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LAND OWNERSHIP SUCCESSION IN THE AGRICULTURAL FRONTIER: THE CASE OF THE SIERRA DEL LACANDÓN NATIONAL PARK, GUATEMALA

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Abstract

This study investigates land ownership turnover in an area that is a priority conservation zone, the Sierra del Lacandón National Park (SLNP), Petén, Guatemala. Migration to Petén since the 1950s has eliminated 60% of Petén's forests. We analyze panel-data consisting of household interviews conducted with subsistence farmers living in the SLNP or its buffer zone in 1998 and 2009: 247 household interviews in eight communities in 1998, and repeat interviews conducted in 2009 when present. In the intervening 11 years, there has been substantial consolidation and splintering of the 1998 farm parcels. Half of the landowning households in 1998 sold land by 2009. The most commonly cited reason for a household to sell its land is for payments related to a medical emergency or debt. Regression analysis suggests early adopters of cattle and higher value crops were less likely to have sold their land by 2009.

Keywords: *Tropical deforestation, migration, Guatemala, subsistence farmers, cattle, hollow frontier*

1. INTRODUCTION

Forests in general and tropical forests in particular are important at both a global and local level. Locally they provide habitats and perform ecosystem services. Deforestation at the local level can have negative impacts on both the immediate environment and in the aggregate, such as with global climate change (Foley, DeFries et al. 2005). Humans have a long history of involvement in forest loss, with agency ascribed to many different sources. The *in situ* agents of deforestation, be they subsistence farmers, highly capitalized farming enterprises, or housing developments are the local, immediate actors affecting land cover change. This *in situ* effect, however, is but one impact of a multi-scalar process conceptualized as proximate causes (more immediate in terms of space and time) and underlying circumstances (more remote across the same two dimensions) (Geist and Lambin 2001).

Although population increase tends to associate positively with the expansion of agricultural areas in Latin America (Bilsborrow and Geores 1994, Perz and Walker 2002, Barbier 2004), population growth in and of itself will not by default lead to increased deforestation. Technology, markets, physical and structural constraints, and agricultural policies are but some of the influences mediating the impact of growing rural populations on the environment. Country-level examinations in many Latin American nations have often shown that despite an overall decline in rural population numbers, deforestation has nonetheless persisted and in some instances has even accelerated (Carr, Barbieri et al. 2006). The deforestation ascribed to small farming households, however, is most often taking place in the frontier areas of Latin America. The agricultural frontier serves as the destination for but a small fraction of migrants, often the poorest and most marginalized.

The agricultural frontier is defined as the outermost edge of human settlement, where land takes on value that is equivalent to the opportunity coast of the least-cost claimant (Mueller 1997). In the frontier forests of the tropics deforestation is of particular concern because of high biodiversity and ecosystem services contained in these areas, the elimination of which may have dramatic effects across a wide range of physical systems (e.g. local to global climate change) as well as social systems (e.g. elimination of a natural resource base for productive use). In these frontier environments migrant farmers seeking cultivable plots are often viewed as the primary proximate agents of deforestation (Rudel and Roper 1996, Geist and Lambin 2001).

1.1 The Sierra del Lacandón National Park

The Northern-most department of Guatemala, the Petén, is the nation's largest department (Figure 1). It spans 35,000 km^2 of the country, comprising one-third of the national land area (Shriar 2006). The area was considered vast and inhospitable by colonial governments (Rodriguez de Lemus 1967, Casasola 1968). The area was sparsely populated for many years, serving as home to some 25,0000 people in 1965 (Schwartz 1990), less than 0.6% of the total population at that time (Shriar 2012).

Figure 1: Map of the study area

Since then, planned and spontaneous colonization of the area has resulted in substantial changes to the region. Projections by the Guatemalan National Census put the 2012 population estimate for Petén at some 660,000 people (INE 2010), though many officials place the department's current population closer to 1 million (Shriar 2011). This dramatic increase in population can be attributed to both high rates of in-migration from elsewhere in Guatemala, and high rates of natural growth among those living in the Petén (Grandia, Schwartz et al. 2001).

By the 1950s, export-oriented agriculture such as expansive cattle ranches, sugar cane, coffee plantations, and fruit orchards claimed most of the land in Guatemala outside of the Petén. Guatemalan investment policy over the centuries has encouraged foreign occupation and production on great swaths of land, dispossessing the subsistence populations (Grandia 2006). The Q'eqchi' Maya was the first group to migrate *en masse* into the Petén in the early 1950s in search of land for subsistence production (Adams 1965). Much of this migration was stepwise as households searched for land. Ladino (*mestizo*) migrants began to join the northward push in the search of land when more southern migration destinations reached saturation in the 1950s and early 60s (Adams 1965). The earliest migrants would seek unoccupied land and make a squatter claim on it, called an *agarrada.*

In-migrants to the area since the 1980s have been primarily land-poor farmers, almost equally divided between *ladino* and Q'eqchi' farm families, originating primarily from the eastern part of the country (Schroten 1987). Land shortages for peasant farmers in the rest of Guatemala, coupled with violence from a protracted civil war, served as the push for sending migrants to the Petén.

Concerned with the advance of the agricultural frontier into the forests of Petén, international and Guatemalan conservationists collaborated to establish a conservation area in Northern Guatemala in the early 1990s. The 2.1 million hectare Maya Biosphere Reserve (MBR) forms a conservation corridor with protected areas in Belize and Mexico. This tri-national conservation area is called the "Maya Forest" (La Selva Maya) (Nations 2006). In addition to restricting activities in areas of high biodiversity, the MBR also seeks to protect cultural patrimony sites. In terms of areal extent, the MBR covers over half of Petén and almost 20% of Guatemala (CONAP 1992).

Within the MBR of the Petén, the Sierra del Lacandón National Park comprises one of the four core biological and Maya cultural heritage conservation zones. It is an area just over 2,000 km^2 (CONAP 2005). Since the late 1980s, arriving waves of colonists are estimated to have reached 20,000 individuals in the park by 1998. Concomitantly, approximately 11% of the park's forest canopy was eliminated, and deforestation has continued (Carr 1999, Suter and Carr 2010). We estimate that the population in the park reached almost 25,000 by 2008, an increase of 25% over the 1998 estimate (Suter and López-Carr 2010).

The communities in what would become the SLNP arrived as both planned and spontaneous colonizers. Of the 28 communities with appreciable land within the SLNP, four began as agricultural cooperatives in the 1960s, though most are now disbanded. The 24 communities on the interior and eastern border of the park were the result of spontaneous colonization. A few of these communities settled as early as the 1970s as camps of *chicle* extractors. Most settled during the 1980s and 1990s after the creation of a road linking the oil fields to the north of the SLNP with the central urban area of Petén (Schwartz 1990), the departmental capital of Flores and its neighboring cities Santa Elena and San Benito.

At the time the SLNP was declared in 1990, relatively few of the households with land in the interior of the park had previously obtained legal title. Those without land title learned they would never be able to legalize their land since it was now a national park. USAID and later the World Bank sponsored a land regularization program in the buffer zone of the MBR starting in the mid-1990s. This program helped thousands of *campesinos* achieve a land title. Though the majority of the parcels within the park are not regularized, in most cases squatting landholders enjoy usufruct rights. There is an extra-legal land market on which households buy and sell land both within the national park zone and in the buffer. Similar to all land before the regularization program, when an owner sells usufruct rights to a buyer, the value is assessed based on the "*mejoras*" or improvements the land exhibits (Gould 2006). Land parcels of interest included in this analysis include lands both with and without title. Including this as a variable, though no doubt an interesting avenue for pursuit, would be difficult, however, as we were unable to verify the regularization status of many land parcels.

