Land markets, migration, and forest conservation on an Amazonian frontier in San Martin, Peru

Timothy G. Holland

Supervisor: Oliver T. Coomes

Department of Geography
McGill University
Montreal, Canada

August 2016

A dissertation submitted to McGill University in partial fulfillment of the requirements of the degree Doctor of Philosophy

Table of Contents

List of Figures

List of Tables

Acknowledgements

I owe a deep gratitude to the many individuals in San Martin who opened their homes to me and took the time to tell me about their family histories, their land, and their perspectives. In all of the communities I visited, I found great hospitality and met warm people who were willing to give me their time, to share meals with me, and to help me better understand their lives and their communities. I am very grateful to the many park guards of the Cordillera Azul National Park who supported me in the field, particularly Amado, Vanessa, and Augustin. Augustin and his entire family were the best hosts I could have asked for.

Funding for this research was generously provided by the Social Sciences and Humanities Research Council of Canada (SSHRC), the Theo Hills Fund, the Trottier Foundation, Roger Warren and the Rathlyn Foundation, and the McGill University Department of Geography. CIMA–the *Centro de Conservación, Investigación y Manejo de Areas Naturales*–provided logistical support in San Martin.

Many staff members of CIMA, Conservation International, SERNANP, MINAM, and ProCeja supported me throughout my research. It was a discussion with Augusto Castro and Laura Secada at MINAM that led me to research in San Martin in the first place. Later conversations I had with Cinthia Mongylardi, Lucia Ruiz, and Daniel Ordoñez at CIMA were essential to the early framing of this research; the current shape of this dissertation has resulted in no small part from their input. Throughout my fieldwork, Cinthia and Daniel connected me with community and district authorities and supported me with logistics in the field. Braulio Andrade at Conservation International spent time with me on many occasions; his openness and patience with my many questions were central to helping me understand the complex processes of change in the Alto Mayo.

Ronald Mori Pezo was my field assistant during all stages of fieldwork; however, that title does not fully capture his importance to this research and to my time in Peru in general. Ronald's openness and gregariousness were essential to building many of the relationships upon which this research depended. In the field, every day was made more enjoyable–and challenges were made less intimidating–as a result of Ronald's companionship, his sense of humour, and his willingness to share with me his deep knowledge of and love of nature. In Tarapoto, Ronald and his family welcomed me into their home and became a central part of my community in San Martin.

I would like to thank my supervisor, Oliver Coomes, for his support for this research from the earliest stages of its framing, through fieldwork, and into its (continuing) writing and analysis. I have lost count of the number of times during this research where a conversation with Oliver gave me new clarity on a point I had previously struggled with or identified a new perspective on my work that had not yet occurred to me. I am grateful for the freedom that Oliver offered me in the direction I took this research as well as for his encouragement at every stage along the way.

My committee members, Catherine Potvin and Jon Unruh, greatly strengthened this dissertation. Catherine's thorough reading and critiques of my proposal and of this dissertation refined my analysis and helped me ensure my research remained relevant to forest conservation policy. Jon helped me refine my conception of land tenure and assisted me in developing research tools that adequately reflected the nuance of land tenure in a frontier environment. My research also benefited greatly through discussion with faculty in the McGill Geography Department, particularly Sebastien Breau, Jeanine Rhemtulla, Brian Robinson, Lea Berrang-Ford, and Sarah Turner.

All stages of this work were made more fruitful and more fun by the company of other members of the Coomes and Rhemtulla labs. Thank you to Sarah Wilson, Sylvia Wood, Chessi Miltner, Meghan Doiron, Geneva List, and Lauren Wustenberg for hashing out ideas with me, for sharing stories and advice for fieldwork in the Amazon, and for good humour along the way. Thank you to Camille Ouellet-Dallaire and Nick Hussey for always being willing to discuss life and grad school over lunch or a beer. Jill Gregory, thank you for always being one step ahead of me and showing me the way; your friendship–from either side of the continent–has always been a huge support.

I would like to thank my family, especially my parents, Dianne and George Holland, and my brother, Byron Holland. Your backing and encouragement have been constant and unwavering through every endeavour I have undertaken, even when sometimes my career took a roundabout path. Mom and Dad, thank you for fostering a love of nature in me at a young age: in many ways, it has led me to the work I am doing now. Lastly, I owe my deepest gratitude to my wife and best friend, Bailey Seybolt. Bailey, whether we were together in Peru, together in Montreal, or with that distance between us, your love and support were my lifeline on the tough days and my joy on the good ones.

Abstract

The Region of San Martin, Peru, has a rate of deforestation that is among the highest in the Amazon basin. The forest being lost in that area, on the eastern slope of the Andes mountain range, is rich in biodiversity, making this area of particular concern for forest conservation. As with frontier areas generally, the dynamics of change in San Martin–demographic, economic, and land cover–are complex and fast moving. In this dissertation, I draw on information from 194 interviews with smallholder farmers in three districts of San Martin in order to illustrate and analyze how these frontier areas have changed through time and what those changes mean for smallholder livelihoods and for the potential effectiveness of forest conservation activities.

I find patterns of change in all three frontier districts that are generally consistent with each other, despite the fact that the districts themselves were settled decades apart (initial settlement times mid-1970s, mid-1990s, late-1990s/early-2000s, respectively). In all cases, the great majority of household heads in these communities are migrants from the Peruvian *sierra* or else are the children of migrants. For migrants arriving to these areas, there is a strong first-mover advantage; although arriving early to the frontier entails hardships in terms of the absence of services and difficult travel, those individuals who arrived earliest acquired the largest land parcels and were best positioned to take advantage of land price increases as the frontier developed. An analysis of land markets in these districts demonstrated several consistent patterns: the land parcels being sold over time tended to become smaller, less forested, and more expensive per hectare. The overall result of these changes was that the opportunity cost to landholders of sparing any remaining forest increased rapidly through time as households paid higher prices for increasingly small parcels. Average parcel sizes declined through time in all three districts, suggesting that a process of land consolidation–as observed in the hollow frontier pattern–is not happening in these coffee-producing landscapes. The lack

of land consolidation by larger landowners in these landscapes may be a result of the nature of coffee itself as a crop: it is generally labour-intensive and may have more limited returns to scale than activities such as cattle-grazing and soy cultivation. In the last results chapter of this dissertation, I document the impact of a coffee rust outbreak that took place between seasons of fieldwork. The response to the outbreak illustrates the importance of legacies of variety choice. Additionally, by creating a severe drop in the diversity of coffee varieties being planted, it demonstrates a potential risk to the ability of the local agricultural system to adapt to future changes.

I conclude the dissertation with suggestions for how these results may be useful to forest conservation policy. I highlight the degree to which patterns of land cover change on frontier areas are in fact structured by processes far away in migrant areas of origin; informational campaigns may be useful in reducing the most problematic forms of land speculation. I also raise questions about the effectiveness of payments-based forest conservation programs in frontier areas where payment levels are unlikely to be able to keep up with rapidly increasing land prices. Appealing to community institutions and social pressure may in fact prove more effective than payments-based structures in this context. Lastly, given the rapid nature of change in these frontier areas–as in many others–I emphasize the importance in forest conservation planning of making as much effort as possible to anticipate patterns of future change and to plan for them in the design of any policy or program.

Résumé

La région de San Martin, Pérou, a un taux de déforestation qui est parmi les plus élevés dans le bassin amazonien. La déforestation de cette région, particulièrement sur le versant oriental de la cordillère des Andes, touche des forêts riches en biodiversité, ce qui rend cette région particulièrement importante pour la conservation. Comme avec la plupart des zones frontalières, les dynamiques de changements–démographiques, économiques, et de l'utilisation des sols–à San Martin sont complexes et rapides. Dans cette thèse, j'utilise l'information recueillie lors de 194 entretiens avec des agriculteurs avec petits terrains dans trois districts de San Martin afin d'illustrer et d'analyser la façon dont ces zones frontalières ont changé au fil du temps et ce que ces changements signifient pour les moyens de subsistance des agriculteurs et pour l'efficacité potentielle des efforts de conservation des forêts.

Je trouve des modèles de changement dans les trois districts frontaliers qui sont généralement compatibles les uns avec les autres, malgré le fait que les districts eux-mêmes aient été colonisés pendant différentes décennies (les dates de colonisation initiales dans les trois districts étant milieu des années 1970, milieu des années 1990, fin des années 1990 / début des années 2000, respectivement). Dans tous les districts, la grande majorité des chefs de ménage dans ces communautés sont des migrants de la *sierra* péruvienne, ou bien sont des enfants de migrants. Pour les migrants qui arrivent dans ces zones, il y a un fort avantage à arriver avant les autres. Malgré le fait qu'arriver tôt à la frontière entraîne des difficultés pour ce qui est de l'absence de services et des difficultés de transport, les personnes qui sont arrivés le plus tôt ont acquis de plus grandes parcelles et ont été les mieux placées pour profiter de la hausse des prix des terres quand la frontière s'est développée. Une analyse des marchés des terres dans ces districts a montré plusieurs modèles cohérents: les parcelles vendues au fil du temps tendent à devenir plus petite, moins boisée, et plus cher à l'hectare. Le résultat global de ces changements est que le coût d'opportunité pour les propriétaires de ne pas déboiser a augmenté rapidement car les propriétaires doivent payer des prix de plus en plus élevés pour

des parcelles plus petites. Les tailles moyennes des parcelles de terrain ont diminué au fil du temps dans les trois districts, ce qui suggère que le processus de consolidation des terres, comme observé dans la modèle du « Hollow Frontier », ne se produit pas dans ces paysages de producteurs de café. L'absence de consolidation des terres par les grands propriétaires terriens dans ces paysages peut être le résultat de la nature du café en tant que produit agricole: il nécessite beaucoup de main-d'œuvre et peut avoir des rendements plus limités à grandes échelles contrairement aux pâturages et à la culture du soja. Dans le dernier chapitre des résultats de cette thèse, je documente l'impact d'une épidémie de rouille du café qui a eu lieu entre les saisons de terrain. La réponse à l'épidémie illustre l'importance des héritages du choix de la variété de café. En outre, la diminution de la diversité des variétés de café utilisées pose un risque potentiel pour la capacité du système agricole local à s'adapter aux futurs changements.

