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INSIGHTS ON FUELWOOD COLLECTION SOURCES BY LAND TENURE IN MEXICO

TESINA

QUE PARA OBTENER EL GRADO DE

MAESTRO EN ECONOMÍA AMBIENTAL

PRESENTA

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Data used in the study is retrieved from the first round of the national survey of rural households in Mexico (ENHRUM) in 2007.

Data is available at: http://investigaciones.colmex.mx/enhrum/inicio.aspx

Abstract

Fuelwood collection in Mexico is a fundamental activity for rural livelihoods because it used on a daily basis for cooking, heating and boiling water. Fuelwood use can generate health and environmental problems which have been addressed poorly by public policy. This study analyzes how different household and resource attributes relate with the selection of the land where this resource is collected, whether is extracted from their own private land, neighboring private land or federal/communal land. This study applies a multinomial probit model where the site of collection differentiated by land tenure is the outcome variable. Results show that education and wealth are correlated with extracting from private land reducing the pressure of communal/federal forests and that permits could help enforce property rights.

Keywords: Fuelwood collection, land tenure, property rights, deforestation, community management, common forests.

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Chapter 1

Introduction

Fuelwood use in rural areas is a common practice around the world because it is a relatively low-cost energy source and the population has easy access to it (Johnson et al., 2013; Masera et al., 2015). In Mexico, households use this resource in traditional stoves primarily for cooking, boiling water and heating (Ghilardi et al., 2007). However, the combustion of this resource on traditional technology leads to three main problems: respiratory system diseases, potential environmental degradation of local forests and global warming (Jeuland et al., 2015). The underlying causes that explain the fuel choice, the patterns of woodfuel use and the lack of energy transitions towards a greener set up have been widely studied around the world. However, land tenure and its interaction with different household and resource attributes has been overlooked in Mexico and what could be more important, more evidence is needed to assess what kind of policy could be effective for reducing the pressure on protected forests or communal lands given the country context.

Previous studies have shown that community managed forests can reduce the pressure on protected areas without affecting rural households' livelihoods (Linde-Rahr, 2003; Damte and Koch, 2011; Jumbe and Angelsen, 2011). Additionally, (St. Clair, 2016) showed that when forest management groups are formed, strengthening woman participation is preferred when it generates gender balanced groups rather than female-dominated groups.

Mexico is a hot spot for energy access and indoor air pollution problems, with approximately 16 million people using fuelwood as their only cooking and heating source (INEGI, 2017). As Ghilardi et al. (2007) summarizes, the non-sustainability of fuelwood as a resource for households is very context specific and diverse, national assessments have masked the heterogeneity of local environments making policy application more difficult.

Fuelwood availability and use in Mexico is a topic that has caught the attention of researchers interested in ecosystem degradation and the implication for rural livelihoods. A group at Mexico National Autonomous University (UNAM) created a tool called WISDOM (Woodfuel Integrated Supply/Demand Overview Mapping) (Ghilardi et al., 2007) which is a spatial-explicit planning tool for highlighting and determining woodfuel priority areas or woodfuel hot spots, meaning, areas where fuelwood is scarce given the population context. Although, this analysis has raised awareness of the challenges policymakers have to face in order to implement impactful measures, there is an ongoing debate about how to do it.

Different efforts have been put in place to reduce the use of fuelwood in rural areas such as improved cookstoves, resource community management groups, enforcing property rights and empowering women within the households. Nonetheless, these programs do not always produce the expected results, for example, the introduction of improved cookstoves or LPG stoves in rural areas seemed as a promising public policy to address this problem, yet the reality is that households do not fully engage in the technology change policymakers expected because individuals do not switch between cooking technologies they rather stack them (Masera et al., 2000; Ruiz-Mercado and Masera, 2015; Hanna et al., 2016).

These previous failed public policies call for an implementation of wider strategies that consider the complexity of rural households' behaviors. Explaining the use of woodfuel in rural households is a multidimensional problem, household behavior will affect the outcome of woodfuel collection, labor allocation, income generation, technology stacking and deforestation rates. The present study adds up to the body of literature that gives more insights in the relationship of rural households characteristics and the attributes of the resource collected focusing on the land tenure from where this resource is obtained.

Chapter 2

Literature Review

2.1 Fuelwood as an energy source

Use of biomass as a source of energy is very common around the world, three billion people use this resource for cooking and heating (Stabridis and van Gameren, 2018); in Sub-Saharan Africa it accounts for 75% of total energy use (Abebaw, 2007), in countries like Malawi its share is even bigger, reaching 90% of total energy consumption (Jumbe and Angelsen, 2011) or in the Democratic Republic of Congo, where it represents around 98% of the non transport energy consumption, which is eight times larger in comparison to a United States average household biomass energy use (Burke and Dundas, 2015). In developing countries these solid biomass fuels such as: fuelwood, charcoal, dung and agricultural waste constitute the main source of energy consumption specially in rural areas for various household activities (Rao and Reddy, 2007).

Focusing more specifically on fuelwood, it is estimated than more than 2 billion people in the world uses exclusively fuelwood (Angel Jimenez, 2013). In Mexico, the 2010 population census shows that 4.1 million households use biomass, where the main fuel is wood (Stabridis and van Gameren, 2018). If we add the people that uses it in combination with LPG, one out of four persons in the country cooks with fuelwood, either alone or combined with LPG (Masera et al., 2005; Ghilardi et al., 2007). Fuelwood is the main resource used as energy source in the country representing 80% of total energy consumption. It is estimated that around 19 millions people use exclusively fuelwood as their cooking and heating source (INEGI, 2017).

In 2009, the Mexican social program *Oportunidades* showed that 80% of rural households use woodfuel as an energetic source and the average expenses on this resource was MXN 207 with significant differences between states. For instance, in the state of Chihuahua the average expenses is around MXN 456 while in the state of Tamaulipas the average is MXN 70 (Gertler et al., 2009) which represents around 17% of their income (Masera et al., 2005). In this sense, Ghilardi et al. (2007) characterizes accurately the fuelwood use pattern in Mexican households as *traditional*, meaning, there is spatial heterogeneity, focused in rural sector with a widespread use of traditional technologies and a diverse array of extraction patterns.