2. THEORETICAL FRAMEWORK: THE MULTIPHASIC MODEL

The establishment of the SLNP has theoretically, and to large part in practice, circumscribed the amount of land available for settlement in the study area. Continual in-migration, combined with a high rate of natural growth, means that the rural population rises while the amount of land available stays static. This makes the application of Bilsborrow's "multiphasic response" conceptual model appropriate for examining this instance of the rural response to increased population pressure. This model has its roots in the demographic model proposed by Kingsley Davis (1963) for examining the response of rural populations to threats to their living standards in the face of population increase. Davis balked at the tendency to investigate only a single hypothesis at a time, such as only contraceptive use or only a delay in marriage. He emphasized situating a possible response within a suite of possible responses, while also recognizing that the contextual circumstances may influence which response could be potentially exhibited.

The demographic model, however, assumed fixed land area and technology. Bilsborrow (1987) expanded this theory to include possible economic responses, such as an increase in the cultivated area. Additionally, he included the possibility of a Boserupian response via an increase in the intensiveness of farming (Boserup 1965). Boserup's theorizations had not allowed for the possibility a demographic response, so Bilsborrow's approach integrated three possibilities in the face of rising population density: (1) demographic (e.g. decreases in fertility), (2) economic (e.g. an increase in the area of land under cultivation or a substitution of more productive crops), and (3) demographic-economic (e.g. migration in any of its many forms, such as permanent, seasonal, rural-rural, rural-urban, or rural-international) (Bilsborrow 1987).

Bilsborrow also placed an added emphasis on the suite of contextual factors with the potential to influence the responses exhibited. He especially highlighted the inclusion of physical environmental factors. This elaboration of Davis' demographic responses allowed for the possibility of shifting the focus from the populations concerned towards an examination of the environmental impact of increasing populations.

Subsequent work by Bilsborrow and Okoth-Ogendo (1992) aimed to tailor this conceptual framework towards examining population-driven land use change in developing countries. They proposed four stages of response to population growth. These responses can be consecutive, concurrent or cumulative. These four phases are classified as:

I. Tenurial – for example the distribution of idle land for agricultural use, the more equitable distribution of land between users, or a reclassification of access rights. In the context of the SLNP, the most common scenario of this will involve the sale of land to more recent in-migrants or parents bequeathing their land to one or more children. One could conflate the term tenurial used in this instance with the subject of land tenure (legal title to the land, as opposed to usufruct rights). Therefore, here we will adopt the term tenurial/division for this category of response.

II. Land appropriation or extensification – the out-migration response, seeking unoccupied arable land outside of the local area. In an area such as the SLNP, this may involve pushing further into the agricultural frontier. This is an important response for new arrivals who do not find adequate land for their needs. Likewise, as the next-generation of farmers come of age, there may not be adequate land in their community to accommodate them. We will address this response more explicitly in future analyses of the SNLP panel data.

III. Adoption of new technologies of land use – in the context of population increase, technological change usually refers to more intensively productive use of the land. The term technology is used in the Boserupian sense, meaning a higher intensity of land use by way of an increase in the frequency of cropping. We will refer to this category as technology/intensity.

IV.Demographic – another possible response to rising rural population density is fertility reduction, whether it be though the postponement of marriage and/or through the reduction of marital fertility. This is usually the last response, if no other intervention takes place. This response will be the subject of future analyses of the panel data.

2.1 Application to the SLNP

The multiphasic model is one of several theorizations treating how the agricultural frontier develops over time. More southern areas of Petén were once the colonization zone, but most of the small farms established in that era are already largely given over to expansive cattle ranges or export agriculture, belonging to a few wealthy individuals. This process, in which numerous small scale agriculturalists are gradually replaced by only a few large-scale owners, is referred to as the "hollow" frontier, called so because it is largely depopulated (James 1959, Rudel, Bates et al. 2002).

In contrast to more southern parts of Petén, the study site remains still largely in the hands of small-scale subsistence producers. Will the study site gradually convert to the land uses and ownership regimes seen in the longer settled regions of Petén? If so, how will that replacement occur? How will land change hands from the smaller-scale producers to the more expansive landowners?

De Sherbinin, VanWey et al. (2008) argue for the necessity of including intergenerational processes in the study of frontier settlement. Household lifecycles (Walker, Perz et al. 2002) appear to explain very little of the land use patterns seen in the frontier, and concern only the short-term timeframe. To understand more long-term patterns of land use and their equilibriums, we must also examine intergenerational dynamics such as co-residence between generations, out-migration of the next generation, and the bequeathing or sale of land.

For the above reasons, we decided to investigate the process by which land changes hands in the developing frontier. We thought that the process would be to a large extent from one generation to the next, but we came to see that relatively few of the land transactions were between parent and child, with the overwhelming majority of sales going to a third party purchaser. Given that in 1998 the average age of a household head was 40 years old, perhaps in 2009 we were still several years away from seeing widespread bequeathal of land from one generation to the next. In this paper, we attempt to model the farm and household characteristics that associate with a higher likelihood of a land sale or bequeathal by the time of the follow up visit to the area in 2009.

We hypothesized that the farm parcels identified as "owned" in 1998 will now either still be the whole parcel unit (though possibly in the hands of a new owner) or will be subdivided into smaller parcels with multiple independent owners (perhaps also including the original owner). Which scenario comes to pass on a plot could have profound impacts on the land cover, since more farms on the same area will most likely deforest a greater area in total (Pan, Carr et al. 2004). As Carr noted (2002), the farms sampled in 1998 had on average over 20 ha of land still in forest, meaning there was significant potential for further deforestation on the internal frontier.

Many studies treating the topic of farm fragmentation define it as a single household using more than one parcel of land, and examine its impact on the household's farming efficiency (Blarel, Hazell et al. 1992, Lon, Hotta et al. 2011). Others define it as the subdivision of a single land parcel into multiple farms under operation by different households (Pan, Carr et al. 2004). Both phenomenon can be seen in the frontier farm area of the SLNP, though the process of interest here is the transfer and subdivision of parcels, similar to the phenomenon seen in the Northern Ecuadorian Amazon (NEA) (Pan, Carr et al. 2004, Barbieri, Bilsborrow et al. 2005).

Similar between the SLNP and the NEA, the frontier is effectively closed (as in all available land in the area was claimed years ago), yet the population has continued to increase from both natural growth and continued in-migration. New households, therefore, need a place to settle, which has resulted in a documented prevalence of farm fragmentation in the NEA. In the NEA, parcels surveyed in 1990 supported almost twice the original number of independently managed farms nine years later. More people supported in a given area typically leads to more forest clearing, while smaller average plot size tends to stimulate intensification (Barbieri, Bilsborrow et al. 2005). Farm size appears to be a highly important variable relating to land use in the agricultural frontier, and a main driver determining plot sizes over time is its subdivision through sales and bequeathals (Pan, Carr et al. 2004). We believe that similar to the example seen in the NEA, we will see extensive fragmentation of the original farm plot in the SLNP. We may not see fragmentation quite to the same extent, however. The original NEA parcels were on average larger and more consistently sized than the SLNP parcels, and thus could more easily accommodate additional households (Pan, Carr et al. 2004).