Je conclus la dissertation avec des suggestions sur comment ces résultats peuvent être utiles aux politiques de conservation des forêts. Je souligne à quel point les modèles de changement de l'utilisation des sols sur les zones frontalières sont en fait structurés par des processus découlant des zones d'origine des migrants; des campagnes d'information peuvent être utiles pour réduire les formes les plus problématiques de la spéculation foncière. Je soulève aussi des questions sur l'efficacité des programmes de conservation basés sur des paiements pour des services écosystémiques dans les zones frontalières où les niveaux de paiements sont peu susceptibles d'être en mesure de faire compétition à l'augmentation rapide des prix fonciers. Faire appel aux institutions communautaires et la pression sociale peut en effet se révéler des mesures plus efficace que les structures à base de paiement. Enfin, étant donné la nature rapide du changement dans ces frontières, comme dans bien d'autres, je souligne l'importance d'anticiper les modèles de changement futur pendant la planification de la conservation et de les inclure dans la conception de toutes politiques ou programmes qui a comme objectif la conservation des forêts.

Preface

This dissertation is a work of original and independent scholarship. I conceived of the project, developed research questions, decided on the research location, built relationships locally, conducted all interviews in the field, organized and cleaned all data, performed all statistical analysis, and wrote the text of this dissertation. I had a research assistant–Ronald Mori Pezo–who was present with me during nearly every interview. Although I conducted the interviews in Spanish, Ronald occasionally assisted me by re-explaining vocabulary or expressions I had not understood.

My supervisor, Oliver Coomes, provided guidance at every stage of this research. He pointed me to relevant bodies of literature, engaged in extensive discussions with me about research questions and field methods, suggested new avenues of analysis for my data, and gave me extensive advise on the framing of this dissertation and on the structure of individual chapters. My committee members, Catherine Potvin and Jon Unruh, engaged in extensive discussion with me during the design phase of this research and in some cases provided me examples of specific research tools. They both reviewed drafts of this dissertation and gave me extensive comments and critiques that have further strengthened it.

This dissertation is written as a collection of four independent manuscripts (Chapters 2-5) that are linked together by a common introduction and conclusion (Chapters 1 and 6, respectively) and by linking statements between each individual manuscript. As a result of this format, there is some repetition among chapters, particularly relating to the study area and to research methods. At the time of writing, Chapter 3 is under review as a co-authored publication at the journal *Land Use Policy*. I am the first author and I drafted the full text; however, Oliver Coomes was involved extensively in revising this article, and so in Chapter 3 I use the first-person plural pronoun. I otherwise use the first-person singular, except when I am referring to field work undertaken by me and Ronald Mori Pezo together.

Foreword

In 2013, I encountered two stories–both relating to land and to migration–that struck me with their similarities. The first is the story of a farmer who lived on a parcel of land several hundred kilometres from the community where he had been born. Because he had not been able to afford to buy a titled piece of land in his home community, he had moved to a remote frontier area where he could claim a parcel of land through his own labour. He endured many hardships in the first years of opening this land. Because the area was so remote, he had to carry in supplies on his back or on a pack animal and the walk from the nearest road took two days. If he had an accident, the nearest place that a nurse or a doctor might visit was that same two-day walk away. The farmer also had few neighbours–for the first two years there were only four other households living within a two-hour walk of his house. Despite all of these hardships, the farmer persevered, clearing forest to make space for crops he would later establish and harvest. Although at first he lived with a foot in two different places–spending three or four months in his home community in between month-long periods of work on his new land–after the first five years he moved permanently to his new farm. Ten years after he established permanently on his land, the farmer had seen enough new people arrive to the area that his remote section of valley had become a community with stores, a pharmacy, a dirt road, and a school.

The second story is about two brothers. In their mid twenties, the brothers crossed an international border to lay claim to two adjacent parcels of granted land. They did not have to pay for the parcels, but similarly to the farmer in the first story they gained a legal right to them by investing their own labour into the land. The brothers worked together and broke new land–first with hand tools, later with draft animals–until after four years of work they had cleared about twenty hectares for each of them. Throughout that period, they had to travel by foot or by horse 30 kilometres to the nearest store and 50 kilometres–one or two days' travel–if they needed anything beyond basic staples. The nearest medical help would have been similarly far. As in the story above, the brothers for several years split their lives between two locations: the farm where they were born and their new land. They would work their new parcels for most of the year but would return to their families and to the town of their birth when the growing season ended. It was not until four or five years had passed that the brothers, at that point both recently married, settled permanently in their new home.

Despite similarities between these stories, they happened a century apart. The first story is that of Don Miguel[1], one of the first settlers to arrive in the upper valley of Alto Biavo district in San Martin, Peru. Originally from a populous rural area in the Peruvian Andes, Don Miguel moved to Alto Biavo in the upper Amazon because of the opportunity to own a large tract of fertile land–an opportunity that would not have been available to him in the Andes. Don Miguel claimed his land in 1998 and settled permanently in the district in 2003; ten years later, he told me the story of his arrival and of the changes he had seen in the district as we sat in front of his house with cattle grazing on his land behind us. The second story–of the two brothers–took place almost one hundred years earlier in Saskatchewan, Canada. The brothers were Emal Anderson and Andy Anderson; Emal was my great-grandfather. They were each granted a quarter section of land as homesteaders near Dubuc, Saskatchewan in 1904 (I had not heard the details of Emal's and Andy's first years in Canada until 2013 when my mother showed me a community history that Dubuc residents had compiled). Originally from a Swedish community in Minnesota, Emal and Andy had looked north to Saskatchewan for what the land there offered them: certainly hard work and isolation, but also the hope of future prosperity for themselves and for their children. That mixed promise of both hardship and opportunity was

[1] Name changed

one that Don Miguel surely knew well as he considered moving to the Amazon from his home in the Andes.

Frontier farmers, whether my great-grandfather in Saskatchewan in 1904 or a coffee farmer in San Martin in 2016, take a great risk when they establish themselves and their families in new and unknown territories. They move in the sure knowledge that their new lives will include hardship and uncertainty; however, they do so hopeful that their efforts will eventually lead them to a better future. In this dissertation, I try to provide insight into the realities of frontier farmers and into processes of change in the landscapes and in the communities where they live. My hope is that this research will improve understanding of frontiers–particularly the ways that people acquire and use their land–that will in turn help policies and programs in these areas work more effectively for the well-being of frontier farmers and for the sustainability of frontier landscapes.

Chapter 1. Introduction

1.1. Statement of problem and research objectives

Frontiers–places where human settlement and agriculture are actively expanding into areas of previously limited human disturbance–are dynamic environments where rapid demographic change and rapid land cover change proceed in tandem (Carr 2009; Caviglia-Harris et al. 2012; Ichikawa et al. 2014). Globally, the highest rates of forest loss are often found along frontiers (Naughton-Treves 2004; Rindfuss et al. 2007, St-Laurent et al., 2013), making these areas centrally important to forest conservation programs and policies. Despite their importance for conservation, frontiers pose particular difficulties for conservation efforts. Organizational capacity–whether of government or of civil-society–is generally relatively low in the early stages of frontier settlement and community structures tend to change often (Rindfuss et al. 2007); this makes land-use planning efforts difficult and creates opportunities for land speculation. Additionally, by their nature, frontiers are data-poor environments; this is partly because of the challenge of access: transportation infrastructure often lags well behind the earliest settlers, rendering large-scale studies difficult at the earliest stages of frontier development. Frontiers also have limited administrative infrastructure which results in little documentation. These information gaps in frontier areas make it difficult to plan activities that address forest loss (Schloegel 2012). In this dissertation, I will examine four sets of related questions that examine how frontiers change through time, what those changes mean for the economic incentives facing frontier landholders, and what the implications are of frontier dynamics for efforts to conserve forests.

1.2. Research questions

To achieve the research objectives described above, I focus on the following four sets of questions:

1) What patterns characterize migration to the upper Amazon in San Martin? Does a household's migration trajectory influence how much land household members acquire when they arrive to frontier communities? Does it affect how much forest they eventually clear? What factors influence households' future migration intentions?
2) How do households acquire land when they arrive in a frontier community? How do land markets evolve through time as a frontier develops? What can land market dynamics tell us about a household's incentive to clear forest?
3) How unequal is land distribution in these frontier communities? Is inequality changing or is it relatively static? Do we see evidence of land consolidation as the "hollow frontier" hypothesis would suggest? What do changes in land distribution tell us about the potential for community-scale forest conservation?
4) How do households respond to a sudden livelihood shock like the coffee rust epidemic of 2012-2013? Does the historical trajectory of development in different study areas affect that response? What implications does a large shock such as coffee rust have for long-term sustainability in a frontier district?

I address these questions through a study of thirteen communities in three districts in the Region of San Martin; the study areas are described at the end of this chapter after a review of relevant literature.

1.3. Literature review

In this dissertation, I draw on intersecting bodies of literature that I present below. The first relates to rural migration and how it interacts with and creates change in frontier areas (1.3.1). Next, I review the literature on land tenure security, land markets, and the relationship of both to the sustainability of land use practices (1.3.2). Expanding on questions of land markets and of land use sustainability, I introduce the broader discussion surrounding the economic incentives to deforestation (1.3.3). Lastly, I discuss forest conservation policies and programs (1.3.4); this is by nature an integrative body of scholarship that uses approaches from several disciplines in order to predict and evaluate the success of different approaches to conserving forests.

1.3.1. Migration and frontier dynamics

Tropical frontiers are dynamic landscapes shaped by population movement and rapidly changing institutional environments (Southgate 1990; Schmink and Wood 1992; Walker 2003; Carr 2004; Rindfuss et al. 2007; Fearnside 2008). Being at the edge of agricultural expansion, they are the sites of a large portion of tropical deforestation globally (Geist and Lambin, 2001; Naughton-Treves 2004; St-Laurent et al. 2013). The process of land cover change at frontiers is driven by both smallholders and larger investors, and in some cases through a synergistic relationship of the two (cf. Rudel and Horowitz 1993 and their concept of growth coalitions). Patterns of rural migration are closely linked with patterns of deforestation. Migration to frontier areas accelerates frontier advance and increases net deforestation rates (Carr et al. 2006; Carr 2009; Caviglia-Harris et al. 2012; Carr and Burgdorfer 2013), while migration from rural areas to urban ones can reduce pressure on forests (Parry et al. 2010; Parry et al. 2010). In some cases, migration to urban areas may reduce pressure on forests to the extent that it leads to a forest transition and forest recovery (Rudel et al. 2002).

In-migration is a defining feature of frontier areas as new arrivals seek to claim new plots of land from forested areas, to engage in resource extraction, to join labour markets, or to speculate on land (Rudel 1995; Carr 2009; Pacheco 2012). The process of migration to forest frontiers and its associated forest loss is well-studied (Rudel and Horowitz 1993; Rindfuss et al. 2007; Tole 2004; Carr 2009). Some early work on the topic has suggested that overall population growth rates in tropical forest countries are the primary driver of deforestation (Ehrlich and Holdren 1971; Allen and Barnes 1985; Bilsborrow 1987). However, empirical work examining processes on a finer scale has demonstrated that population growth on its own explains less of tropical deforestation than do other factors (Lambin et al. 2001; Bax et al. 2016). Non-demographic factors play an important role in structuring the rate and pattern of forest loss, with landholders responding to economic opportunities that arise when the government decides to open part of the forest frontier through resource extraction or development projects and their associated infrastructure (Rudel and Horowitz 1993; Lambin et al. 2001; Lopez-Carr and Burgdorfer 2013; Arima 2016).