The use of biomass in developing countries is likely to remain stable or increase in the near future because other fuels are too expensive for rural families to afford it (Romieu et al., 2009). In Mexico, despite the fact that households have been incorporating more LPG in their energy mix, fuelwood use has remain constant in the last 4 decades (Masera et al., 2005; INEGI, 2017), furthermore, Serrano-Medrano et al. (2014) project scenarios of fuelwood use in Mexico and present three important results: i) An important future growth of mixed fuelwood – LPG users is expected at least until 2030, ii) more than half of Mexican counties will have high levels of fuelwood dependence, iii) the aforementioned counties are in turn amongst the highest in poverty levels. Ultimately, this evidence and the fact that even with subsidized prices for LPG, households still use fuelwood (Serrano-Medrano et al., 2014), lead to support the theory that many rural households in Mexico follow a stacking pattern, where they do not switch to other technologies but rather generate a contingent of technologies that can be reliable for many different situations (Masera et al., 2000,0).

2.2 Problems of fuelwood use

Despite the importance of fuelwood for rural livelihoods, not only as an energy source, its usage and collection could generate negative outcomes for their income generation, health, the ecosystems they depend on and in drastic cases, the climate.

Studies show negative outcomes of fuelwood use in terms of income generation because time invested in this activities reduces the overall productivity of the household, specially from women (Das et al., 2018). More specifically, higher dependence on biomass energy reduces the probability of female members entering the labor force (Burke and Dundas, 2015). An study in Nepal showed that on average male and female members of the household spent 460 hours and 810 hours per year collecting fuelwood (not cooking) respectively. Therefore, in areas where woodfuel is mainly collected rather than purchased policies targeting labor opportunities and physical resources should be preferred. (Amacher et al., 1996)

This loss of income caused by collecting time is worsened when respiratory systems diseases arise because of particulate matter ($PM_{<2.5}$) generated by inefficient cooking technology such as traditional three stones cookstoves, this health issues affect specially women and children that stay inside far longer than any other member of the family (Masera et al., 2005; Romieu et al., 2009; Burke and Dundas, 2015; Hanna et al., 2016; Das et al., 2018). Despite government efforts to address this issue by promoting improved cookstoves (LPG or fuelwood improved stoves), the desired technological switching is not happening because this process is more complex than foreseen by policymakers (Masera et al., 2000,0,0; Jeuland et al., 2015; Hanna et al., 2016), moreover, as mentioned in the previous section the stacking hypothesis is more likely to happen as evidence in Mexico have showed (Masera et al., 2005; Ruiz-Mercado and Masera, 2015)

These factors that arise as a consequence of the fuelwood dependence are a key contributor to generate poverty traps within rural households (Duflo et al., 2008).

Ecosystem degradation caused by fuelwood collection can become unsustainable, specially when this resource is used to be commercialized in local markets or transformed into charcoal (Jumbe and Angelsen, 2011; Amare et al., 2017; Bošković et al., 2018). Intensive fuelwood collection generates rapid forest degradation (Das et al., 2018), for example, in Malawi, charcoal production is accounted for 33% of their deforestation, this deforestation comes from important forest reserves (Kim et al., 2017). This results are contrasted with insignificant impacts in the environment in areas with low dependence or relative resource abundance where most of the fuelwood collection comes from dead trees or dry branches and is used mainly for self consumption (May, 2013; Kim et al., 2017) or even with positive outcomes where collection reduced the probability of fires and plagues (Quiroz-Carranza and Orellana, 2010). In Mexico, a national assessment using a model called Woodfuel Integrated Supply and Demand Overview Mapping (WISDOM) determined several hot spots of possible environmental degradation by evaluating both the population pressure on the resource and the resilience of the ecosystem showing that environmental degradation is more of a contextual problem (Ghilardi et al., 2007).

Finally, in terms of global warming mitigation it has been shown that combustion of fuelwood generates black carbon, the second most important greenhouse gas (GHG) contributing to climate change. To exemplify this issue, as Jeuland et al. (2015) explain, due to cultural and seasonal practices a north region in India presents moments with high presence of regional contamination that influences significantly the generation of GHG emissions in the world.

2.3 Fuelwood use determinants and collection sources

Several studies have been done analyzing the determinants of fuelwood in many aspects. In general, researchers distinguish the results between household attributes, resources specific attributes (where collection source is included) and government/NGO programs effects. Different models have been applied to answer different research questions: determinants of fuel choice/energy source, fuel consumption, fuel collection, time allocation/labor allocation, market purchases. In this subsection we present a brief review of relevant results from some studies done in this area.

Attributes such as age of the head of the household and household size increase the probability of using fuelwood as an energy source in comparison to other sources such as LPG (Rao and Reddy, 2007; Stabridis and van Gameren, 2018). However, amongst fuelwood users, larger households appear to reduce fuelwood consumption (Abebaw, 2007), which can be explained by the fact that this resource is used with heat purposes lowering the consumption per capita the larger the household is. Education level of the household head and indigenous background are significant factors influencing the choice of fuelwood as energy source (Rao and Reddy, 2007; Behera et al., 2015; Lee et al., 2015; Rahut et al., 2016; Stabridis and van Gameren, 2018).

Higher income is an important determinant for adoption of *cleaner* energy sources, such as LPG, but it does not overthrown fuelwood use, supporting the stacking model; as households obtain more income they add different fuels to their energy mix (Abebaw, 2007; Manning and Taylor, 2014; Burke and Dundas, 2015; Rahut et al., 2016); correspondingly, poverty status increases the probability of using fuelwood (Stabridis and van Gameren, 2018). More interestingly, to avoid endogeneity problems and considering that in rural areas income could be a misleading measure because of self consumption, several studies use assets as a measure of wealth to determine fuel choices. Assets wealth increases fuelwood consumption across all percentiles (Baland et al., 2010), similarly, asset poverty increases the probability of using fuelwood while wealthier households use cleaner energy sources (Pattanayak et al., 2004; Behera et al., 2015; Stabridis and van Gameren, 2018).