Figure 2 diagrams the four different responses to rising population density theorized within the multiphasic framework. Of the four categories of response presented in the multiphasic framework, we will examine one aspect of *in situ* land management as an outcome variable: the tenurial/division category (shaded in Figure 2). In the context of land ownership patterns seen in the SNLP, the tenurial/division phase refers to land ownership retention or turnover. We will model it as a function of variable representing a selection of the other possible multiphasic responses, in addition to other variables.

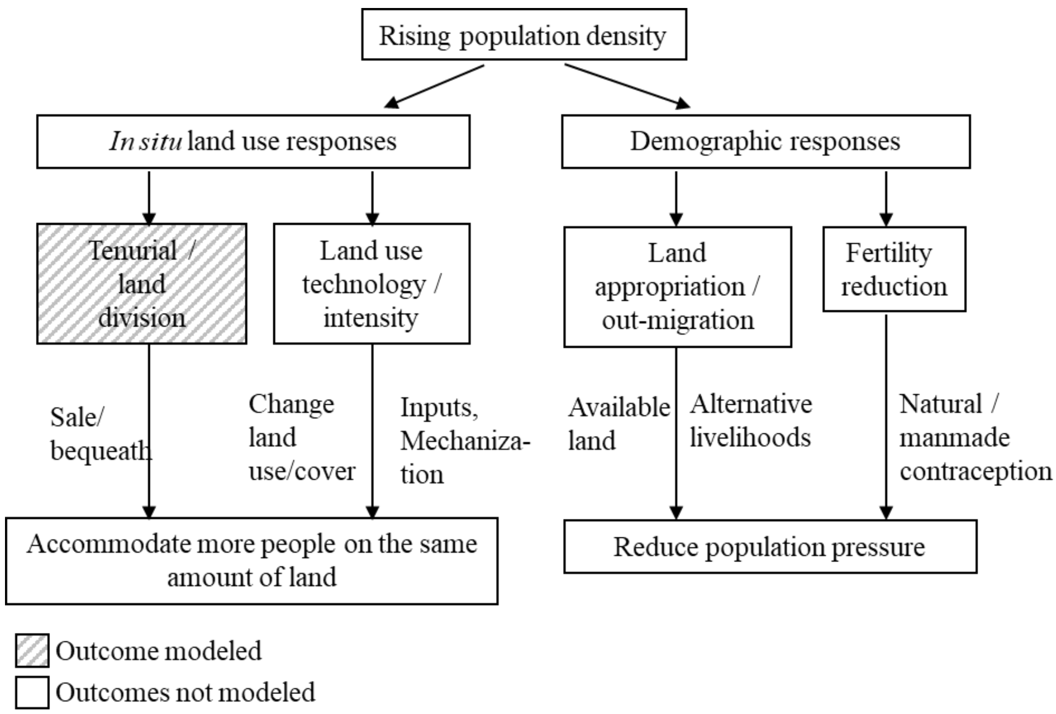

Figure 2: Diagram of multiphasic responses

3. LAND SUCCESSION

There are several theories characterizing how the frontier changes over time, but there are few examples examining this topic employing panel data collected in the agricultural frontier (Browder, Pedlowski et al. 2008). Panel data will allow the examination of a topic important to understanding how the frontier changes over time: the succession of land from one owner to the next (de Sherbinin, Carr et al. 2007). The number and characteristics of households making use of a given plot of land have strong implications for the types and qualities of different land covers present (Pan, Carr et al. 2004). This is an under-examined phenomenon given its importance for shaping the frontier over time. Some parcels will remain under the same ownership, while some that previously supported one household will grow to support many over time, and others still will be consolidated into the portfolio of larger landholders.

These different scenarios can impact the land covers and ecological characteristics of the land, as well as the wellbeing and livelihood strategies of the rural population living there. The first step in effecting these changes is the original households' decision to sell all, some, or none of their landholdings. The majority of the farmers who came to the area were landless in their origin areas. Who, therefore, are the farmers who are willing to give up the land they sacrificed so much to obtain, and what motivates their decision to sell it? The answers to these questions will help understand the process by which the frontier is transformed.

3.1 Methods and data: 1998 and 2009

The eight communities in which we conducted research are a sample of the communities located within the SLNP, shown in Figure 3. The second author López-Carr selected these eight communities in 1998 for his household study of frontier land use. We revisited these communities in 2009 to track how the frontier changes over time at both the level of the household and the farm parcel. López-Carr originally chose these communities as part of a clustered probability sample of the communities with farmer landholdings located within the park boundaries. He formed three clusters: two located along the major transportation routes (both unpaved roads at the time) fringing the northeastern and southern borders of the park, and one comprised of the communities wholly contained within the park. He selected two of the five communities on the Bethel road in the south of the park, two of the nine communities in the interior of the park, and four of the fourteen communities along the road to Naranjo in the northeast region of the park.

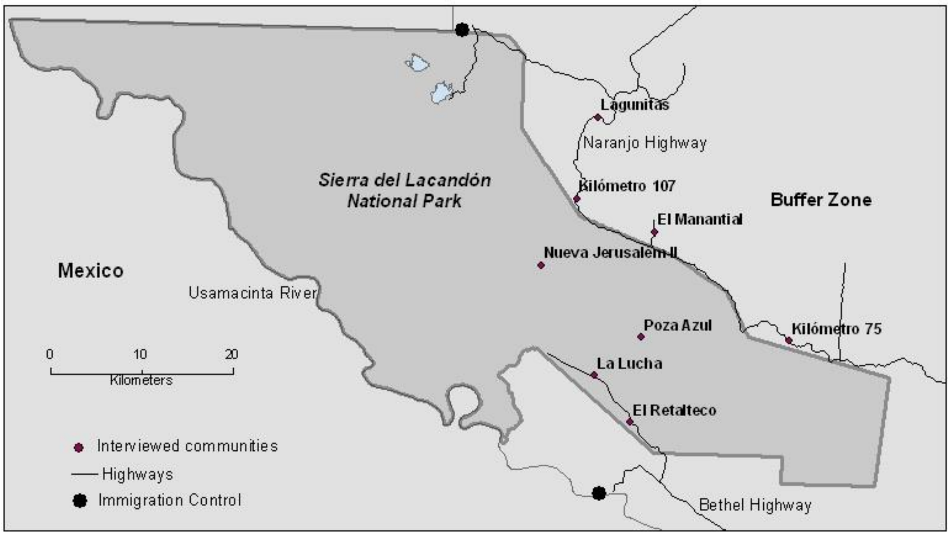

Figure 3: Map of the Sierra del Lacandón National Park and the eight subject communities

Communities in the region follow a clustered settlement pattern. A 1998 survey team headed by López-Carr visited the selected communities, and community leaders indicated the extent of the homes in the community. Members of the survey team then dispersed to different areas of the community with instructions to select households as randomly as possible. They interviewed at least 30% of the households of each community. Overall, they interviewed approximately 35% of the households within all eight communities. López-Carr's team interviewed a total of 247 households, with 241 of these households meeting the criteria for inclusion in his land use models.