Several authors have identified a pattern termed the "hollow frontier" (Rudel et al. 2002; Hecht 2005; Schelhas and Sánchez-Azofeifa 2006). The hollow frontier describes a situation where smallholders are the first arrivals to the forest frontier; they make informal land claims and clear small areas for agricultural production, generally of subsistence crops (Rudel et al. 2002). As more land is cleared and productivity of cultivated land declines, the early-arrivals often cede or sell land to wealthier landowners who consolidate land parcels and often convert agricultural land to pasture. As this occurs, smallholders move further into forested areas, thus largely depopulating the area they leave behind (Hecht 2005; Schelhas and Sánchez-Azofeifa 2006; Carr and Burgdorfer 2013). This dynamic has at times been exploitative of the smallholders being displaced further into forested areas (Schmink and Wood 1992). In this vein, the literature has highlighted the importance of land tenure to deforestation patterns, as insecurity of tenure is often one of the reasons early-arriving smallholders are unable to hold onto their land as larger landowners arrived (Schmink and Wood 1992; Hecht 2005). Thus, lack of tenure security can accelerate a process–often initiated by declines in productivity–of smallholders moving further into forested areas and advancing the forest frontier.

The motivations causing people to migrate to the frontier cannot be entirely explained by processes at the frontier itself. The process of in-migration to the frontier is necessarily linked to a process of out-migration somewhere else (Carr 2004). Migration will be driven by a combination of pull factors, those factors that attract migrants to the frontier, and push factors, those that encourage them to leave their places of origin (Fearnside 2008; Carr 2009; Gray 2009). The characteristics of the frontier itself therefore provides only part of the explanation for patterns of land cover change; economic dynamics and availability of resources in places of origin also play an important role in determining patterns of migration and therefore of frontier land cover change (Carr 2009). Few studies have explicitly looked at place of origin of migrants as a predictor variable for land cover outcomes. Kaimowitz and Angelsen (Kaimowitz and Angelsen 1998) provide a thorough (if now dated) overview of household-level empirical models of land use; none of those models included variables related to household origin. More recent scholarship has often included overall migration rate as a predictor variable in regional and larger-scale models of land use and deforestation (Lopez-Carr and Burgdorfer 2013); however, the role played by differences among migrants based on their places of origin has been understudied. Several studies suggest that migrants have a distinctly different impact on local resources than longer-term residents (Sierra 1999; Cassels et al. 2005). These disparities are mediated by several factors, including relative differences in resources available to migrants and non-migrants, knowledge of and ability to integrate into local institutions, and differences in land tenure security. Actors from different places of origin may also have different motivations for moving to the frontier in the first place (Carrero and

Fearnside 2011). Fearnside (Fearnside 2008) provides one example where individuals engaged in land speculation (whom he describes as "landgrabbers") tended to come from one particular part of Brazil where people tended to be wealthier. Other work has demonstrated that migrants to a new area may retain land management practices particular to their areas of origin (Parry et al. 2010; Redo 2011).

1.3.2. Tenure security and land markets

One of the ways in which newer migrants to an area may face a different set of incentives than longer-term residents is that they often have less secure land tenure. This can result in migrants clearing more land because their relative tenure insecurity compared to long-term residents leads them to feel the need to physically demonstrate the legitimacy of their claim (Mulley and Unruh 2004; Unruh et al. 2005; Brown et al. 2016). There is a well-established literature on the impact of land tenure security on land use decisions (Barbier and Burgess 2001; Southgate 1990; Alston et al. 1999) which has suggested that insecurity of tenure is often associated with greater rates of forest clearing and lower investment in sustainable management of the land parcel. The link between tenure insecurity and deforestation has often resulted from two factors. First is the tendency for forest clearing to be used as part of an argument for a claim to land (Rudel 1995; Unruh 2003; Mulley and Unruh 2004; Unruh et al. 2005; Brown et al. 2016). Second, households tend to be less likely to make longer-term investments in land when they feel more tenure insecure, which in many cases means investments that are less environmentally sustainable. In some cases this may mean choosing to clear land for the more rapid investment return of annual crops rather than waiting for returns from activities that may require less forest clearance such as agroforestry or selective timber harvesting (Barbier and Burgess 2001).

Programs to register and formalize tenure in frontier areas have existed for many decades. They have often been justified from an economic standpoint by assertions that legal title to land would lead to more productive land uses by activating land and rental markets, would stimulate more investment in land with greater tenure security, would allow title-holders access to credit (Ballantyne et al. 2000; de Soto 2000). Land reforms have also been used for political purposes, and have often formed part of government strategies to assert territorial control over largely remote forest areas (Vandergeest and Peluso 1995; Zimmerer 2011; Brottem and Unruh 2009). In recent years, forest conservation policy has been an increasingly important motivator of tenure formalization efforts in forests as a result of the relationship described above between tenure security and improved sustainability (Pacheco et al. 2012). It is important to note, however, that the relationship between tenure security and sustainability does not necessarily have to involve formal tenure. In many frontier areas, informal–or customary–tenure tends to dominate while holding statutory land title is relatively rare. Empirical work has shown that a landholder's willingness to invest in improved use of his/her land is not related to formal land title specifically, but rather tenure security more generally (Lemel 1988; Wiebe and Meinzen-Dick 1998). In this context, the most important fact determining behaviour is likely not an abstract measure of tenure security, but rather a landholder’s subjective perception of his/her security (Unruh et al. 2005). For this reason, tenure formalization efforts, when they are undertaken in areas where informal tenure is already relatively secure, may have limited effect. There is an additional risk of tenure reform programs in that they may serve to undermine local livelihoods through the imposition of additional costs on households or through restricting access to economically important land and resources; the cost of land titling on households has been documented in several locations (Schmink and Wood 1992; Gould 2006; Pritchard 2013).

In Peru, the land tenure regime has undergone immense changes in the past 50 years. Before 1964, Peru operated under a highly unequal latifundio system. Two agricultural reform laws in 1964 and 1969 began a process of land redistribution such that by 1977, 75% of the land was under collective ownership (Alvarado 1995). Through the 1980s, many of these agricultural co-operatives went bankrupt, resulting in pressure from farmers to allow forms of private title to be held over the collective land (Ballantyne et al. 2000; Fort 2008). In 1991, the government passed laws that promoted land titling in rural areas and loosened restrictions on land markets (Fort 2008). From an equality perspective, these decades saw enormous change. In 1961, before the land reform, inequality in land ownership had a Gini index of 0.94, where 1 is perfect inequality. By 1994, that index had fallen to 0.51 (Zegarra 1999). In Peru, the majority of rural land ownership is under informal tenure. Although the number has surely risen in the two decades since, the estimate in 1990 was that only 10% of rural properties in Peru were covered by formal title (Zegarra 1999). In 2008, a national decree established COFOPRI (*Organismo de Formalización de la Propiedad Informal*), a government body with the specific mission of formalizing informal tenure (Llanos and Feather 2011). The activities of COFOPRI have accelerated the rate of land titling in Peru in both rural and urban areas (Fernández-Maldonado and Bredenoord 2010).

De Soto (2000) points out that many agrarian reforms have given poor farmers title to tracts of land; however, in many cases the property regime in which these titles were embedded did not provide the structures required for those titles to be effectively used as a means of generating capital through access to credit and further investment. In some cases, insufficient legal mechanisms available to the poor have allowed a situation where the elites have been able to dispossess poor and indigenous groups of land, thus worsening the situation relative to before titles were granted (de Soto 2000, p. 167). When tenure arrangements imposed through legal instruments are in disaccord with the intentions of small holders regarding how they wish to use and exchange their land, it often results in the continuation of land markets outside the legal structure (de Soto 2000; Pacheco et al. 2012).

The ability to sell and rent land is one of the economic justifications for promoting tenure formalization (Feder and Nishio 1999; Ballantyne et al. 2000; Fort 2008). There is evidence to support the assertion that formalization of land rights can increase activity in land markets (Assies 2008; Deininger and Feder 2009); however, this is not a universal relationship. In some cases land markets may remain relatively inactive even when formal title is provided (e.g., Larson et al. 2003); conversely, informal land markets in the absence of tenure exist in many locations (Pacheco 2012; Gould et al. 2006).

The behaviour of land markets and land prices are crucial factors in determining the dynamics of land conversion in frontier areas, and by extension the success of forest conservation programs. Conversely, conservation programs themselves may influence land prices. Several studies have used hedonic models to describe the factors determining land prices in frontier areas, which in turn determine incentives for speculation. Many commonalities emerge from these models. Work in the Brazilian Amazon has shown that a greater percentage of cleared forest leads to higher land values (Merry et al. 2008; Sills and Caviglia-Harris 2008). Across all models, likely the most consistent factor for determining land value is the distance from market and the presence of infrastructure for travel, which is consistent with the predictions of the von Thünen model of land use (Thünen 1966). Tenure status has a less consistent effect on land prices; some work has shown that tenure status exerted a strong influence on land value (Gould et al. 2006) while another study–using a stricter definition of formal tenure–showed that it made little difference (Merry et al. 2008). The importance of title to land prices tends to decrease with the distance from market; in some cases there exists a certain distance beyond which tenure effectively has no value (Angelsen 1995; Alston et al. 1999). This effect of distance to market on the relationship between tenure and land value may be part of the reason why one study described above saw an effect of tenure status on land value while the other did not.

As land markets become more active, land speculation becomes more prevalent. This is particularly true in frontier areas, where a correct prediction regarding where a new road will arrive can provide handsome returns on selling a plot of land (Schmink and Wood 1992; Rudel and Horowitz 1993). With respect to tenure and land value, it seems that any positive relationship that tenure security has on land price decreases as the lot gets more distant from market (Alston et al. 1999; Sunderlin et al. 2005). As a result, in the more remote parts of the frontier, efforts to regularize tenure may have little impact on land prices or the extent of land speculation. However, closer to markets and population centres, this relationship may become more important, and land titling initiatives may have very real effects on the land market.