Regarding the role of women and gender differences, the results are very consistent across different studies, when a female is head of the household, is more likely to use a cleaner fuel source (Rao and Reddy, 2007; Behera et al., 2015; Burke and Dundas, 2015; Rahut et al., 2016; Amare et al., 2017; Stabridis and van Gameren, 2018). This result supports various government/NGO programs that empowers women in rural areas, because increasing decision power decision within the household proves to improve technological transitions reducing the harmful effects of fuelwood.

Finally, referring to collection sources, studies have made different classifications for these sources but in general they distinguish the sources by some of these categories: private land (own or not own),managed communal land, protected forests, public land, plantation forests and market sources, which in most cases can be reduced to the dichotomy between private land source vs public/communal land source. (Pattanayak et al., 2004; Jumbe and Angelsen, 2011; Behera et al., 2015; Lee et al., 2015; St. Clair, 2016; Kim et al., 2017).

Jumbe and Angelsen (2011) finds that asset-poverty does not have a significant effect in determining the fuelwood collection source, in contrast, Linde-Rahr (2003); Damte and Koch (2011); Behera et al. (2015); Lee et al. (2015) found that increasing wealth is associated with less probability of extracting from communal land and increasing probability of extracting from private land or market sources . Moreover, Kim et al. (2017) found a difference by income, rich households in general extract from their own land or gardens while other income groups extract evenly from all sources.

The older the head of the households are, the higher the probability of extracting from their own land (Damte and Koch, 2011; Behera et al., 2015; St. Clair, 2016). Education of the head of the household increases the probability of using their own source or a community land source (Damte and Koch, 2011; Behera et al., 2015). Female heads of the household are more likely to extract from their own land or communal land rather than buying from market sources (Behera et al., 2015; Kim et al., 2017). Household size increases the probability of extracting from communal lands (Lee et al., 2015; St. Clair, 2016) and diversifying to multiple sources (Damte and Koch, 2011)

Land tenure measured in hectares reduces the probability of extracting from communal lands and increases the probability of collection from their own land (Damte and Koch, 2011; Behera et al., 2015), although others have found that land tenure decreases the probability of extracting from their own land (St. Clair, 2016).

Jumbe and Angelsen (2011) also found that while distance increases the pressure on community forests, access restrictions reduces it, in this sense, other studies have found that giving communities the power to manage open access areas reduces the pressure on protected forests despite the increase in distance (Linde-Rahr, 2003; Pattanayak et al., 2004; Damte and Koch, 2011) suggesting the same as St. Clair (2016) findings: communal management could effectively reduce the probability of collect fuelwood from protected areas. However, Bošković et al. (2018) found that restraining access to forests increases fuelwood collection; despite the seemingly contradictory nature of this result, the authors attribute this effect to increasing fixed collection costs thus increasing the fuelwood price in the market attracting more sellers and ultimately accelerating the deforestation process. In the end, this result is in line with other studies (Shaanker et al., 2004; Jumbe and Angelsen, 2011; St. Clair, 2016) because the effect of fuelwood extraction restrictions depend more on how the community manages their resources and enforces their rules. (Amare et al., 2017).

Chapter 3

Methods

3.1 Model

The methodology proposed in the study follows the theoretical frameworks of Jumbe and Angelsen (2011). The random utility model defines a household i that collects fuelwood from j different forest sources differentiated by the ownership or property rights on the land (own private, others private, federal/communal property), i.e., j=1,2,3. The utility of the individual can be expressed as:

$$U_{ij} = U(r_{ij}, x_{ij}) \tag{3.1}$$

Where r represents the attributes of the resource differentiated by household and land ownership and x represent the household specific attributes. The response variable will be categorical according to what the individual has declared, assuming that the utility obtained by choosing a j source is the product of a utility maximization rationale. The model proposed will be estimated using a multinomial probit model. Although a multinomial logit model was considered, the probit model allows to relax the independence of irrelevant alternatives (IIA) assumption in order to get more robust results.

3.2 Data Source

The data used for this study is taken from the national survey of rural households in Mexico (ENHRUM) in 2007. This survey was designed to have national representativeness and has accurate measures of fuelwood collection, distance to collection places, assets in the household, socioeconomic information and other resource usage attributes. Table 3.1 describes the variables extracted that were used in the study.

Table 3.1: Variables Description

Role	**Name**	**Description**	**Type**	
Dependent variable	Fuelwood source	Fuelwood collection source grouped by land tenure	Categorical	Private own, Private not own, Federal/Communal
Household attributes	Sex	Household head sex	Dichotomous	Male 1, Female 2
	Age	Household head age	Numerical	
	Education	Household head years of education completed	Numerical	
	HH Size	Household size	Numerical	
	Indigenous Language	Household head proficiency in an indigenous language	Dichotomous	No 0, Yes 1
	Assets	An index of assets/facilities owned by the household: vehicles, rooms per capita, independent kitchen, toilet facilities, tubed water, drainage, fix phone and refrigerator	Numerical	
	Stacking fuels	Indicator of using a mix of fuelwood and LPG	Dichotomous	No 0, Yes 1
Resource attributes	Land per capita	Land owned by the household (ha/individual)	Numerical	
	Distance	Distance to collection places (km)		
	State	State of the fuelwood collected	Categorical	Green, Dry, Both
	Permit	Permit needed to collect the fuelwood	Dichotomous	No 0, Yes 1

The dependent variable $Fuelwood\ Source$ refers to the type of land tenure from where the fuelwood is collected by the household, the third category (Federal/Communal) groups lands that belong to communities, $ejidos$ (communal land used for agricultural purposes) and lands that belong to the federal government. It was important to the study that the households included in the sample had access to all alternatives presented to ensure robustness in the analysis; there are 80 different villages surveyed in the ENHRUM 2007 but not all of them collected fuelwood, moreover, we assumed that if at least one household collected fuelwood from each category in a village, that village, and therefore the households that collected fuelwood within it, could be included in the sample.