López-Carr's survey team used questionnaires created by him comprised of questions on migration and land use that incorporated demographic, political-economic, socio-economic, and ecological/geographical factors. Household surveys were fixed-format with a few short open-ended questions per subsection. Please see Carr (2002) for further description on the design of the survey instrument.

When the first author revisited the study area 11 years later, we wanted to create a panel data set that tracks the evolution of the frontier over time. Therefore, we did not want to focus exclusively on the shifting cast of characters who come and go in the frontier by pursuing exclusively another random sample, though we did do that as well. We also wanted to follow up on that which does not move, the land itself. My choice of the parcel as the unit for examination is supported by research that posits (though has not yet conclusively shown), that a more dominant process in shaping land use in a frontier may not be the household lifecycle (e.g. Walker, Moran et al. 2000, Perz 2001, McCracken, Siqueira et al. 2002, Walker, Perz et al. 2002). Instead, frontier land use might be more strongly determined by the property or farm lifecycle (Barbieri, Bilsborrow et al. 2005, VanWey, D'Antona et al. 2007). Attempts to tease out the effects of farm vs. household lifecycle remain incipient (Barbieri, Bilsborrow et al. 2005, VanWey, D'Antona et al. 2007).

The 1998 survey team selected households not according to their farm parcel, but as a random selection of dwellings located in the community cluster, removed from the actual farming area. As such, the households selected represent a mixture of land owners (with or without legal tenure), renters, households who both owned and rented, and some households with no access to land. Of the 247 households interviewed in 1998, we were able to confirm in 2009 that 186 of them did indeed "own" their farm parcel in the area in 1998 (meaning either with legal property title, informal squatters' rights, or at some stage of the process in between, e.g. land had been surveyed). The remaining 58 households either rented land from other community members or did no farming on their own behalf, typically working as wage laborers on the farms of others.

To follow up on the "owned" farm parcels from 1998, in 2009 we tracked down the 1998 interviewees who had claimed to be landowners. We then had locally hired interviewers administer interviews to these households. We developed the 2009 survey instruments using the surveys employed by Dr. López-Carr in 1998 as a template. The most striking difference of relevance here between the two surveys is the 2009 surveys contained a section following up on the landholdings of the household previously interviewed in 1998. When a 1998 landholder was re-interviewed in 2009, they were asked to confirm or correct the size of the land parcel they claimed to own in 1998. They would then be asked if and when they had sold any or all their 1998 landholding, for what motive, and to whom (friend, family, neighbor, stranger, etc.). If the 1998 landholder no longer lived in the area, we would attempt to locate a relative, friend, community leader, or a current owner or owners who we could interview about the land parcel in question.

Of the 247 households interviewed in 1998, we were able to obtain adequate information for evaluating 238 of these households for inclusion in our analysis on land sales (Table 1). Of these 238 households with access to land in 1998, 78% (186 households) "owned" a quantity of agricultural land. Around 22% of the 1998 sample (52 households) did not own land, meaning they either rented or borrowed land to farm.

Table 1: Landowners in 1998 and percentage who sold none, some, or all of that land since 1998

	1998 Landowner?		Of the 1998 landowners		
Community	No	Yes	Sold none	Sold some	Sold all
Kilómetro 107	15%	85%	49%	3%	49%
Kilómetro 75	24%	76%	25%	31%	44%
La Lucha	9%	91%	60%	0%	40%
Lagunitas	16%	84%	56%	7%	37%
Manantial	48%	52%	29%	0%	71%
Nueva Jerusalén II	8%	92%	61%	0%	39%
Poza Azul	9%	91%	43%	0%	57%
Retalteco	43%	57%	41%	24%	35%
Grand Total %	22%	78%	48%	6%	46%
Grand Total #	52	186	89	12	85
	238		186		

The 186 confirmed landholdings of the 1998 interviewees, therefore, are the parcels of interest that we shall follow through the possible transactions that would bring them under the management of a different household or households by 2009. For the sake of brevity we use the term "sold", but in fact there were many mechanisms by which farm land changed hands in the communities. These include selling the land, bequeathing it to a family member, abandoning the land, or having the land involuntarily taken. Of the 186 households who owned land in 1998 (Table 1), almost half (48%) maintained the original parcel wholly intact, selling no portion of it by 2009. An almost equal number (46%) sold their entire parcel, sometimes as one unit, sometimes in pieces. A small number (6%) of households maintained part of their parcel and sold a portion of it to another household.

3.2 Parcel splitting and consolidation

Although land consolidation is certainly an issue in the area, parcel splitting is the more obvious phenomena when examining the fates of the 1998 "owned" parcels of interest. Ultimately, the number of land "splinters" created by splitting up parcels in land sales may be extremely important because it results in more households supported by a given area, possibly overtaxing the natural resource environment. Fragmentation of landholdings has been linked to deforestation in the highlands of Honduras (Stonich 1989). Also, parcel fragmentation may result in households with land parcels below the minimum size for sustaining the large families typical of the area.

Table 2 summarizes the total number of land transactions that took place in the intervening eleven years, with the 97 total households who sold all or a portion of their land engaging in 110 land transactions, be they sales or bequeathals to offspring or a purchaser. The discrepancy between these two figures (13) comes from the times a household sold or bequeathed their land in separate transactions.

Table 2: Land sellers, number of transactions, number of buyers, and total number of landowners after first round of land sales after 1998

Community	Sold some or all	Total number of land transactions	Total # buyers (1st round only)	Total # land owners after 1st round of sales
Kilómetro 107	16	18	23	41
Kilómetro 75	12	15	16	25
La Lucha	5	12	13	25
Lagunitas	12	14	16	33
Manantial	13	12	13	18
Nueva Jerusalén II	13	13	15	35
Poza Azul	14	14	15	24
Retalteco	12	12	20	31
Grand Total	97	110	131	232

Although most of these 110 land transactions had one household as the recipient, a fair number went to multiple persons, such as a father bequeathing each of his several children a portion of his land, or brothers pooling money to purchase a parcel together. Possibly in these scenarios joint owners will manage the asset together, but just as likely multiple owners will result in subdivision of the original parcel or sub-parcel. This first round of 110 land transactions, therefore, transferred the land to 131 households (Table 2). With the addition of the number of households who still owned all or part of their 1998 parcel (101 households), the land that in 1998 belonged to 186 households then belonged to 232 households after the first round of sales. The analysis presented here covers only the first round of land sales. However, we calculate that after additional rounds of land sales, the same 186 land parcels from 1998 belonged to 269 households in spring 2009, a 45% increase in the number of landowners.

Most of the households that purchased the original 1998 parcels are small-scale subsistence agriculturalists, similar in many respects to the first waves of settlers who colonized the area. A few of the current landowners, however, are more similar to large-scale landowners and ranchers, with a few reputed to be *narco-ganaderos*, (narcotraffikers involved in ranching as an investment or for money laundering). Although only a few of the newer land buyers may be land consolidators, replicating the pattern of *"mucha tierra, pocos dueños*" ("much land, few owners") seen in most of Guatemala requires only a few such households. A panel study of frontier farm parcels in the Amazonian state of Rondônia between 1992 and 2002 found a similar pattern of simultaneous property fragmentation and consolidation (Browder, Pedlowski et al. 2008).