The role of land speculation in Latin America seems to have increased in the last decade. In 1998, in reference to land markets on forest frontiers, Fearnside (1998) stated that the "critical role of speculation is basically unique to Brazil" (p. 285). Around the same time, Imbernon (1999) provided a comparison of four forest frontier areas in Peru and Brazil and found that the two areas in Brazil showed active land markets and accompanying land speculation, while both of the Peruvian areas showed few land transactions. Even areas closer to the coast in Peru, and with legal land titles, showed little activity in land markets in 1997-1999 (Larson et al. 2003). If in the late 1990s, Brazil was the exception in Latin America in terms of the important role that land speculation played there; this has changed since. Active land markets on the frontier are now a feature common in many Latin American countries; these have been documented in Guatemala (Gould et al. 2006), Peru (Erler et al. 2011; Castro et al. 2011), and Mexico (Farley et al. 2012).

1.3.3. Economic incentives to deforest

The economic incentives faced by landholders in frontier areas are central to understanding patterns of forest loss and to designing effective policies and programs to conserve forests. Higher rates of forest clearing are associated with higher commodity prices

(Barona et al. 2010; Verburg et al. 2014), greater labour availability (Shively and Fisher 2004), improved infrastructure and the associated lower costs of transportation (Verburg et al. 2004; Soler and Verburg 2010; Bax et al. 2016), and land prices that are low but increasing rapidly (Kaimowitz and Angelsen 1998; Roebeling and Hendrix 2010). The economic costs that forest conservation efforts impose upon colonist farmers–and, perhaps just as importantly, how farmers perceive those costs–have important implications for the level of local support that conservation programs will receive (Zanella et al. 2014).

The opportunity cost of avoiding deforestation–the foregone benefits that a landholder would have received had he/she cleared the forest–are a standard metric for evaluating the economic incentive to deforest (Engel, Pagiola, and Wunder 2008; Wünscher et al. 2008; Borrego and Skutsch 2014; Veronesi et al. 2015); they also provide a framework for conceptualizing the trade-off between development and forest conservation (Chomitz et al. 2005). High quality information on the opportunity cost of avoiding deforestation is essential to the design of efficient programs and policies to reduce deforestation (Pagiola and Bosquet 2009; Delacote et al. 2014). This is particularly the case in payments for ecosystem services schemes where a higher opportunity cost of standing forest increases the minimum payments that landholders would be willing to accept to conserve forests (Wunder 2005; Wunder 2007; Börner et al. 2010; Veronesi et al. 2015; Lin et al. 2014).

The majority of studies that estimate opportunity costs of avoiding deforestation look at annual economic returns to competing land uses (Chomitz et al. 2005; Naidoo and Adamowicz 2006; B. Fisher et al. 2011; Knoke et al. 2011; Borrego and Skutsch 2014). This is conceptually straightforward, and has be advantage of being able to be modeled across large landscapes or at national scales using agricultural census data (e.g., Naidoo and Ricketts 2006; B. Fisher et al. 2011). However, estimates based on agricultural productivity do not explicitly account for the economic incentives created by land markets; these incentives are particularly pronounced in frontier environments where they may be a deciding factor on whether or not an area is a profitable one to settle and claim land (Chomitz et al. 2005; Poffenberger 2009; Bowman et al. 2012). Land prices increase as frontiers advance, and this affects incentives for future land use and forest clearing (Sills and Caviglia-Harris 2008). Expectations of rising land price encourage land speculation, leading individuals to acquire larger areas of land and clear more forest than they would considering only the land's productive potential (Poffenberger 2009; Naidoo and Ricketts 2006). The rate of change in land prices has an important effect on the likelihood that individuals will engage with projects that require them to invest in their land for conservation–for example through agroforestry, reforestation, or long-term monitoring of forest stocks. If price increases are sufficiently rapid, landholders may have more of an incentive to speculate on land than they do to invest further in an existing plot; this may induce higher rates of lot turnover and of frontier advance (Gould et al. 2006).

Frontiers are difficult environments in which to estimate the opportunity cost of forest sparing. They are inherently dynamic environments where returns from agricultural production may change rapidly with changing levels of access to services and to markets (Caviglia-Harris et al. 2012; Celentano et al. 2012). Calculating frontier opportunity costs is further complicated by the role of land speculation on the frontier, which introduces an additional economic incentive for land acquisition and forest clearing that is not accounted for when opportunity costs are estimated based on returns to agriculture (Fearnside 2002; Kirby et al. 2006; Carrero and Fearnside 2011). One alternate approach to estimating opportunity costs of forest sparing is evaluating landholders' willingness to accept compensation which can be accomplished using choice experimentation (Carson et al. 1994; Hoyos 2010). Another approach may be to use hedonic models of land prices to estimate the expected increase in the sale price of a land parcel with additional forest clearing.

1.3.4. Forest conservation policies and programs

Global forest conservation has for decades been an international policy priority; in recent years as the contribution of forest loss to climate change has become clear, the focus on forests has increased still further (Buizer et al. 2014). Forest loss was responsible for between 12% and 20% of world greenhouse gas emissions in the 1990s and 2000s (van der Werf et al. 2009; Saatchi et al. 2011); additionally, the loss of tropical forests is one of the most important threats to biodiversity globally (Gibson et al. 2011). At local scales, tropical forests provide essential services for agricultural and resource-extractive communities, in particular by regulating water flows and by providing access to timber and non-timber forest products (Wunder 2001; Chhatre and Agrawal 2009).

In recent years, payments to governments and to landholders have been promoted as methods to use financial incentives to change land use decisions and reduce rates of forest clearing (Angelsen 2010; Pattanayak et al. 2010). Payments-based modes of forest conservation include Payments for Ecosystem Services schemes (PES) as well as Reducing Emissions from Deforestation and Degradation plus conservation, sustainable management of forests, and enhancement of carbon stocks (REDD+). REDD+ has been adopted through the United Nations Framework Convention on Climate Change (UNFCCC) as a strategy to reduce greenhouse gas emissions resulting from forest loss. Among climate change mitigation strategies, REDD+ has been promoted partly because of its perceived low cost per unit of emissions reduction (Stern 2007; Kindermann et al. 2008). International climate policy, of which REDD+ is one aspect, is based on the precept of "common but differentiated responsibility" for climate change. While all countries share the responsibility to address climate change, the nature of that responsibility differs depending on a country's circumstances and history (UNCED 1992).

REDD+ has an important relationship with land tenure. In the Brazilian Amazon, it is projected that 67 percent of future deforestation will take place either on unclassified state land, or on privately-held land where boundaries or title are unclear (Börner et al. 2010). Any attempt to conserve forests in a frontier environment with unclear tenure and continuing in-migration is likely to be difficult. However, frontier environments may be particularly problematic for REDD+ as a result of the question of carbon rights. Given the uncertainty surrounding land rights on the frontier, it is reasonable to assume that carbon rights and rights to the associated payments will be similarly unclear. PES schemes often use a payment per unit area model where each farmer who meets his/her targets is eligible to an amount of money per hectare (Hope et al. 2005; Wunder et al. 2005; Engel et al. 2008). At present there is no consensus on how rights to REDD+ payments should best be assigned. As mentioned earlier, many authors promote tenure clarification as central to equity in assigning REDD+ benefits (Cotula and Mayers 2009; Angelsen et al. 2009; Day and Naughton-Treves 2012). However, it is difficult to see how a strategy of land titling followed by REDD+ payment agreements would work with new migrants, who may begin clearing land as soon as they arrive. As discussed above, tenure insecurity is likely to make individuals less likely to invest heavily in their land. It seems the same argument could be made for carbon: if a new household does not trust that carbon payments will be delivered, then they are likely to proceed with what they know to be a safe livelihood activity. As with land, a household's perception of its tenure security often has less to do with the legal land rights it has been granted and more to do with the extent to which it feels the surrounding community respects its claim (Berry 1997; Unruh 2003; Unruh et al. 2005).

Conservation attitudes or "buy-in" have been shown to be central to eventual program success (Chen et al. 2009). One implication of a forest conservation scheme that is payments-based is that if the benefits from the programs cannot compete with the opportunity cost of lost investment opportunity, then it is unlikely landholders will be interested in participating (Grieg-Gran 2006; Potvin et al. 2007). The income that stakeholders forego as a result of forest conservation activities is therefore a central factor in determining the degree to which stakeholders are willing to support a conservation program (Swallow et al. 2005; Wunder 2006; Swallow et al. 2009). Considerations of opportunity costs for individual stakeholders are balanced in the negative by the monetary cost of violating conservation guidelines and in the positive by the financial benefit received from program activities, either through direct payments or other forms (Keane et al. 2008; Swallow et al. 2009). Predicting the success of programs based on PES and REDD+ therefore relies on accurate estimation of opportunity costs; as has been discussed above, however, reliable estimates of opportunity cost of avoiding deforestation are difficult to determine in frontier areas.

While an economic cost-benefit analysis is important to understanding the motivations of stakeholders, it is not the only factor that influences support for programs: social norms also play an important role in structuring individuals' choices regarding forest conservation. Examples of social groups working together to conserve a shared resource can be found throughout the common property literature (Agrawal 2001; Wollenberg et al. 2007). Even in frontier areas in the Amazon basin, social norms have been shown to prevent new arrivals from claiming and clearing land as fast as they might otherwise (Rudel 1995). Community forest management has often been one of the success stories of forest conservation (Pfaff et al. 2010; Sunderlin 2011). In Brazil, indigenous reserves were shown to be more effective at preventing deforestation by outsiders than were government-managed protected areas (Nepstad et al. 2006). It has also been said in Brazil that rural residents actively prevent more deforestation and illegal logging than do protected areas and their staff (Schwartzman 2000). Supporting similar conclusions, Hayes (2007) found that indigenous groups in protected areas in Nicaragua and Honduras were more effective at excluding new colonists from frontier areas than were state protected areas.

While there have been significant successes with community forest management, it may prove particularly challenging in a frontier environment. Theory of common property resource management suggests that not all groups are equally effective: common social norms and group homogeneity can be important for determining the success of resource management by a group (Ostrom 1999). Common identity and history are important factors in determining a group's likelihood of success in the conservation of a common resource (Varughese and Ostrom 2001). New arrivals on a forest frontier are less likely to share a common background than are members of longer-established communities; as a result, voluntary adherence to group management decisions on forest frontiers may not happen as easily. As such, frontier areas with a large proportion of relatively new migrants may show less capacity for community organization in support of common resource management.