The variable $Assets$ was constructed using the first component of a Principal Component Analysis (PCA), although the second and third components where also considered to be included they were ultimately dropped out of the analysis because they did not add significant variation to the model. This variable is meant as a proxy to household wealth allowing to reduce the endogenous problem of including income as other authors have previously suggested (Filmer and Pritchett, 2001; Baland et al., 2010; Jumbe and Angelsen, 2011).

$Stacking\ fuels$ allows to evaluate if there is a stacking pattern within the household.

$Permit$ determines if there is one required by any entity or person such as the federal government, environmental protection agencies, local government, the property owner or any other entity that can restrain the use of fuelwood in that land.

Additionally, in the ENHRUM there is a variable that measures the amount of fuelwood collected but it had not a single and comparable measure between observations(kilograms, pieces, units, etc.), generating too many missing data, therefore we decided to not use it.

Many other variables were also considered but like the amount of collected fuelwood, they had many missing observations, they lacked variation or both. Some examples are: Internal rules of the land where fuelwood was collected, sanctions if collected illegally, fuelwood donations to other households, amount of months where fuelwood was collected in a year, household labor to collect fuelwood, migrant before getting married, English proficiency, health status, female ratio in the household.

As Rao and Reddy (2007) and Jumbe and Angelsen (2011) mention, it is important to note that despite the fact that the cross sectional nature of the data do not capture true dynamics within the households, it does not diminish the usefulness of the analysis of relationships of fuel sources and different attributes.

Chapter 4

Results

4.1 Descriptive Statistics

As stated in the previous section, the analysis used a subsample of the ENHRUM with households that collected fuelwood and that had access to all sources in their respective villages. There were 33 villages with 396 households in Mexico. In Table 4.1 we characterize the data used for the model.

In first place, the socioeconomic characteristics are seemingly balanced across the subsamples, although there are roughly twice the amount of observations in federal/communal lands. The representation of women as head of the household is low in this rural areas, with a mean age of 53 years, a household size of 7.7 individuals and an average of 5.7 years of education completed which corresponds to finishing basic primary education. There is a significant presence of indigenous people, between 31% and 41% of household heads master an indigenous language. In terms of assets and considering the mean household size there is a low presence of vehicles per capita as well as individual rooms and drainage, conversely, most of the houses have independent kitchens, tubed water, electricity, refrigerator and some toilet facility.

In terms of stacking cooking technologies we can see there is a difference between people

Table 4.1: Summary Statistics

Variable				
Property Rights		Private Own	Private not own	Federal/Comunal
Sex	Male	87.4%	82.3%	89.3%
	Female	12.6%	17.7%	10.7%
Education	Mean	6.10	5.29	5.65
	Std. Dev.	3.48	3.01	3.12
	Min-Max	0-18	0-16	0-18
Age	Mean	55.09	51.42	52.56
	Std. Dev.	15.60	15.42	14.41
	Min-Max	23-93	27-90	26-90
HH size	Mean	7.90	7.66	7.61
	Std. Dev.	3.34	3.40	3.53
	Min-Max	1-20	2-18	1-21
Indigenous language	Yes	40.8%	31.3%	39.6%
Vehicles in the household	Mean	0.282	0.260	0.350
	Std. Dev.	0.617	0.528	0.584
	Min-Max	0-3	0-2	0-2
Rooms per capita	Mean	0.448	0.403	0.423
	Std. Dev.	0.418	0.253	0.303
	Min-Max	0.077-3	0.056-1.5	0.067-2
Independent Kitchen	Yes	85.4%	84.4%	87.3%
Toilet Facilities	No facility	3.9%	9.4%	13.7%
	Latrine	44.7%	42.7%	37.6%
	Toilet	51.5%	47.9%	48.7%
Tubed water	Yes	71.8%	75.0%	78.2%
Drainage	Yes	26.2%	28.1%	29.4%
Fix Phone	Yes	29.1%	25.0%	22.8%
Refrigerator	Yes	64.1%	61.4%	52.8%
Electricty available	Yes	95.2%	92.7%	95.4%
Cooking fuel	LPG	14.6%	5.2%	6.6%
	Fuelwood	45.6%	39.6%	51.8%
	Both	39.8%	55.2%	41.6%
Land per capita	Mean	3.683	0.490	0.471
	Std. Dev.	18.661	1.342	0.813
	Min-Max	0-178.2	0-7.5	0-4.5
Distance	Mean	2.87	3.26	4.13
	Std. Dev.	3.16	4.92	5.38
	Min-Max	0.005-18	0.1-30	0.1-30
State of fuelwood	Green	11.7%	5.2%	4.6%
	Dry	77.7%	84.4%	86.3%
	Both	10.7%	10.4%	9.1%
Permit	Yes	8.7%	18.8%	16.2%
Obs.		103	96	197

Source: author’s calculations based on data from ENHRUM that collect from their own land where the exclusive use of gas is present more than twice as often compared to the other categories. Between 40% and 55% of households stack fuels using LPG and fuelwood to cook. Although the variable used in the model is dichotomous it is interesting to disaggregate the fuels used for cooking.

There is a significant difference in land owned per capita between people that collect fuelwood from their own land and the other categories, private land owners have significantly larger amounts of land per capita. Moreover, there is people that do not collect from their own land that is willing to travel 12 kilometers more, nevertheless, the mean distance traveled is similar. Fuelwood is collected dry in approximately 8 out of 10 cases but more people collect it green from their own land.