3.2 Motives for land transactions

Most households who migrated to the agricultural frontier of the Petén did so in search of a parcel of land to farm (Lopez-Carr, Martinez et al. 2017). Once attained, a household who gave up all or a portion of said parcel would do so only for a compelling reason. Suter and López-Carr (2010) includes a discussion of the motivations cited by the 1998 landholders who had sold, bequeathed, or abandoned land by 2009. An understanding of these motives could be key for crafting policy aimed at staunching the flow of migrants pushing farther into the frontier upon selling or losing their land.

For the 110 land transactions that took place as the first round of land sales following the 1998 interview, we categorized most motives into one of eight categories. The most commonly cited motive for selling land (23% of cases) was the need to cover a medical expense. This bolsters the notion that in an area of weak institutions such as the frontier, land can act as an insurance policy or a savings account in times of duress. The second most common motive was selling the land out of a desire to relocate, including returning to their place of origin. The resettlement scheme to the land collective *Finca la Paz* was one example motivating a block of landholders in the community Nueva Jerusalén II. Selling a land parcel to buy a different, superior parcel, often in the same community, was a reason cited for 12% of the land sales. Another 12% of land transactions were land bequeathals to children or other relatives upon retirement, in anticipation of death, or upon death. This occasionally included a larger portion of land allocated to the child who paid the parent for the land. A less common yet still prevalent reason cited for was selling or losing land was because of a conflict over ownership (7%). In some instances, they lost the land directly to whomever they were in conflict with, while in other instances they sold the land to a third party to avoid further dispute over the contentious property. Other cited motives for selling land was to pay off a debt (5%), cover the costs of migrating to the USA for themselves or a child (5%), or to invest in a business proposition (6%). Reasons outside of those cited here accounted for 2% of the sales, and in 7% of the cases the reasons were unknown by those we interviewed (Suter and López-Carr 2010).

The motives cited for selling land by these 1998 farm owners show some similarity to the motives cited by frontier land owners/sellers in Rondônia. Although medical expenses were not a commonly cited motive in Rondônia, the overarching motive for selling land in both Rondônia and in the SLNP was to raise cash, suggesting they have few other liquid assets, such as savings, to call upon (Browder, Pedlowski et al. 2008).

3.3 Year of transaction

Figure 4 shows the percentage per year of the total 110 land transactions that took place between the two interview dates, 1998 and 2009. Land transactions took place at a relatively constant rate. The year with the highest percentage of land transactions was 1999. This can be attributed in part to a relocation package offered to the residents of Nueva Jerusalén II by the park administration. Members of this community and other communities located in the Recuperation Zone of the park received the option of a resettlement deal of farmland, to be held in common, elsewhere in Petén. This of course violates the assumption of independence of the sample. Future work will include community-level effects to account for this. As an aside, this resettlement community, called *Finca La Paz*, dissolved within approximately seven years because of internal conflicts and logistical difficulties, and many of these relocated households returned to the frontier to reclaim their old land or in pursuit of new land.

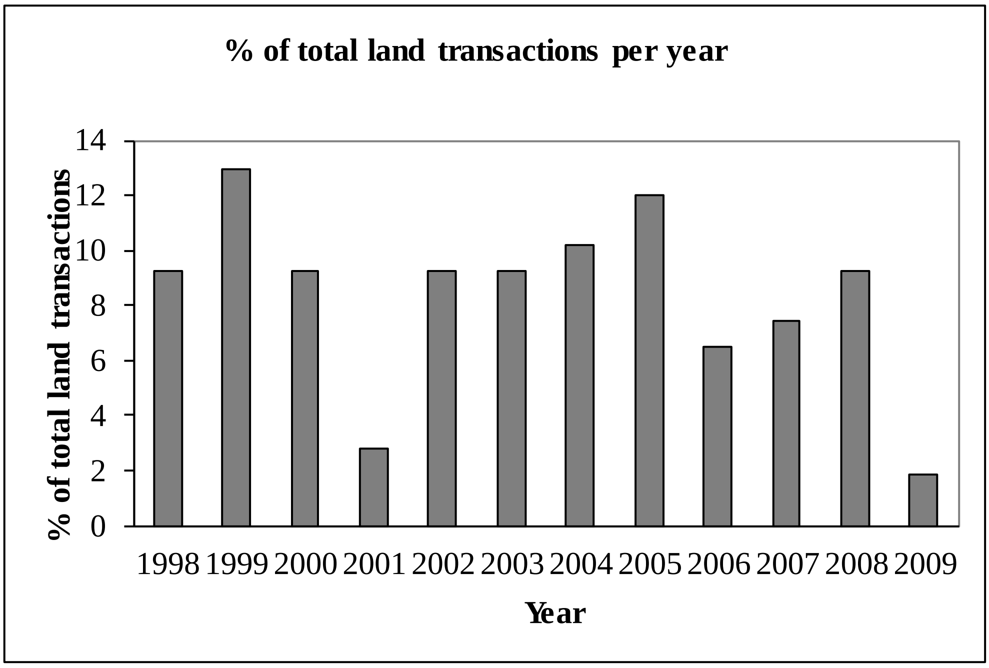

Figure 4: Percentage of total land transactions per year (of 110 total)

4. LOGISTIC MODEL METHODS

When appropriate, an important step in data analysis can be the application of regression methods. These serve to illustrate how an outcome variable relates to one or more possible explanatory variables (Hosmer and Lemeshow 2000). When the outcome modeled is a discrete response, with two or more possible values, the logistic regression model has gained prominence within certain fields as the primary method for modeling this response. As with any model building in statistics, the principle goal in creating a logistic regression model is to find the best fit and most parsimonious model. In the models explored here, the discrete outcome examined is a binary response.

The following section gives an overview of logistic regression methods. The following notation is adopted from Tabachnick and Fidell (2007), and additional detail on logistic regression methods can be found there and in Hosmer and Lemeshow (2000). In logistic regression, the response variable, $\hat{Y}$, is the probability of either one or another proposed outcomes based on a nonlinear function of the best linear combination of predictors.

$$\hat{Y}_i = \frac{e^u}{1+e^u}$$

Here, $\hat{Y}_i$ is the estimated probability that the *i*th case (i = 1, 2, …, n) is in one of the response categories. The superscript, *u*, denotes the linear regression equation, with *A* serving as the constant, B_j as the coefficients, and X_j as the predictors for j=1, 2, …, k predictors.

$$u = A + B_1X_1 + B_2X_2 + \ldots + B_kX_k$$

This linear regression equation forms the *logit*, or the natural log of the probability of falling into one outcome group as the dividend, and the probability of falling into the other outcome group as the divisor:

$$\ln\left(\frac{\hat{Y}}{1-\hat{Y}}\right) = A + \sum B_j X_{ij}$$

Estimating the coefficients is accomplished using the maximum likelihood technique, which seeks the best linear combination of the predictors included in the model to achieve those outcome frequencies observed in the phenomenon studied. The parameter estimates are iteratively adjusted, seeking to recreate the expected frequencies of the outcomes seen in the sample data (Hox 2002, Tabachnick and Fidell 2007).

The goodness-of-fit test, which employs the log-likelihood, is used to help the researcher determine which models are the most apt, when compared to the basic empty model (consisting of only the intercept term) and more complex models, possibly with multiple predictors and interaction terms.

$$\text{Log-likelihood} = \sum_{i=1}^{N} [Y_i \ln(\hat{Y}_i) + (1-Y_i)\ln(1-\hat{Y}_i)]$$

Each model's goodness-of-fit is presented in the form of the area under the ROC (receiver operating characteristic) Curve. The area under the ROC curve, which ranges from zero to one, is a measure summarizing the model's ability to differentiate between those subjects in the outcome category of interest versus those who are not. If ROC = 0.5, the model does not discriminate beyond mere chance. An ROC value $\geq$ 0.7 is considered acceptable discrimination (Hosmer and Lemeshow 2000).

