forests. Our data, however, suggest that some of the decline in the forest area of Malacatancito can be attributed to the fact that San Cristobaleños do not get their firewood from forests in their immediate vicinity. This conclusion suggests that the forests of Malacatancito are not managed in a sustainable manner. We must note, though, that in our analysis of forest cover through time, secondary growth and brush demonstrated the lowest coincidence levels in the error analysis. This might mean that the analysis is not capable of capturing regrowth of forest in its early stages in the Malacatancito area.

About one fifth of households in San Cristóbal report that they purchase firewood from coffee plantations on the Pacific Slope. This practice is becoming more common as more Guatemalans move into towns and small cities where they no longer have direct access to free firewood. Purchase of wood from any source in Guatemala has increased dramatically as forest area decreases and competition over resources increases. Indeed, owners of large coffee, cattle, and rubber estates that we have interviewed in the course of our field work have stated that theft of firewood from their land has increased in the last decade. Large coffee plantations trim their shade trees every year to ensure optimal shade for the growth of the coffee bushes. Likewise, wood from coffee bushes makes its way into the energy market when the bushes are drastically cut back every ten to fifteen years. If coffee continues as a valuable cash crop and it is grown under shade trees, these plantations could prove to be sustainable sources of firewood.

Conclusions

Migrant households in San Cristóbal, for the most part, continue to use firewood for cooking. The results of this study add evidence to the growing number of studies that call for a nuanced fuel and income ladder theory that includes variables beyond income (Arnold, Kohlin, and Persson 2006; Maconachie, Tanko, and Zakariya 2009). Instead of moving up the ladder, migrants with increased income make rational decisions about their cooking fuel purchases and use a mix of fuels. Also, although migrants can afford LPG and indeed purchase LPG stoves, they rarely use these stoves because the adoption of this new fuel also requires changes in food preparation traditions. In current and pending discussions about the adoption of improved cookstoves by entities like the GACC, it is important to note that adoption of improved wood-burning stoves by migrants illustrates how increases in income and access to credit can lead to the adoption of more efficient stoves. This is an important revelation as these institutions move ahead with their plans to provide 100 million households with improved biomass cookstoves.

In this study we hesitate to make a determination on the sustainability of this renewable resource in Guatemala because wood is sourced from many areas in both sustainable and nonsustainable ways. Our

analysis does show, however, that forest area has declined in an area that is cited as a significant firewood source area.

Future studies on firewood use must take into account the recent global recession. Cash remittances to Guatemala fell by 10 percent in 2010. In an economy that is cash-strapped, will even more people turn to "free" or more affordable cooking fuels like firewood and will more people begin to collect their own wood and put pressure on local forests? Based on this study in Guatemala, we also recommend in-depth studies of household energy use around the world. These studies must include sufficient detail and cultural considerations that can be incorporated into the design of more efficient biomass stoves. Detailed studies that move away from simplistic versions of the fuel and income ladder theory will ensure that new stoves are widely disseminated and adopted.

Importantly, and this bears repeating, the number of households and the amount of firewood used each year in the developing world increases. Thus, because billions of people around the world already employ a form of renewable energy—biomass—scientists and policymakers must examine the use of this energy with local integrated production systems in mind. Simply, woody biomass, if managed in a renewable way and if efficient conversion technologies are employed, is a major existing renewable energy source. If we are serious in our attempts to meet the Millennium Development Goals, we must, as others observe (Bailis, Ezzati, and Kammen 2008; Cherian 2009), address biomass burning in cookstoves on a massive scale because its use is directly tied to several of the goals, including health, gender equity, and environmental sustainability.

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