Finally, the need for a permit to collect fuelwood is higher in private land not owned by the individual than in federal and communal lands, which can be explained by private individuals reinforcing more their property rights.

4.2 Empirical results

Results from the multinomial probit model are presented in Table 4.2. In this model the base outcome is the own land source, therefore all the results in this analysis will be in comparison with the probability of extracting from this source.

Increasing years of education reduces the probability of extracting from a private land not own or a federal/communal land, a similar result is found for increasing the hectares own by the household. Household size decreases the probability of extracting from federal/communal land and the effect becomes stronger the larger the household is. Conversely, a marginal increase in distance (km) to the source will increase the probability of extracting from a private or communal land.

In terms of stacking, households that incorporate an energy mix of fuelwood and LPG increase the probability of using a neighboring private land.

Table 4.2: Multinomial Probit Model Results

Own Land (base outcome)		**Private land not own**		**Federal/Communal land**	
Variable		**Coefficient**	**Std. Error**	**Coefficient**	**Std. Error**
Sex (Female)		0.274	0.331	−0.226	0.320
Age		−0.004	0.054	0.057	0.050
Age squared		−0.0001	0.000	−0.001	0.000
Education		−0.120***	0.043	−0.075*	0.039
HH Size		−0.164	0.135	−0.279**	0.124
HH Size squared		0.007	0.007	0.012*	0.006
Indigenous Language		0.147	0.284	0.306	0.260
Assets		0.016	0.095	0.059	0.089
Stacking fuels		0.535**	0.264	0.070	0.243
Land per capita		−0.395***	0.105	−0.589***	0.109
Distance		0.073**	0.036	0.111***	0.035
Fuelwood State	Green		Base Outcome		
	Dry	1.021**	0.440	1.341***	0.418
	Both	1.029*	0.561	1.246**	0.528
Permit needed		3.786**	1.557	3.164**	1.461
Age*Permit needed		−0.057**	0.028	−0.050*	0.026
Constant		0.532	1.510	−0.506	1.411
Obs. = 396	Prob > chi2 = 0.0001		Log pseudolikelihood = -365.4908		

*Significant at the 10% level; **significant at the 5% level; ***significant at the 1% level.
Source: author's calculations based on data from ENHRUM

If a permit is required for extraction the probability of collecting fuelwood from a land not own (private or communal) is higher in comparison with the base outcome. However, as the head of the household becomes older the probability of extracting from a land not own decreases if a permit is needed.

Finally, when comparing the state of the fuelwood collected is noticeable that dry and dry/green fuelwood is more likely collected in land not owned by the household (private or communal) in comparison to users that extract only green fuelwood from their own land.

The results of the average marginal effects from the multinomial probit model are presented in Table 4.3.

Table 4.3: Multinomial Probit Model - Average Marginal Effects

Obs = 396		Own		Private not own		Federal/Comunal	
		Pr. = 0.25886		Pr. = 0 .24359		Pr. = 0.49755	
Variable		dy/dx	Std. Err.	dy/dx	Std. Err.	dy/dx	Std. Err.
Sex (Female)		0.004	0.0601	0.1018	0.0689	−0.1058	0.0714
Age		−0.006	0.0094	−0.0101	0.0099	0.0161	0.0113
Age squared		0.0001	0.0001	0.0001	0.0001	−0.0001	0.0001
Education		0.0188***	0.0072	−0.0158**	0.0078	−0.003	0.0089
HH Size		0.0485**	0.0232	0.0048	0.0244	−0.0533*	0.0276
HH Size squared		−0.0021*	0.0012	−0.0002	0.0012	0.0024*	0.0014
Indigenous Language		−0.0497	0.0471	−0.0132	0.0515	0.0628	0.0585
Assets		−0.0088	0.0166	−0.0053	0.0176	0.014	0.0202
Stacking fuels		−0.0503	0.0451	0.1121**	0.0502	−0.0619	0.056
Land per capita		0.1058***	0.0171	−0.0011	0.0204	−0.1048***	0.0246
Distance		−0.0199***	0.0067	−0.0001	0.005	0.0199***	0.0062
Fuelwood State	Green			Base Outcome			
	Dry	−0.293***	0.0918	0.0583	0.0751	0.2347***	0.0867
	Both	−0.2816**	0.1102	0.0748	0.1003	0.2068*	0.1138
Permit needed		−0.0787	0.0549	0.0865	0.0662	−0.0078	0.0717

*Significant at the 10% level; **significant at the 5% level; ***significant at the 1% level.
Note: dy/dx for factor levels is the discrete change from the base level.
Source: author's calculations based on data from ENHRUM

In regards to the socioeconomic variables, household size increases the probability of extracting fuelwood from their own land but the effect becomes weaker the larger the household size is. Conversely, household size has the opposite effect on Federal/Communal land, decreasing the probability of extracting from there with a stronger effect the larger the household is. This results are nuanced by the analysis of the predicted probabilities for each household size. In Figure 4.1 is more notable that this effect is significantly different for households with less than 9 individuals. Moreover, Figure 4.1 shows that the marginal effect for private land not own is not different than other sources when taking the confidence intervals into account.