4.1 Logistic models predicting land sales

In this paper we will construct logistic regression models predicting land sales executed by a 1998 landowner at some point during the intervening eleven years between interviews. While we employ the term "sales" for the sake of brevity, the category also includes when a person bequeaths land to a family member, and three cases of land abandonment.

We chose to leave these grouped together for several reasons. We wanted to see if a dominant process in precipitating land changing hands would be related to household lifecycles, i.e., a household head maturing beyond his productive years, spurring a divestment of land. In such a case, the household head could pass the land on to his children, a third party, or abandon his holdings. That process would perhaps be obscured if we limited the examination only to third party sales. In several of the cases involving a land transaction between the parent and offspring, the adult offspring did pay his parent for the land, so the distinction between a land bequeathal and a land sale may not always be clear cut. In a related analysis conducted by Pan, Carr, and Bilsborrow (2004) modeling the splitting of farms into sub-parcels in the Northern Ecuadorian Amazon, the authors do not distinguish between parcel fragmentation brought about by sharing with offspring versus a third party land owner taking over a portion of the land, even though the practice of subdividing a parental plot to share with children is more widespread in that region.

The models predict whether a 1998 landowner kept all of the land that they "owned" in 1998, which serves as the reference category, or whether they sold all or part of their land. The dependent variable of whether a household had sold land or not comes from the 2009 interviews. The independent variables all derive from data collected during the 1998 interview.

We ran the logistic regression models allowing for the stepwise entry of any or all of the variables listed in Tables 3 through 7. We then ran an additional model including a suite of potentially confounding and theoretically important variables, and then examined the stepwise selected variables for remaining significant in predicting the outcome variable. Aside from the preliminary study presented in Pan, Carr et al. (2004) examining a farm's propensity to subdivide in the Northern Ecuadorian Amazon, we know of no study predicting land transactions in the agricultural frontier. Pan, Carr et al. (2004) examined the trend of parcels subdividing using the Cochran-Armitage test over variable categories. Variables examined by them included many characteristics that correspond closely with variables included here. This is because both studies examine parcel transactions as a function of the household lifecycle theory, farm lifecycle theory, and geographical/ecological characteristics.

Table 3: Pool of labor saving independent variables

Labor saving variables of interest	N	Mean/ Proportion	Std. Deviation	Min.	Max.
Total land (ha)	186	42.1	20.4	3.5	135.2
Maize (0=no, 1=yes)	186	0.95		0	1
Area of Maize (ha)	185	5.7	4.8	0.0	40.8
% land in maize	185	17%	18%	0%	100%
Pasture (0=no, 1=yes)	186	0.30		0	1
Area of pasture (ha)	185	1.6	5.1	0.0	45.1
% land in pasture	185	3%	11%	0%	100%
Cattle (0=no, 1=yes)	186	0.15		0	1
Number of Cattle	186	1.3	4.6	0.0	35.0
Herbicide (0=no, 1=yes)	186	0.45		0	1
Plowed with tractor (0=no, 1=yes)	186	0.00		0	1
Own chainsaw (0=no, 1=yes)	186	0.08		0	1

Table 4: Pool of land saving independent variables

Land saving variables of interest	N	Mean/ Proportion	Std. Deviation	Min.	Max.
Higher value crops (0=no, 1=yes)	186	0.22		0	1
Area in higher value crops (ha)	185	0.6	1.5	0.0	9.9
% land higher value crops	185	1%	4%	0%	22%
Black bean (0=no, 1=yes)	185	0.01		0	0
Area of black bean (ha)	185	0.5	0.9	0.0	6.3
% land in black bean	185	1%	2%	0%	17%
Total cropped land (ha)	185	6.7	5.2	0.0	40.8
% land cropped	185	20%	19%	0%	100%
Area of fallow (ha)	185	9.5	10.3	0.0	49.3
% land fallow	185	24%	23%	0%	98%
Total cleared land (ha)	185	18.5	13.1	1.4	67.6
% land cleared	185	49%	28%	3%	100%
Forest (0=no, 1=yes)	186	0.91		0	1
Area of forest (ha)	185	23.1	16.9	0.0	90.1
% land forest	185	51%	28%	0%	97%
Chemical fertilizer (0=no, 1=yes)	186	0.07		0	1
Green manure (0=no, 1=yes)	186	0.41		0	1
Either green manure OR herbicide (0=no, 1=yes)	186	0.69		0	1
Home garden (0=no, 1=yes)	186	0.45		0	1

Table 5: Pool of demographic independent variables

Demographic variables of interest	N	Mean/ Proportion	Std. Deviation	Min.	Max.
Age of household head	186	40.8	13.0	18.0	78.0
HH head began primary school (0=no, 1=yes)	186	0.56		0	1
HH head finished primary school (0=no, 1=yes)	186	0.11		0	1
Total household count	186	6.7	3.1	2.0	16.0
Child dependency ratio	186	1.0	0.8	0.0	4.0
Years on farm	186	9.6	6.0	0.0	36.0
Ethnicity (0=ladino, 1=non-ladino)	186	0.26		0	1

Table 6: Pool of socio/political-economic independent variables

Socio/political-economic variables of interest	N	Mean/ Proportion	Std. Deviation	Min.	Max.
Received credit in previous year (0=no, 1=yes)	186	0.06		0	1
% of total maize production sold to market^	186	78%	26%	0%	100%
Off-farm work previous year (0=no, 1=yes)	186	0.38		0	1
Cement floor (0=no, 1=yes)	186	0.09		0	1
Assets[a]	186	1.3	0.8	0.0	4.0
Rents farm land (0=no, 1=yes)	186	0.06		0	1
Contact with NGO/GO (0=no, 1=yes)	186	0.44		0	1
Land prior to migration (0=no, 1=yes)	186	0.31		0	1
Land prior to migration (ha)	186	2.1	8.6	0.0	90.1

^ 1st harvest (*primera*)

[a] Guttman scale: assigns one point each for households assets horse, radio, chainsaw, automobile

Table 7: Pool of environmental independent variables

Environmental variables of interest	N	Mean/ Proportion	Std. Deviation	Min.	Max.
Distance to road of primary plot (Km.)	186	6.5	5.3	0.0	20.0
Cultivate maize on flat land (0=hilly, 1=flat)	186	0.41		0	1
Land in >1 plot (0=no, 1=yes)	186	0.13		0	1
Fertile land (0=no, 1=yes)	186	0.44		0	1

Therefore, we selected the potentially confounding variables for their theoretical relevance to either the multiphasic model or to other theoretical frameworks discussed here, such as the household lifecycle model or the farm lifecycle model, as well as a geographical variable of potential economic importance. These household lifecycle variables included are *Age of household head* and *Total household count*. The farm lifecycle variable is *Years on farm*. The geographical variable is *Distance to road of primary plot (Km.)*. For the multiphasic model, we invoked two intensification and one extensification variables to determine if they had any potential impact on the decision to sell land at some point in the intervening eleven years. We selected the use of *Either green manure OR herbicide (0=no, 1=yes)* or *% land higher value crops* as the intensification variables, and one extensification variable, the *Number of head cattle*. If one of these potentially confounding variables or a closely related variant of it (e.g. *Higher value crops (0=no, 1=yes)* instead of *% land in higher value crops*) had already entered the model in a stepwise fashion, we did not re-enter the same variable or its closely related variant in the test of confounding variables.