A recent edited volume by Naughton-Treves and Day (2012) provides many useful case studies of developing REDD+ projects. Only two of those studies discussed recent migrants to the area and the impact they had on land cover change (Bradley 2012; Evans et al. 2012); in both of those, the discussion was entirely focused on how project communities were able to exclude migrants from the area. There was no discussion of engaging migrants in program activities in any way. This is not an unreasonable approach in a situation where there is an established community in the forest area, which can potentially protect the forest from invasions; in areas of high forest cover, the majority of deforestation is caused by individuals from outside (Börner et al. 2010). However, a model of empowering established communities to prevent incursion by outsiders poses difficulties in a frontier area where recent arrivals represent the majority of inhabitants. Forest conservation projects aiming to work directly through agreements with individuals–as has been the modality with some REDD+ projects (e.g., Conservation International 2011; Schloegel 2012; Vhugen and Miner 2012)–will likely have a greater challenge identifying and working with new migrants than with individuals who have lived in the area longer. As such, it may be that conservation programs in frontier areas are biased towards longer-term residents (cf. Schloegel 2012). A program that preferentially engages established communities and households would be of limited effect in a situation where the primary drivers of forest change are new arrivals.

1.4. Study area and methods

I completed the fieldwork for this dissertation in the Region of San Martin, Peru. San Martin is located in the *selva alta* of Peru–the high jungle–which is the transition zone between the Andean *sierra* and the lowland Amazon (Figure 1-1). The region as a whole varies from a minimum elevation of 200m near its border with the Region of Loreto to a maximum elevation of 4000m along its southwestern border with La Libertad. The flat, central valleys of the region were settled in the mid-nineteenth century; production in these areas tends to be large-scale mechanized agriculture, particularly rice and corn. At higher elevations in the region, coffee predominates. San Martin produces 22% of Peru's total coffee output, which ranks it second in the country after the Region of Junin (MINAGRI 2013). Coffee is particularly important in considerations of land cover change in San Martin; it is prevalent at higher elevations (800m to 2500m) in the region which tends to be where much of the region's recent deforestation is happening (INRENA 2008); the lower elevation valleys largely were cleared of forest decades previously. Coffee, along with cacao, was actively promoted in the region of San Martin by USAID and Peruvian government agencies (particularly DEVIDA, the *Comisión nacional para el desarollo y vida sin drogas*) as an alternative to the coca that had been a mainstay of the regional economy in the 1980s and 1990s (Kent 1993; Young 1996; Salisbury and Fagan 2011).

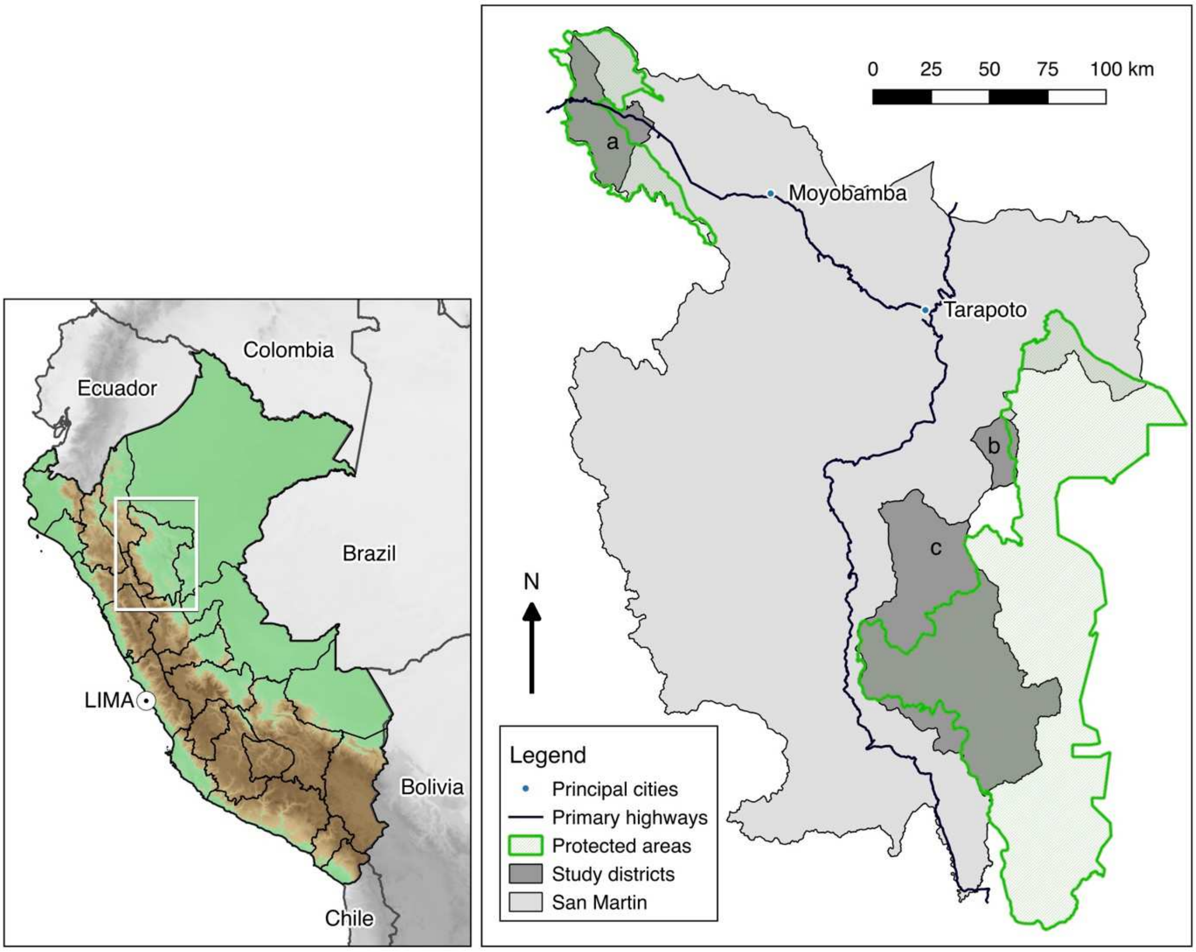

Figure 1-1: Map of study region.
(L) Location of San Martin within Peru. (R) Map of San Martin indicating three study districts: (a) Pardo Miguel, (b) Shamboyacu, (c) Alto Biavo. Indicated protected areas are Alto Mayo Protected Forest in the northwest and Cordillera Azul National Park in the east.

Migration from the Andes has long been an important component of demographic change in San Martin. For many years this was part of national-scale process: land reforms in the mid-1970s by the government of Peru led to a propaganda campaign encouraging people to move to the *selva* with promises of fertile land (Brack Egg 1997; cited in Schjellerup 2000). This was concurrent with large scale land reforms redistributing tenure from large latifundios to smaller producers (Ballantyne et al. 2000). In the late-1990s, Inge Schjellerup (2000) conducted a case study of a small village in western San Martín that was established by migrants from the *sierra.* She found that word of mouth and social networks played a major role in attracting new colonists and rapidly populating the village. These findings pointing to the importance of social networks in driving migration are consistent with migration work elsewhere in Latin America (Carr 2009). More recent work has confirmed that rates of migration from the *sierra* continue to be high in San Martin, particularly in areas of forest conservation concern (N. Shanee et al. 2015).

Peru as a whole has the fourth-highest volume of above-ground carbon of any country in the world (Saatchi et al. 2011) and land use change in Peru is projected to contribute 800 megatons of carbon to the atmosphere in the next decade (Asner et al. 2014). The eastern slope of the Andes where San Martin is located is consistently identified as a priority area for biodiversity conservation (Brooks et al. 2006; Swenson et al. 2012). From the late-1980s until the present, San Martin has had the highest rate of deforestation in Peru; the region has a higher rate of deforestation than almost all other administrative divisions in the Amazon basin with the exception recently of the states of Mato Grosso and Rondonia in Brazil (Perz, Aramburú, and Bremner 2005; Hansen et al. 2013; Piu and Menton 2014) (see Table 3-5). San Martin also has the highest total area deforested of any Peruvian region (Castro et al. 2011). A significant portion of this deforestation has been caused by in-migration of colonists from the *sierra,* a process which has been happening since the 1970s as a result of promotion by the national government (Brack Egg 1997; cited in Schjellerup 2000). This pattern continues in the present, with migration from Andean regions representing the majority of new arrivals on forest frontiers in San Marin (INRENA 2006; Erler et al. 2011; Ichikawa et al. 2014).

Imbernon (1999) described deforestation patterns in northern San Martín as being determined by limited market access but free access to abundant land for informal claiming. This resulted in a relatively dispersed deforestation pattern with high remaining potential for agricultural expansion but little market pressure. In the decade since the publication of that paper, two major highways have connected that part of the region to the south and west (GORESAM 2009). Improved market access has been a central reason for San Martin's rise nationally as a destination for migrants and for deforestation (Shanee et al. 2015). Land markets in Peru have traditionally been relatively inactive, even in situations where formal title existed (Larson et al. 2003). However, there is evidence that this has changed, at least in San Martin, with active land markets observed in both planned study areas (INRENA 2006; Conservation International 2011). The high rate of migration has increased the role of land markets and land speculation in the area (INRENA 2006); this stands in contrast to Imbernon's (1999) description of land speculation playing a very limited role in the region.

1.4.1. Conservation in San Martin

San Martin's identity as a deforestation hotspot has made it a priority area for the central governments for forest conservation (Castro et al. 2011). This focus has been further promoted during the regional presidency of César Villanueva Arévalo. Villanueva's left-leaning government was elected in 2007 and worked to brand San Martín as the "*Region Verde*" (green region). This orientation is particularly apparent with the region's REDD+ plans. Along with the region of Madre de Dios in the southeast of the country, San Martín is being used as a national piloting region for REDD+ activities (Erler et al. 2011; Castro et al. 2011). The regional government (*Gobierno Regional de San Martín* or 'GORESAM') supports a regional roundtable on REDD+ (*mesa REDD*) that includes all of the main NGOs working on conservation in the region. The government has also developed a regional assessment on drivers of deforestation, and has created a regional land-use zoning plan with a focus on maintaining carbon stocks (GORESAM 2009). Monitoring suggests that protected areas in the Peruvian Amazon are relatively effective, showing low rates of forest loss (Oliveira et al. 2007).

The REDD+ strategy of San Martin is to partner with NGOs in the region in order to pilot different strategies both for forest conservation and for carbon accounting. Two of the

NGO partners in this effort are Conservation International (CI) and the *Centro de Conservación, Investigación y Manejo de Áreas Naturales* (CIMA), each of which has relative autonomy to run forest conservation programs in the buffer zones of two national protected areas in San Martin. Protected area buffer zones cover more than 10% of the national territory of Peru and while they remain locations of significant population ingress, they have been shown to be effective at reducing rates of forest loss relative to matched control areas (Weisse and Naughton-Treves, 2016). The conservation projects in the two buffer zones where this study is situated vary greatly from each other. In the Alto Mayo Protected Forest (BPAM), Conservation International (CI), an American environmental NGO, is implementing a project with financing from Disney Corporation (Conservation International 2011). In this case, the investment is being driven by the outside investor–Disney–seeking to use the project as part of its corporate strategy to offset its emissions with forest carbon credits. In the PNCA, on the other hand, CIMA has a 20-year contract with the national government to manage the park, whether or not any payments are made for carbon offsets (INRENA 2006). CIMA program staff said to me in interviews that they viewed REDD+ as a promising potential funding source, but that it was not likely to greatly alter their conservation strategy.