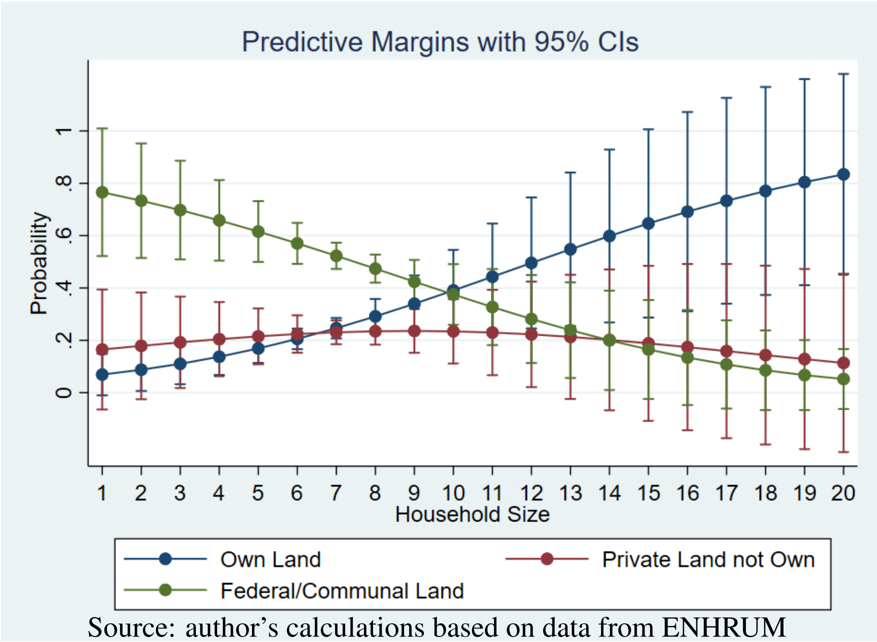
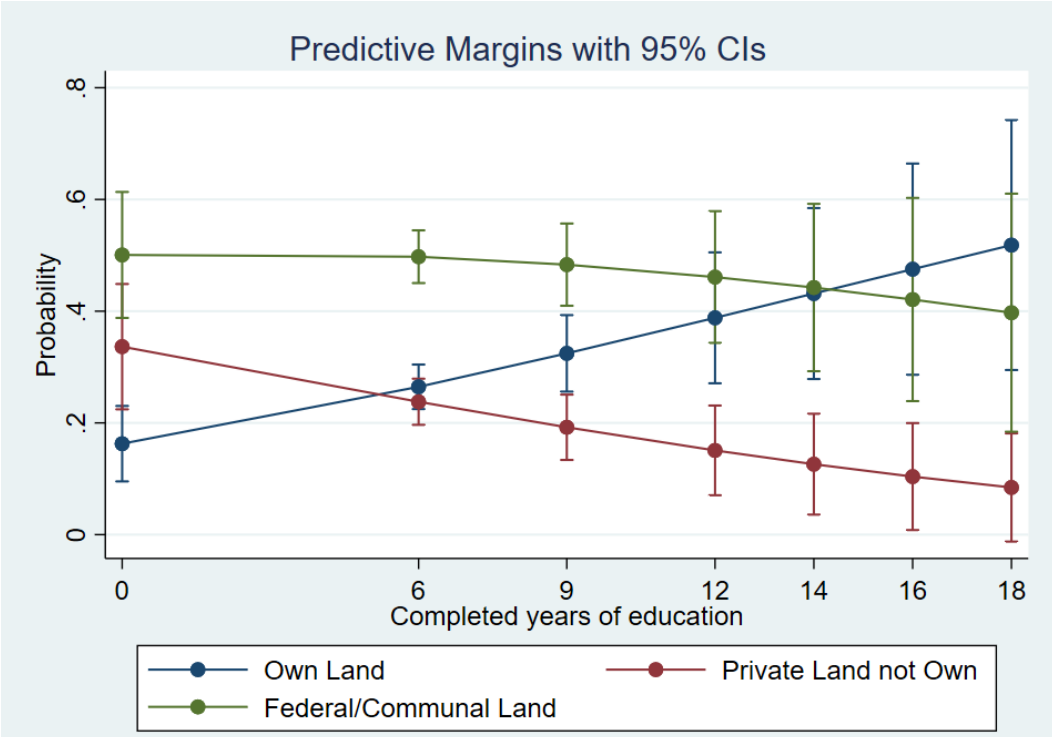


Figure 4.1: Predicted Probabilities of household size by land tenure

Increasing a year of education increases the probability of extracting from their own land by 1.9%, and reducing the probability of extracting from a private neighboring land in 1.6%. Figure 4.2 show that the marginal effect for head of the households with no education is significantly different between households that extract form their own land and from federal/communal land. Furthermore, the marginal effect of people that completed basic education (6 years of primary and 3 years of lower secondary education) is significantly different, therefore, in households where the head have completed basic education it is more likely to extract from communal lands and less likely to extract from private lands not own. The significant average marginal effect reported on Table 4.3 is more evident the more years of education are completed by the head of the household.



Source: author's calculations based on data from ENHRUM

Figure 4.2: Predicted Probabilities by Level of Education

In terms of stacking and cooking fuels there is a significant effect in the households that use both, gas and fuelwood, increasing 11% the probability of collecting fuelwood from private lands not owned in comparison with households that only use either gas or fuelwood exclusively.

Land per capita has a significant marginal effect, an additional hectare of land increases the probability of extracting fuelwood from their own land by 10.6%, while the same marginal increase in land decreases the probability of extracting from federal/communal land by a similar amount. Figure 4.3 present the plot of the predicted probabilities with their confidence intervals, it is noticeable that this marginal effect is significantly different for all values except when households that have around 2 hectares.