The initial models, presented later in Tables 8 and 9, include 185 members of the 1998 landowning population (one household had incomplete land use data in 1998, therefore the household was omitted from the model).

4.1.1 Hypotheses concerning direction of influence of theoretical variables

Hypotheses related to the expected direction of influence of each variable on the outcome merit discussion before launching into the regression modeling. The outcome variable is whether a household sold some/all of their 1998 farm plot (Y=1) vs. none (Y=0). The theoretical predictor variables from 1998 data are: *Age of household head*, *Total household count*, *Years on farm*, *Distance to road of primary plot (Km.)*, *Either green manure OR herbicide (0=no, 1=yes)*, *% land higher value crops*, and *Number of head cattle*. This is in addition to the large pool of candidate variables eligible for stepwise inclusion into the model, presented in Tables 3 through 7.

Age of household head (Table 5) comes from the household lifecycle hypothesis, serving as a covariate for household demographic structure. An older household head, for example, will most likely have more household members of a mature age and the original household head may subdivide the land to accommodate grown children (Pan, Carr et al. 2004). Alternatively, an older householder may sell all or part of his land because of an inability to work as large an area as he ages, the desire to retire, or from the need to pay medical bills as he and his partner encounter age related illnesses.

Total household count (Table 5) also derives from the household lifecycle hypothesis and is an unrefined means of examining household structure. A larger household in 1998 would be more likely to have children entering maturity before 2009, and the household head may have given land to his children. Pan, Carr et al. (2004) found that a household with a larger amount of either adult male household members or adult female household members in 1990 was more likely to have subdivided by the time of the second interview in 1999, supporting this hypothesis. From another point of view, a larger household may find that there is greater probability of a crisis popping up among them and land may be sold to cover the crisis. Alternatively, a larger household may help support the original household head as he ages, thus heading off the need to sell land when crisis strikes.

Years on farm (Table 5) is a proxy for the household lifecycle stage (Marquette 1998, McCracken, Siqueira et al. 1999), or more recently counts among the variables included in the farm lifecycle hypothesis (Barbieri, Bilsborrow et al. 2005, VanWey, D'Antona et al. 2007). The longer a household has been located on a farm, the more likely that the children are mature and ready for their own plots. Also, the household head who has spent more years on a farm will have cleared more land (Carr 2002), thus making the land more valuable to sell. Pan, Carr et al. (2004) found that farms with more years of habitation were significantly more likely to have subdivided between 1990 and 1999.

Distance to road of primary plot (Km.) (Table 7) is a geographical variable that may be influential in predicting the outcome variable. Pan, Carr et al. (2004), found that while road access to the parcel (yes vs. no) did not have a discernible impact on a farm's propensity for subdividing in the NEA, the parcel's distance to nearby urban centers did, with less frequent subdividing occurring farther from the urban center. In the study area, the main hurdle for a household taking their product to market would be transporting it to the main road, where they typically trade with middlemen in trucking. Because of their greater access to transportation routes and market, therefore, we would expect parcels closer to the road to be more valuable and thus more likely for the household head to have sold all or part of the farm. Alternatively, because of their greater ease of transporting products to market, perhaps the original owners in 1998 would be loath to sell the plot and instead expand production for market-oriented crops.

Either green manure OR herbicide (0=no, 1=yes) (Table 4) refers to intensification techniques, one land saving the other labor saving, and thus of interest relevant to the multiphasic theory. Intensification of land use is considered one of the four responses within the multiphasic theory that may take place when land shortages occur because of rising population density (Bilsborrow and Okoth-Ogendo 1992). Given the reasoning that households would have to meet their needs on less land if they sell all or some of it, one might expect the land sale or division to precede the intensification. However, employing this variable from 1998 will examine if households who were already taking measures to intensify in 1998 did so in preparation for making do with less land. Alternatively, perhaps the greater affluence suggested by their ability to intensify in 1998 may indicate they would be less likely to need to sell their land later. Perz (2003) found that herbicide use was more prevalent among households with a higher level of wealth upon arrival to the Amazonian frontier, underscoring the importance of capital investment. Green manure (*Mucuna pruriens*) requires a large labor investment, possibly necessitating hired labor if household labor is insufficient. Also, unless the seeds are provided by an organization promoting their use, the seeds are costly and can be difficult to come by (Shriar 2001). Therefore, the use of either herbicide or green manure may be indicative of relatively high household affluence. A household's willingness to establish a green manure plot, which is extremely labor intensive, may also signal their intention to stay in their current plot and not move on from this frontier area. We expect a household employing either or both techniques to be less likely to sell their land because of the affluence suggested by their use.

% land higher value crops (Table 4) is another variable relevant to intensification and thus potentially of importance with regard to the multiphasic theory. Similar to the previous variable, *Either green manure OR herbicide (0=no, 1=yes)*, the logical flow in the multiphasic model should be sale first, followed by intensification measure afterwards. However, perhaps instead the ability to intensify in the first place with a higher value crop in 1998 may suggest a relative affluence that would help a household hold onto their land over the years. Like above, it may suggest an investment and thus a plan to stay on the land over the long haul. Pan, Carr et al. (2004), however, found that a household with more land in perennials in the first time period was more likely to have bequeathed part of the land to their offspring than those with less land in perennials, apparently giving their children part of the land with some long-term improvements already in place.

Number of head cattle (Table 3) is a variable also relevant to the multiphasic theory, but on the side of extensification instead of intensification. A household that intends to profit from producing on the land itself instead of profiting from the sale of the land may choose to raise cattle since it is land extensive but with lower labor requirements (Loker 1993). Cattle may also serve as an insurance substitute in areas such as the frontier where those services are unavailable, as they can be sold at will in the face of an unforeseen household need, such as a medical crisis (Loker 1993, Tourrand, da Veiga et al. 1996, Perz 2003). Cattle require a considerable investment because in addition to clearing sufficient land for the low stocking density, they require infrastructure such as fencing and a watering hole. Therefore, we expect that cattle ownership in 1998 will more likely be indicative of a household that does not sell land by 2009, given its initial investment as well as the insurance function of cattle

4.1.2 Logistic regression model results

The basic model presented in Table 8 includes all landowning households from 1998 with complete data, 185 households. This model includes only the stepwise selected variables, selected from among the 51 candidate variables presented in Tables 3 through 7. Overall, according to the area under the ROC curve (ROC AUC = 0. 68), the model does a better job of predicting the membership in the outcome category than a coin-toss, but it does not reach the level of acceptable discrimination (ROC AUC = 0.7). The variables that entered the model and maintained their significance are *Number of head cattle, Off-farm work previous year (0=no, 1=yes),* and *% of land in higher value crops*.