The two programs differ further in their approach to forest conservation. CI in the BPAM is using a market-type approach that more closely mirrors the idea of payments for ecosystem services programs as the sale of a carbon offset credit from producer to buyer. In this case, they are using financing from Disney to sign conservation contracts with individual farmers in exchange for in-kind payments such as tools and trainings (INRENA 2008; Conservation International 2011). CIMA, by contrast, is not engaged in any direct payments to households but rather focuses on improved enforcement at the park border (more border posts with more rangers), extension activities to promote agro-forestry, micro-scale land use zoning, and education on the link between tree cover and water flows (INRENA 2006). Despite the large differences between the conservation projects themselves, the driving forces behind deforestation that both projects attempt to address are very similar. In both cases, migration of individuals from the *sierra* looking for better land drive much of the new land clearing.

1.4.2. Study communities and data collection

I conducted my fieldwork primarily in 2012 and 2013. The year before, in 2011, I made a one-month preliminary visit where I met with government officials in the Ministry of Environment in Lima as well as with representatives of government and NGOs in San Martin. In 2012 and 2013 I was in San Martin for three months and five months, respectively. I chose to work in three different districts of the Region of San Martin. These were the regions of Pardo Miguel (Rioja Province), Shamboyacu (Picota Province), and Alto Biavo (Bellavista Province). I based these choices on information I gathered during discussions with NGO staff and officials in San Martin. My goal in choosing research locations was first to select areas that were in the buffer zones of protected areas and were continuing targets for forest conservation activities, and second that the areas collectively represented frontiers at different stages of development. My study communities in Pardo Miguel were all located in the buffer zone of the Alto Mayo Protected Forest (BPAM) while those in Shamboyacu and Alto Biavo were all situated in the buffer zone of the Cordillera Azul National Park (PNCA). In all cases, they were inside the project areas of the two conservation projects described above (1.4.1); communities in Shamboyacu and Alto Biavo were in CIMA's project area while those in Pardo Miguel were in CI's project area.

I worked in 13 communities in total; three in Pardo Miguel, six in Shamboyacu, and four in Alto Biavo. All 13 were settler communities populated by individuals of *mestizo* origin (of combined European and Amerindian ancestry). In San Martin, there are many indigenous communities, particularly *Awajún* (sometimes called *Aguaruna*) ones. However, *Awajún* settlements in the region are generally more to the north and east than any of my study areas.

There is no competition between Indigenous land claims and settler ones in any one of my 13 study communities.

In the case of Pardo Miguel, there were only three communities in the district that fell within the marked buffer zone of the BPAM but that were not inside the protected area; I was informed by NGO staff and local residents that communities in the park itself were difficult to work with and possibly dangerous–the simple existence of the communities in a protected area was technically illegal, a fact that had led to violent confrontations with park staff, and so I restricted myself to the three communities in the buffer zone. In Alto Biavo, I worked in one valley that was remote from the rest of the district. While other parts of the district have been settled for much longer (since the mid twentieth century or earlier), the upper valley of the Biavo River is recently-settled and is disconnected from the rest of the district to the point that to travel by vehicle from the upper valley to the rest of Alto Biavo, one has to leave the district entirely (into the neighbouring district of Bajo Biavo) and re-enter it on a different access road. Within this upper part of the valley, there were only four communities, and I worked in all four. In Shamboyacu, there were more communities to select for fieldwork than I would have been able to effectively collect data in. In this part of PNCA, the protected area buffer zone is wide to the point of not being particularly meaningful (parts of the buffer zone include areas of industrialized agriculture that have been under active cultivation for at least several decades). Therefore, buffer zone was not useful as a tool for selecting communities. In the district itself, most new forest clearing is in the parts of the valley above the district capital (also called Shamboyacu). Above the town, there is one side of the valley that slopes upwards towards the national park that is the primary focus of conservation outreach efforts by CIMA. I restricted my sampling to the communities that were in this area: the valley above the district capital on the side of the National Park. This resulted in seven communities being selected; however, in one community officials declined to be involved in the research project, so I worked in six communities in Shamboyacu.

My data collection consisted primarily of semi-structured interviews with heads of households. Interviews were conducted in Spanish by myself and Ronald Mori Pezo, my field assistant who was present at every interview. Spanish was sufficient for this study because all household heads were either native Spanish speakers or were fluent second-language speakers. Interviews were based on a standard survey form (Appendix 1) that elicited information on household demographics, migration history, land acquisition, land holdings, land use, agricultural income, and interactions with forest conservation programs. I did encourage discussions to deviate during interviews to the degree that respondents were interested, particularly on topics relating to stories of migration, intentions for the future, community history, and perspectives on forest conservation efforts in the area.

In order to select households for participation in interviews, I first created a hand-drawn map of each community with all dwellings indicated. In most cases, I walked the entire community with a community authority (Municipal Agent, Lieutenant Governor, or President of the *Ronda Campesina*) in order to be sure that I did not miss any dwellings and to learn if any had been abandoned. I included dwellings that fell within a thirty-minute walk (two kilometres) of the community centre; I again relied on community authorities to indicate to me where all of the dwellings were. Once I had created a map, I numbered it sequentially from one side to the other. I then selected these dwelling numbers at a regular interval starting at a random point. By using sequential numbering from one end of the community to the other and then selecting using a regular interval, I ensured that the households selected would be geographically representative of the community. This was important because dwelling locations in a community are often spatially-structured, for example with wealthier people or longer-term residents living close to the centre, and extended family groups tending to live close together. It was my goal to sample either twenty percent of households in each community or else twenty households total in communities that were too large for twenty percent to be practical. I succeeded in this sampling goal in 11 of 13 communities, and fell slightly short in two; one community where I interviewed 17 households representing 14% of the community, and one where I interviewed 14 households representing 18% of the community (Table 3-4). In total, I interviewed 194 heads of household among the three communities.

1.5. Thesis structure

The following chapters draw on information collected in the field to address the research questions described above (1.2). Chapter 2 describes national-scale patterns of migration to the Peruvian Amazon and evaluates linkages in the study areas between migration trajectories and land use outcomes. In Chapter 3, I evaluate the process of land acquisition in frontier areas and analyze how land markets change through time as frontier areas develop. Chapter 4 examines the distribution of land holdings, evaluates changes through time in land distribution, and discusses implications of changing land distribution for forest conservation. Chapter 5 provides a case study of how farmers in two of the study districts responded to a shock–an outbreak of the fungal pathogen coffee rust–and how the impact of the shock and the response to it were both mediated by district settlement histories. Lastly, Chapter 6 concludes the dissertation with a summary of each of the results chapters and with a discussion of policy implications of the research and suggestions for further study.

1.6. References

Agrawal, A. 2001. Common property institutions and sustainable governance of resources. *World Development* 29(10): 1649–72.

Allen, J. C., and Barnes, D. F. 1985. The causes of deforestation in developing countries. *Annals of the Association of American Geographers* 75(2): 163–84.

Alston, L. J, Libecap, G. D. and Mueller, B. 1999. *Titles, Conflict, and Land Use: The Development of Property Rights and Land Reform on the Brazilian Amazon Frontier*. University of Michigan Press. Ann Arbor.

Alvarado, J. 1995. Los derechos de propiedad de la tierra: una aproximación desde la economía. *Debate Agrario* 23(December): 1–12. http://www.cepes.org.pe/debate/num-ante.htm.

Angelsen, A. 1995. Shifting cultivation and 'deforestation': a study from Indonesia. *World Development* 23(10): 1713–29.

Angelsen, A. 2010. "Policies for reduced deforestation and their impact on agricultural production. *Proceedings of the National Academy of Sciences* 107(46): 19639–44.

Angelsen, A., Brockhaus, M. Kanninen, M. Sills, E. O. Sunderlin, W. D. and Wertz-Kanounnikoff, S., eds. 2009. *Realising REDD+: National Strategy and Policy Options*. CIFOR. Bogor, Indonesia.

Arima, E Y. 2016. A spatial probit econometric model of land change: the case of infrastructure development in western Amazonia, Peru. Edited by Paulo De Marco Júnior. *PLoS ONE* 11(3): 1–22.

Asner, G. P., Knapp, D. E., Martin, R. E., Tupayachi, R., Anderson, C. B., Mascaro, J., Sinca, F., Chadwick, K. D., Higgins, M., Farfan, W., Llactayo, W., Silman, M. R. 2014. Targeted carbon conservation at national scales with high-resolution monitoring. *Proceedings of the National Academy of Sciences* 111(47): E5016– E5022.

Assies, W. 2008. Land tenure and tenure regimes in Mexico: an overview. *Journal of Agrarian Change* 8(1): 33–63.

Ballantyne, B., Bristow, M., Davison, B., Harrington, S., and Khan, K. 2000. How can land tenure and cadastral reform succeed? an inter-regional comparison of rural reforms. *Canadian Journal of Development Studies/Revue Canadienne D'études Du Développement* 21(3): 693–723.

Barbier, E. B., and Burgess, J. C. 2001. Tropical deforestation, tenure insecurity, and unsustainability. *Forest Science* 47(4): 497–509.

Barona, E., Ramankutty, N., Hyman, G., and Coomes, O. T. 2010. The role of pasture and soybean in deforestation of the Brazilian Amazon. *Environmental Research Letters* 5(2): 1-9.

Bax, V., Francesconi, W., Quintero, M., 2016. Spatial modeling of deforestation processes in the Central Peruvian Amazon 29, 79–88.

Berry, S. 1997. Tomatoes, land and hearsay: property and history in Asante in the time of structural adjustment. *World Development* 25(8): 1225–41.

Bilsborrow, R. E. 1987. Population pressures and agricultural development in developing countries: a conceptual framework and recent evidence. *World Development* 15(2): 183–203.

Borrego, A., and Skutsch, M. 2014. Estimating the opportunity costs of activities that cause degradation in tropical dry forest: implications for REDD+. *Ecological Economics* 101(C): 1–9.

Bowman, M. S., Soares-Filho, B. S., Merry, F. D., Nepstad, D. C., Rodrigues, H., and Almeida, O. T. 2012. Persistence of cattle ranching in the Brazilian amazon: a spatial analysis of the rationale for beef production. *Land Use Policy* 29(3): 558–68.