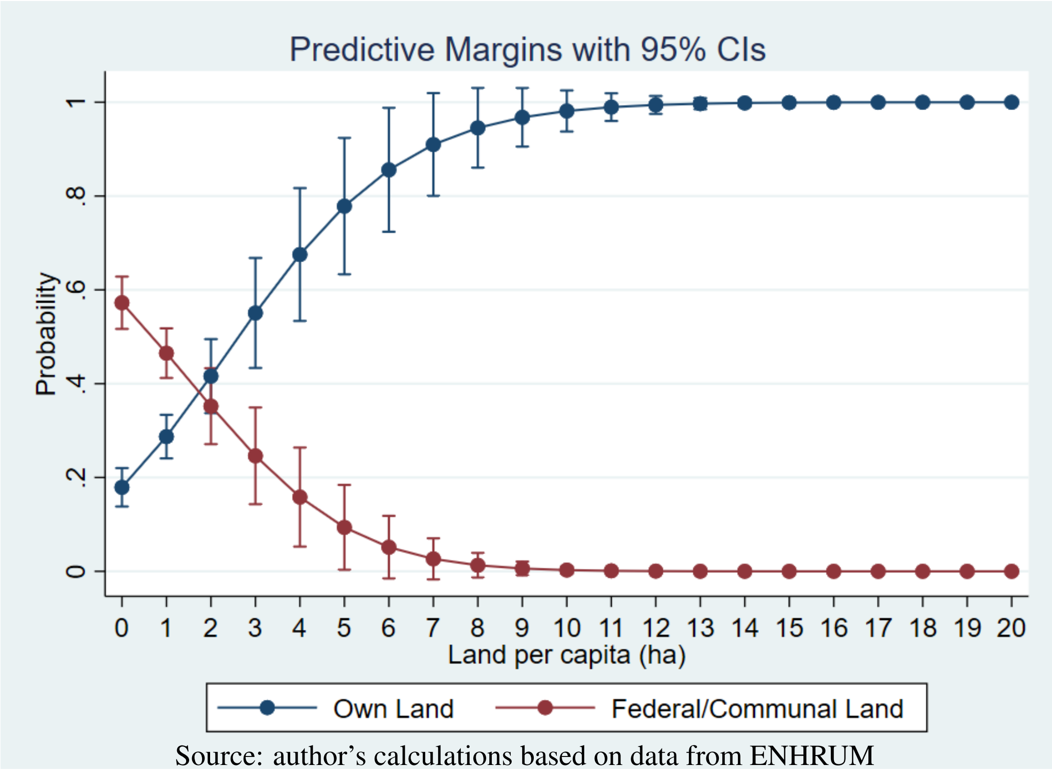
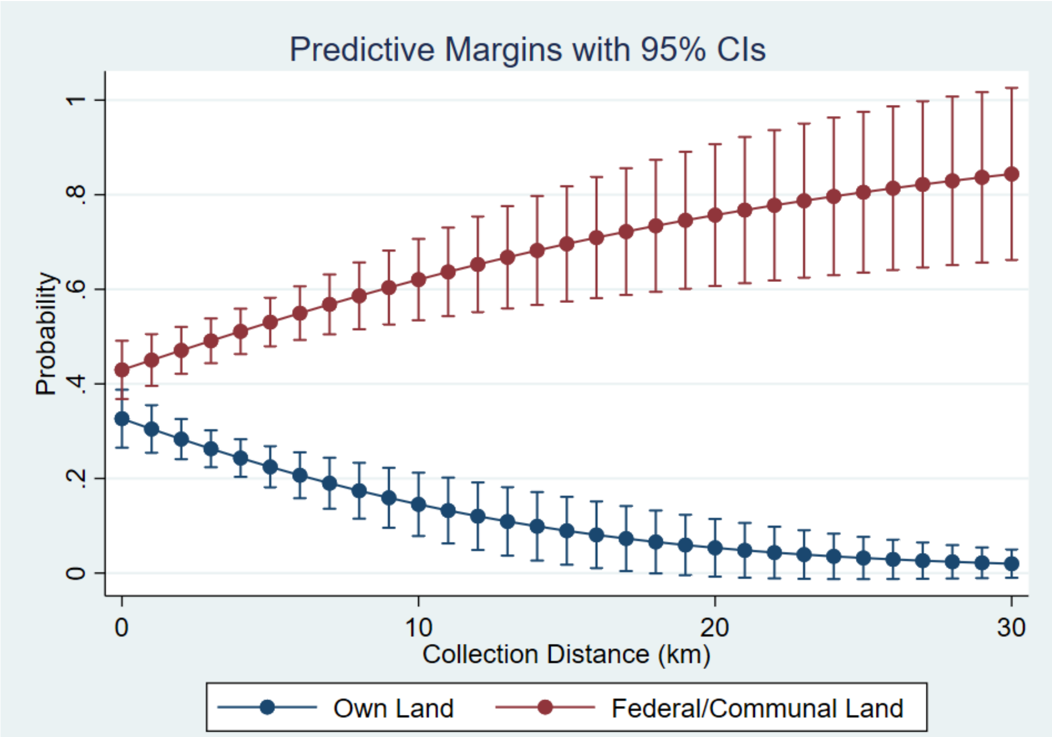


Figure 4.3: Predicted Probabilities of land per capita marginal effects

When analyzing attributes related to resource characteristics, the average marginal effects of distance and fuelwood state have significant effects for own and federal/communal land. An additional kilometer to collect fuelwood reduces by 2% the probability of extracting from their own land but increases by the same amount the probability of extracting from federal/communal lands. Figure 4.4 shows that this effect is significantly different for distances higher than 1km.



Source: author's calculations based on data from ENHRUM

Figure 4.4: Predicted Probabilities of land per capita marginal effects

Finally the state of fuelwood collected is also significant, if they extract dry or a mix of dry/green wood it reduces the probability of extracting this resource in their own land by 29% in comparison with extracting only green fuelwood, conversely in Federal/Communal lands there is an increased probability of 20%-23% of extracting from this lands if the fuelwood is dry or dry/green mixed in comparison with people that only extract green fuelwood from this lands.

4.3 Additional robustness analysis

Because similar studies have made no separation within the extraction from private lands (own or not own) and to give a robustness check for our main model, we applied a simpler probit model that evaluates the same variables as the multinomial probit model presented in the previous section but only between private (own and not own) and federal/communal lands. Results from this model are presented in Table 4.4

From results presented in Table 4.4 we can note that collection distance and land per capita coefficients are still highly significant confirming the results presented in the previous section, moreover, this support the hypothesis that increased distance to collection sources exert pressure on communal and protected lands and that wealth (measured by land owned) decreases this pressure.

In terms of household attributes, the size of the household maintains the significance and the effect of the coeffcient in the multinomial probit model. A difference is found with the age coefficient, it gains a significance at the 10% level increasing the probability of extracting from federal/communal land the older the head of the household is and the effect becomes weaker the older this person is.