Table 8: Logistic model predicting land sales, all landowning households from 1998

N = 185 ROC AUC = 0.68

Variable	B	S.E.	Sig.	Exp(B)
Number of head cattle	-0.12	0.06	0.03	0.88
Off-farm work previous year (0=no, 1=yes)	0.64	0.32	0.05*	1.89
% land in higher value crops	-0.12	0.05	0.01	0.89
Constant	0.15	0.21	0.46	1.16

* Significant at p<0.05 by change in -2* log-likelikhood

The variable *Number of head cattle* has a negative relationship with whether a household has sold land by 2009. This could relate to cattle serving as insurance or functioning as a bank account in an area where these services are not readily available (Loker 1993, Tourrand, da Veiga et al. 1996, Perz 2003). The frequency with which households sold their land to pay for a medical emergency or to finance other ventures supports this interpretation of the relationship between the variables. Households with cattle also have an alternative use for their land once depleted following many maize cycles and would not need to sell their land in order to push on and find more vital soils.

The second significant variable, *Off-farm work previous year (0=no, 1=yes),* is positively related to land sales since 1998. This suggests that household heads who had engaged in wage-labor in the year prior to the 1998 interview were more likely to have sold land since 1998 than a household head who had not engaged in wage-labor. This implies that the household may have not been making ends meet solely on the proceeds of their excess grain sales, and therefore had to seek off-farm labor for extra cash. Almost all households sell the majority of their maize. There is, however, a mild negative correlation between what percentage of household grain production goes to market and the propensity to sell land. This state of low-cash reserves may have required a land sale down the line to raise cash. Those who engaged in off-farm work did not tend to have smaller parcels, so it does not appear that households on the subsistence-land threshold were selling off. Alternatively, these households may have found that with off-farm labor they had less time to work their own land and therefore could sell off all or a portion of it. This is a less likely scenario, however, since most household heads who did engage in off-farm labor did so for only a few weeks on average, and for the equivalent of a few dollars per day, making off-farm labor generally not a dependable source of adequate income.

Finally, the third variable *% of land in higher value crops* relates negatively to a household selling land, meaning a household with a higher percentage of their land in higher value crops is less likely to have sold land. This could suggest that a greater household income from farm products could provide an economic buffer, providing them the cash reserves to deal with a household crisis. The Guttman scale variable *Assets* (not included in this model) is the intended proxy for measuring household economic wellbeing, given its expected association with forest clearing for crops and pasture (Almeida 1992, Murphy, Bilsborrow et al. 1997). However, the socioeconomic proxy supposedly represented by *Assets* may in fact turn out to be the function served by this land use measurement, *% of land in higher value crops,* which typically requires a higher cash outlay for seeds and inputs than the more ubiquitously farmed maize and which carries a higher risk (Shriar 2001). Diversifying into higher value crops may also signify an intention to remain in the area.

Table 9 shows the same model as Table 8, but with the inclusion of potentially confounding control variables. The area under the ROC curve for the new model is now within the range of acceptable discrimination (ROC AUC $\geq$ 0.7), though actually indistinguishable from the ROC AUC of the previous model given the lower and upper bounds of the confidence intervals (Table 10). Because *Number of head cattle* and *% land in higher value crops* already appeared as statistically significant variables in Table 8, we did not need to re-enter them as control variables. None of the newly entered control variables proved to be significant. The addition of the control variables did, however, render the marginally significant variable *Off-farm work previous year (0=no, 1=yes)* from the previous model even more marginal. These models do a relatively poor job in predicting which households will sell their land by the second time period. The households' self-reported motivations for selling their land are the most critical evidence presented thus far, but they do not follow any predictable distribution.

Table 9: Logistic model predicting land sales, all landowning households from 1998, with control variables

N = 185 ROC AUC = 0.7

Variable	B	S.E.	Sig.	Exp(B)
Number of head cattle	-0.12	0.06	0.03	0.88
Off-farm work previous year (0=no, 1=yes)	0.64	0.33	0.05	1.89
% land in higher value crops	-0.13	0.05	0.01	0.88
Age of household head	0.00	0.01	0.86	1.00
Total HH count	0.04	0.05	0.42	1.04
Years on farm	-0.02	0.03	0.49	0.98
Distance to road of primary plot (Km.)	-0.04	0.03	0.25	0.96
Either green manure OR herbicide (0=no, 1=yes)	-0.21	0.35	0.55	0.81
Constant	0.55	0.75	0.46	1.73

Table 10: ROC Area under the curve comparison between logistic model for all 1998 landowners with stepwise variables only and model with addition of control variables

Area Under the Curve

Test Result Variable(s)	Area	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Lower Bound	Asymptotic 95% Upper Bound
Step-wise variables	.681	.039	.000	.604	.758
Step-wise plus control variables	.695	.038	.000	.620	.770

The test result variable(s): Predicted probability has at least one tie between the positive actual state group and the negative actual state group. Statistics may be biased.
a. Under the nonparametric assumption
b. Null hypothesis: true area = 0.5

The household lifecycle variables *Age of household head* and *Total household count* are not significantly related to whether or not a household sells land, nor is the farm lifecycle variable *Years on farm*. A household head maturing beyond productive years, or offspring maturing into productive years, does not appear to be a dominant factor in determining land transactions for all landowners in 1998. The environmental variable *Distance to road of primary plot (Km.)* does not relate significantly to land sales, meaning parcels near or far from the road in 1998 had no significant difference in the probability of their sale by 2009. Finally, the other multiphasic variable related to intensification, the use of *Either green manure OR herbicide (0=no, 1=yes)* in 1998, proved to not relate significantly to land sales. This means that a household who used either the labor intensive or capital intensive method of intensification (green manure and herbicide, respectively) in 1998 had no bearing on the probability of them selling their land by 2009.

5. CONCLUSIONS

This article sought to characterize land turnover in the frontier, examining under what circumstances landowners from an earlier interview date in 1998 divested themselves of all or part of their land by the time of the second interview in 2009. This provides an opportunity for understanding how the frontier changes over time, vis-à-vis land turnover. The hollow frontier theory, for example, expects a repeating cycle of wealthy landowners consolidating the land cleared by peasant smallholders upon in-migration (Rudel, Bates et al. 2002, Browder, Pedlowski et al. 2008). Theories such as these can be more thoroughly examined by understanding how land changes hands and how the cast of characters changes over time in the dynamic frontier (Pan, Carr et al. 2004).

The models created for predicting the land sales for households originally interviewed in 1998 focused primarily on independent variables chosen to represent theories often applied to land use in the agricultural frontier, the multiphasic model, household lifecycle model, and the farm or property lifecycle model. In these models, none of the household lifecycle variables nor the farm or property lifecycle variable showed an apparent relationship to a household's propensity towards selling their land by 2009, such as *Total household count* and *Years on farm* (alternatively counted as a property lifecycle variable) or *Age of household head*. The geographical variable *Distance to road of primary plot (Km.)* likewise was not significant when examining land sales. Overall, multiphasic variables related to intensification (*% land higher value crops* in 1998) and extensification (*Number of head cattle* in 1998) did have some success in predicting whether or not a household sold land by 2009, but the direction of influence was negative in both cases despite expectations and despite their dramatically different land vs. labor requirements. Their significance, therefore, did not seem to derive from the necessity to make due with more or less land as expected from the multiphasic framework. Rather, their significance appeared to relate more to what the variables represented in terms of the household's material wealth and its dedication of the same to farming and ranching. Household economy and individual agency, not including household provided labor, may trump the influences deemed important by the multiphasic model, household lifecycle model, or property lifecycle model in determining land turnover.

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