Börner, J., Wunder, S., Wertz-Kanounnikoff, S., Tito, M. R., Pereira, L., and Nascimento, N. 2010. Direct conservation payments in the Brazilian Amazon: scope and equity implications. *Ecological Economics* 69(6): 1272–82.

Brack Egg, A. 1997. Pobreza y manejo adecuado de los recursos en la Amazonia Peruana. *Revista Andina* 15: 15–40.

Bradley, A. 2012. Does community forestry provide a suitable platform for REDD?: a case study from Oddar Meanchey, Cambodia. In *Lessons About Land Tenure, Forest Governance and REDD+: Case Studies From Africa, Asia and Latin America*, edited by Naughton-Treves, L. and Day, C., 61–72. USAID.

Brooks, T. M., Mittermeier, R. A., da Fonseca, G. A. B., Gerlach, J., Hoffmann, M., Lamoreux, J. F., Mittermeier, C. G., Pilgrim, J. D., and Rodrigues, A. S. L. 2006. Global biodiversity conservation priorities. *Science* 313(5783): 58–61.

Brottem, L., and Unruh, J. D. 2009. Territorial tensions: rainforest conservation, postconflict recovery, and land tenure in Liberia. *Annals of the Association of American Geographers* 99(5): 995–1002.

Brown, D.S., Brown, J.C., Brown, C., 2016. Land occupations and deforestation in the Brazilian Amazon. Land Use Policy 54, 331–338.

Buizer, M., Humphreys, D., and de Jong, W. 2014. Climate change and deforestation: the evolution of an intersecting policy domain. *Environmental Science & Policy* 35: 1–11.

Carr, D. L. 2004. Proximate population factors and deforestation in tropical agricultural frontiers. *Population and Environment* 25(6): 585–612.

Carr, D. L. 2009. Population and deforestation: why rural migration matters. *Progress in Human Geography* 33(3): 355–78.

Carr, D. L, Suter, L., and Barbieri, A. F. 2006. Population dynamics and tropical deforestation: state of the debate and conceptual challenges. *Population and Environment* 27(1): 89–113.

Carrero, G. C., and Fearnside, P. M. 2011. Forest clearing dynamics and the expansion of landholdings in Apuí, a deforestation hotspot on Brazil's transamazon highway. *Ecology and Society* 16(2).

Carson, R. T., Louviere, J. J., Anderson, D. A., Arabie, P., Bunch, D. S., Hensher, D. A., Johnson, R. M. Kuhfeld, W. F., Steinberg, D., Swait, J., Timmermans, H., Wiley, J. B. 1994. Experimental analysis of choice. *Marketing Letters* 5(4): 351–67.

Cassels, S., Curran, S. R., and Kramer, R. 2005. Do migrants degrade coastal environments? Migration, natural resource extraction and poverty in north Sulawesi, Indonesia. *Human Ecology* 33(3): 329–63.

Castro, A., Gómez, E., Durand, E., Allende, M., Pedroni, L., and Hofstede, R. 2011. *Readiness Preparation Proposal (R-PP): Peru (Final English Translation)*. Ministry of Environment, Peru. Lima.

Caviglia-Harris, J. L, Sills, E. O., and Mullan, K. 2012. Migration and mobility on the Amazon frontier. *Population and Environment* 34(3): 338–69.

Celentano, D., Sills, E. O., Sales, M., and Veríssimo, A. 2012. Welfare outcomes and the advance of the deforestation frontier in the Brazilian Amazon. *World Development* 40(4): 850–64.

Chen, X., Lupi, F., He, G. and Liu, J. 2009. Linking social norms to efficient conservation investment in payments for ecosystem services. *Proceedings of the National Academy of Sciences* 106:11812–11817.

Chhatre, A., and Agrawal, A. 2009. Trade-offs and synergies between carbon storage and livelihood benefits from forest commons. *Proceedings of the National Academy of Sciences* 106(42): 17667–17670.

Chomitz, K. M., Alger, K., Thomas, T. S., Orlando, H. and Vila Nova, P. 2005. Opportunity costs of conservation in a biodiversity hotspot: the case of southern Bahia. *Environment and Development Economics* 10: 293–312.

Conservation International. 2011. Iniciativa De Conservation Del Bosque De Protection Alto Mayo. Conservation International. Lima.

Cotula, L., and Mayers, J. 2009. *Tenure in REDD: Start-Point or Afterthought?* International Institute for Environment and Development (IIED). London.

Day, C., and Naughton-Treves, L. 2012. Lessons from early efforts to secure land tenure within forest carbon management projects. In *Lessons About Land Tenure, Forest Governance and REDD+: Case Studies From Africa, Asia and Latin America*, edited by Lisa Naughton-Treves and Cathy Day, 1–10. USAID. Washington, D.C.

de Soto, H. 2000. *The Mystery of Capital: Why Capitalism Triumphs in the West and Fails Everywhere Else*. First edition. Basic Books. New York.

Deininger, K., and Feder, G. 2009. Land registration, governance, and development: evidence and implications for policy. *World Bank Research Observer* 24(2): 233–66.

Delacote, P., Palmer, C., Bakkegaard, R. K., and Thorsen, B. J. 2014. Unveiling information on opportunity costs in REDD: who obtains the surplus when policy objectives differ?. *Resource and Energy Economics* 36(2): 508–27.

Ehrlich, P. R, and Holdren, J. P. 1971. Impact of population growth. *Science* 171(3977): 1212–17.

Engel, S., Pagiola, S., and Wunder, S. 2008. Designing payments for environmental services in theory and practice: an overview of the issues. *Ecological Economics* 65(4): 663–74.

Erler, D., Frank, S., Hein, J.-I., Hotz, H., Santa Cruz Melgarejo, A.-M., and Zelli, F. 2011. Inclusión social en el proceso REDD en el peru: una perspectiva de gobernanza en múltiples niveles. nota técnica # 2. DIE: Deutsches Institut fur Entwicklungspolitik. Lima.

Evans, T., Arpels, M., and Clements, T. 2012. Pilot REDD activities in Cambodia are expected to improve access to forest resource use rights and land tenure for local communities. In *Lessons About Land Tenure, Forest Governance and REDD+: Case Studies From Africa, Asia and Latin America*, edited by Lisa Naughton-Treves and Cathy Day, 73–82. USAID.

Farley, K. A., Ojeda-Revah, L., Atkinson, E. E. and Eaton-González, B. R.. 2012. Changes in land use, land tenure, and landscape fragmentation in the Tijuana river watershed following reform of the ejido sector. *Land Use Policy* 29(1): 187–97.

Fearnside, P. M. 1998. Missing a moving target? Colonist technology development on the Amazon frontier; Michael Richards (Review). *Environmental Conservation* 25(3). Cambridge Univ Press: 279–89.

Fearnside, P. M. 2002. Can pasture intensification discourage deforestation in the Amazon and pantanal regions of Brazil. In *Deforestation and Land Use in the Amazon*, edited by Charles H Wood and Roberto Porro, 299–314. University Press of Florida. Gainseville.

Fearnside, P. M. 2008. The Roles and Movements of Actors in the Deforestation of Brazilian Amazonia. *Ecology and Society* 13(1).

Feder, G., and Akihiko N. 1999. The benefits of land registration and titling: economic and social perspectives. *Land Use Policy* 15(1): 25–43.

Fernández-Maldonado, A. M., and Bredenoord, J. 2010. Progressive housing approaches in the current Peruvian policies. *Habitat International* 34(3): 342–50.

Fisher, B, Lewis, S. L., Burgess, N. D. and Malimbwi, R. E. 2011. Implementation and opportunity costs of reducing deforestation and forest degradation in Tanzania. *Nature Climate Change* 1: 161-224.

Fort, R. 2008. The homogenization effect of land titling on investment incentives: evidence from Peru. *NJAS - Wageningen Journal of Life Sciences* 55(4): 325–43.

Geist, H.J., Lambin, E.F., 2001. What drives tropical deforestation? A meta-analysis of proximate and underlying causes of deforestation based on subnational case study evidence. LUCC Report Series No. 4. Louvain-la-Neuve. 1–136.

Gibson, L., Lee, T. M., Koh, L. P., Brook, B. W., Gardner, T. A., Barlow, J., Peres, C. A. 2011. Primary Forests Are Irreplaceable for Sustaining Tropical Biodiversity. *Nature* 478(7369): 378–81.

GORESAM. 2009. Las Potencialidades Y Limitaciones Del Departamento De San Martín: Zonificación Ecológica Y Económica Como Base Para El Ordenamiento Territorial. Gobierno Regional de San Martín (GORESAM). http://www.cnpp-otca.gob.pe/index.php?q=node/334. Moyobamba.

Gould, K. A. 2006. Land regularization on agricultural frontiers: the case of northwestern Petén, Guatemala. *Land Use Policy* 23(4): 395–407.

Gould, K. A, Carter, D. R., and Shrestha, R. K. 2006. Extra-legal land market dynamics on a Guatemalan agricultural frontier: implications for neoliberal land policies. *Land Use Policy* 23(4): 408–20.

Gray, Clark L. 2009. Environment, land, and rural out-migration in the southern Ecuadorian Andes. *World Development* 37(2): 457–68.

Grieg-Gran, M. 2006. The Cost of Avoiding Deforestation. International Institute for Environment and Development (IIED). London.

Hansen, M C, Potapov, P. V., Moore, R. Hancher, M., Turubanova, S. A., Tyukavina, A., Thau, D., Stehman, S. V., Goetz, S. J., Loveland, T. R., Kommareddy, A., Egorov, A., Chini, L, Justice, C. O. and Townshend, J. R. G. 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. *Science* 342(6160): 850–53.

Hayes, T. M. 2007. Does tenure matter? a comparative analysis of agricultural expansion in the Mosquitia forest corridor. *Human Ecology* 35(6): 733–47.

Hecht, S. B. 2005. Soybeans, development and conservation on the Amazon frontier. *Development and Change* 36(2): 375–404.

Hope, R. A., Porras, I. T., and Miranda, M. 2005. Can payments for environmental services contribute to poverty reduction? a livelihoods analysis from Arenal, Costa Rica. *Centre for Land Use and Water Resources Research.* Newcastle Upon Tyne, UK.

Hoyos, D. 2010. The state of the art of environmental valuation with discrete choice experiments. *Ecological Economics* 69(8): 1595–1603.

Ichikawa, M., Ricse, A., Ugarte, J., and Kobayashi, S. 2014. Migration patterns and land use by immigrants under a changing frontier society in the Peruvian Amazon. *Tropics* 23(2): 73–82.

Imbernon, J. 1999. A comparison of the driving forces behind deforestation in the Peruvian and the Brazilian Amazon. *Ambio* 28(6): 509–13.