In general this results confirm the analysis presented in the previous section, but hides some heterogeneity found between private land owned and not owned such as the effect of education levels and the influence of stacking fuels within the households.

Moreover, results from the multinomial model with robust standard errors are presented in Table 4.5. Robust standard errors are not always an efficient tool to be implemented in non linear models estimated with maximum likelihood method. Robust standard errors in non linear models can be used to control when outliers are a problem. Results in Table 4.5 show that the coefficients signs and their significance in the original model in Table 4.2 are consistent.

Table 4.4: Alternate Probit Model Results

Private Land (base outcome)		**Federal/Comunal land**	
Variable		**Coefficient**	**Std. Error**
Sex (Female)		−0.300	0.198
Age		0.054*	0.031
Age squared		−0.0005*	0
Education		−0.012	0.024
HH Size		−0.150*	0.077
HH Size squared		0.007*	0.004
Indigenous Language		0.162	0.16
Assets		0.047	0.055
Stacking fuels		−0.184	0.152
Land per capita		−0.302***	0.07
Distance		0.045***	0.016
Fuelwood State	Green	Base outcome	
	Dry	0.619**	0.279
	Both	0.523	0.344
Permit needed		0.372	0.682
Age*Permit		−0.007	0.013
Constant		−1.221	0.881
Obs. = 396			
Prob > chi2 = 0.0002			
Log likelihood = -253.62082			

*Significant at the 10% level; **significant at the 5% level; ***significant at the 1% level.
Source: author's calculations based on data from ENHRUM

Table 4.5: Multinomial Probit Model Results with Robust Standard Errors

Own Land (base outcome)		Private land not own		Federal/Communal land	
Variable		**Coefficient**	**Robust Std. Err.**	**Coefficient**	**Robust Std. Err.**
Sex (Female)		0.274	0.335	−0.226	0.324
Age		−0.004	0.051	0.057	0.050
Age squared		−0.0001	0.0004	−0.001	0.0004
Education		−0.120***	0.041	−0.075*	0.039
HH Size		−0.164	0.136	−0.279**	0.126
HH Size squared		0.007	0.007	0.012*	0.006
Indigenous Language		0.147	0.276	0.306	0.251
Assets		0.016	0.097	0.059	0.088
Stacking fuels		0.535**	0.266	0.070	0.243
Land per capita		−0.395***	0.123	−0.589***	0.093
Distance		0.073**	0.034	0.111***	0.031
Fuelwood State	Green	Base Outcome			
	Dry	1.021**	0.46	1.341***	0.401
	Both	1.029*	0.556	1.246**	0.505
Permit needed		3.786***	1.239	3.164**	1.308
Age*Permit needed		−0.057**	0.022	−0.050**	0.024
Constant		0.532	1.464	−0.506	1.398
Obs. = 396	Prob > chi2 = 0.0000			Log pseudolikelihood = -365.4908	

*Significant at the 10% level; **significant at the 5% level; ***significant at the 1% level.
Source: author's calculations based on data from ENHRUM

Chapter 5

Discussion

In this study we analyzed how different household and resource attributes relate with the household decision to collect fuelwood from a given source. Despite the extensive literature that looks into determinants of fuel choice and labor/time allocation in rural households the source from where this resource is obtained has had little attention. Using a sample of a Mexican national survey applied in 2007 we applied a multinomial probit to evaluate fuel source choices.

In the model we defined three type of sources from where households could collect fuelwood: Own land, Private land not own and Federal/Communal Land. Some results from the model are in line with the literature. Education level of the head of the household has a significant effect on reducing the probability of extracting from communal and private land not owned, which has been reported in previous studies (Damte and Koch, 2011; Behera et al., 2015), this effect could be correlated because education levels opens the opportunities that households have to access different technologies, for example, in our sample, people that extracted from their own land used LPG fuel more frequently.

Contrary to previous findings (Lee et al., 2015; St. Clair, 2016) our model estimated that as household size increases the probability of extracting from communal lands decreased, however, this result must be taken with caution because, as the marginal analysis showed, despite the evident reduction in the marginal average effect as the household size increases, for households sizes below the average (7.9 persons) the probability of extracting from a communal land was the highest and the average marginal effect was only significantly different and smaller for households with more than 17 people (which is the result that would support more accurately the findings of the model in Table 4.2)

Land per capita have the effect reported on other of similar studies (Damte and Koch, 2011; Behera et al., 2015), increasing the probability of extracting from their own land as more hectares per capita are owned by the household, which could be seen as a measure of wealth. Similarly to Jumbe and Angelsen (2011) findings, the assets measure was not significant for any fuelwood source in the model.

Another variable that has the expected sign according to other studies (Pattanayak et al., 2004; Jumbe and Angelsen, 2011) is distance to the collection source, larger collection distances exert pressure on federal/communal lands and even in private lands that are not own by the households, moreover, when some kind of permits are required to collect this resource the probability of extracting from neighboring private lands or federal/communal lands is increased.

An interesting significant effect is that older head of the households that are required a permit have a decreased probability of extracting from land different from their own; a plausible explanation for this effect is that older head of the households do not like to ask for a permit in order to avoid bureaucracy that could be costly, we recommend that future research looks into this phenomenon. Moreover, future research should analyze deeper the endogenous relationships that income and consumption have with fuelwood collection and the selection of the source the household relies on, although this would require more detailed data from the households.

Finally, results from this study allow to gain more insight to the decision of collecting fuelwood from different sources available to the households. Increasing the level of education and wealth (measured by land owned) are factors that could be a focus for public policy allowing policymakers or communal resource managers to reduce the pressure off federal, communal or protected lands. Households seem to be willing to reach agreements (or obtain permits) with their neighbors (or the government) to collect fuelwood which could be a good indicator that promoting social capital and enforcing extraction restrictions in small villages could also reduce the pressure on protected or degraded ecosystems.

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