INRENA. 2006. Plan Maestro De Cordillera Azul (2003-2008). Instituto Nacional de Recursos Naturales (INRENA). http://sinia.minam.gob.pe/index.php?idElementoInformacion=267&idformula=&idTipoElemento=. Lima.

INRENA. 2008. BP Alto Mayo: Plan Maestro 2008 - 2013. Instituto Nacional de Recursos Naturales (INRENA). Lima.

Kaimowitz, D., and Angelsen, A. 1998. Economic models of tropical deforestation: a review. CIFOR. Bogor, Indonesia.

Keane, A, Jones, J. P. G., Edwards-Jones, G., and Milner-Gulland, E. J. 2008. The sleeping policeman: understanding issues of enforcement and compliance in conservation. *Animal Conservation* 11(2): 75–82.

Kent, R B. 1993. Geographical dimensions of the Shining Path insurgency in Peru. *Geographical Review* 83(4): 441–54.

Kindermann, G., Obersteiner, M., Sohngen, B., Sathaye, J., Andrasko, K., Rametsteiner, E., Schlamadinger, B., Wunder, S. and Beach, R. 2008. Global cost estimates of reducing carbon emissions through avoided deforestation. *Proceedings of the National Academy of Sciences* 105(30): 10302–7.

Kirby, K. R, Laurance, W. F., Albernaz, A. K., Schroth, G., Fearnside, P. M., Bergen, S., Venticinque, E. M. and da Costa, C. 2006. The Future of Deforestation in the Brazilian Amazon. *Futures* 38(4): 432–53.

Knoke, T., Steinbeis, O-E., Bösch, M., Román-Cuesta, R. M., and Burkhardt, T. 2011. Cost-effective compensation to avoid carbon emissions from forest loss: an approach to consider price–quantity effects and risk-aversion. *Ecological Economics* 70(6): 1139–53.

Lambin, E. F., Turner, B. L., Geist, H. J., Agbola, S. B., Angelsen, A., Bruce, J. W., Coomes, O.T., Dirzo, R., Fischer, G., Folke, C., George, P.S., Vogel, C., Xu, J. 2001. The causes of land-use and land-cover change: Moving beyond the myths. *Global Environmental Change-Human and Policy Dimensions* 11(4): 261–69.

Larson, J. M., Smith, S. M., Abler, D. G., and Trivelli, C. 2003. An economic analysis of land titling in Peru. *Quarterly Journal of International Agriculture* 42(1): 79–97.

Lemel, H. 1988. Land titling: Conceptual, empirical and policy issues. *Land Use Policy* 5: 273-290.

Lin, L., Sills, E. O. and Cheshire, H. 2014. Targeting areas for reducing emissions from deforestation and forest degradation (REDD+) projects in Tanzania . *Global Environmental Change* 24: 277–86.

Llanos, R. E., and Feather, C.. 2011. The Reality of REDD+ in Peru: Between Theory and Practice. AIDESEP and FPP. Lima.

Lopez-Carr, D, and Burgdorfer, J. 2013. Deforestation drivers: Population, migration, and tropical land use. *Environment: Science and Policy for Sustainable Development* 55(1): 3–11.

Merry, F. D., Amacher, G. and Lima, E. 2008. Land values in frontier settlements of the Brazilian Amazon. *World Development* 36(11): 2390–2401.

MINAGRI. 2013. Producción Agrícola 2012. Ministro de Agricultura y Riego; República del Perú. http://siea.minagri.gob.pe/. Lima.

Mulley, B. G., and Unruh, J. D. 2004. The role of off-farm employment in tropical forest conservation: labor, migration, and smallholder attitudes toward land in western Uganda.. *Journal of Environmental Management* 71(3): 193–205.

Naidoo, R., and Ricketts, T. H. 2006. Mapping the economic costs and benefits of conservation. *Plos Biology* 4(11): e360.

Naidoo, R., and Adamowicz, W. L. 2006. Modeling Opportunity Costs of Conservation in Transitional Landscapes. *Conservation Biology: the Journal of the Society for Conservation Biology* 20(2): 490–500.

Naughton-Treves, L. 2004. Deforestation and carbon emissions at tropical frontiers: a case study from the Peruvian Amazon. *World Development* 32(1): 173–90.

Naughton-Treves, L, and Day, C. 2012. *Lessons About Land Tenure, Forest Governance and REDD+: Case Studies From Africa, Asia and Latin America*. Edited by Lisa Naughton-Treves and Cathy Day. USAID.

Nepstad, D. C., Schwartzman, S., Bamberger, B., Santilli, M., Ray, D., Schlesinger, P., Lefebvre, P. 2006. Inhibition of Amazon deforestation and fire by parks and indigenous lands. *Conservation Biology* 20(1): 65–73.

Oliveira, P. J. C., Asner, G. P., Knapp, D. E., Almeyda, A., Galvan-Gildemeister, R., Keene, S., Raybin, R.F., and Smith, R.C. 2007. Land-use allocation protects the Peruvian Amazon. *Science* 317(5842): 1233–36.

Ostrom, E. 1999. Revisiting the commons: Local lessons, global challenges. *Science* 284(5412): 278–82.

Pacheco, P. 2012. Actor and frontier types in the Brazilian Amazon: assessing interactions and outcomes associated with frontier expansion. *Geoforum* 43(4): 864–74.

Pacheco, P., Barry, D., Cronkleton, P., and Larson, A. M. 2012. The Recognition of Forest Rights in Latin America: Progress and Shortcomings of Forest Tenure Reforms, *25*(6): 556–571.

Pagiola, S., and Bosquet, B. 2009. *Estimating the costs of REDD at the country level* (pp. 1–23). Forest Carbon Partnership Facility (FCPF), World Bank. Washington D.C.

Parry, L., Day, B., Amaral, S., and Peres, C. A. (2010a). Drivers of rural exodus from Amazonian headwaters. *Population and Environment*, *32*(2-3): 137–176.

Parry, L., Peres, C. A., Day, B., and Amaral, S. (2010b). Rural-urban migration brings conservation threats and opportunities to Amazonian watersheds. *Conservation Letters*, *3*(4): 251–259.

Pattanayak, S. K., Wunder, S., and Ferraro, P. J. 2010. Show Me the Money: Do Payments Supply Environmental Services in Developing Countries? *Review of Environmental Economics and Policy*, *4*(2): 254–274.

Perz, S. G., Aramburú, C., and Bremner, J. L. 2005. Population, Land Use and Deforestation in the Pan Amazon Basin: a Comparison of Brazil, Bolivia, Colombia, Ecuador, Perú and Venezuela. *Environment, Development and Sustainability*, *7*(1): 23–49.

Pfaff, A., Sills, E. O., Amacher, G. S., Coren, M. J., Lawlor, K., and Streck, C. 2010. *Policy impacts on deforestation: Lessons learned from past experiences to inform new initiatives* (pp. 1–54). Nicholas Institute, Duke University. Durham.

Piu, H. C., and Menton, M. 2014. *The context of REDD+ in Peru: Drivers, agents and institutions* (Occasional Paper 106) (pp. 1–84). Center for International Forestry Research (CIFOR). Bogor, Indonesia.

Poffenberger, M. 2009. Cambodia's forests and climate change: Mitigating drivers of deforestation. *Natural Resources Forum*, *33*, 285–296.

Potvin, C., Coomes, O. T., and Grimard, F. 2007. Will RED Work Where It Should? *Science*, July 10.

Pritchard, M. F. 2013. Land, power and peace: Tenure formalization, agricultural reform, and livelihood insecurity in rural Rwanda. *Land Use Policy*, *30*(1): 186–196.

Redo, D. 2011. The role of the individual producer in driving land change: the case of Santa Cruz, Bolivia, 1986–2006. *GeoJournal*, *78*(1): 69–84.

Rindfuss, R. R., Entwisle, B., Walsh, S. J., Mena, C. F., Erlien, C. M., and Gray, C. L. 2007. Frontier land use change: Synthesis, challenges, and next steps. *Annals of the Association of American Geographers*, *97*(4): 739–754.

Roebeling, P. C., and Hendrix, E. M. T. 2010. Land speculation and interest rate subsidies as a cause of deforestation: The role of cattle ranching in Costa Rica. *Land Use Policy*, *27*(2): 489–496.

Rudel, T. K. 1995. When do property rights matter? Open access, informal social controls, and deforestation in the Ecuadorian Amazon. *Human Organization*, 1–8.

Rudel, T. K., and Horowitz, B. 1993. Tropical deforestation: Small farmers and land clearing in the Ecuadorian Amazon. Columbia University Press. New York.

Rudel, T. K., Bates, D., and Machinguiashi, R. 2002. A tropical forest transition? Agricultural change, out-migration, and secondary forests in the Ecuadorian Amazon. *Annals of the Association of American Geographers*, *92*(1): 87–102.

Saatchi, S. S., Harris, N. L., Brown, S., Lefsky, M., Mitchard, E. T. A., Salas, W., et al. 2011. Benchmark map of forest carbon stocks in tropical regions across three continents. *Proceedings of the National Academy of Sciences*, *108*(24): 9899–9904.

Salisbury, D. S., and Fagan, C. 2011. Coca and conservation: cultivation, eradication, and trafficking in the Amazon borderlands. *GeoJournal*.

Schelhas, J., and Sánchez-Azofeifa, G. A. 2006. Post-frontier forest change adjacent to Braulio Carrillo National Park, Costa Rica. *Human Ecology*, *34*(3): 407–431.

Schjellerup, I. 2000. La Morada. A case study on the impact of human pressure on the environment in the Ceja de Selva, Northeastern Peru. *Ambio*, *29*(7): 451–454.

Schloegel, C. 2012. An Analysis of Structural Impediments to Landowner Participation in Ecuador's Socio Bosque Program. In L. Naughton-Treves and C. Day (Eds.), *Lessons about land tenure, forest governance and REDD+: Case studies from Africa, Asia and Latin America* (pp. 93–100). USAID.

Schmink, M., and Wood, C. H. 1992. Contested frontiers in Amazonia. Columbia University Press. New York.

Schwartzman, S. 2000. Rethinking tropical forest conservation: Perils in parks, *Tropical Forest Conservation* 14(5): 1351-1357.

Shanee, N., Shanee, S., and Horwich, R. H. 2015. Effectiveness of locally run conservation initiatives in north-east Peru. *Oryx*, *49*(2): 239–247.

Shively, G., and Fisher, M. 2004. Smallholder labor and deforestation: a systems approach. *American Journal of Agricultural Economics*, 86: 1361–1366.

Sierra, R. 1999. Traditional resource-use systems and tropical deforestation in a multi-ethnic region in North-West Ecuador. *Environmental Conservation* 26(2): 136-145.

Sills, E. O., and Caviglia-Harris, J. L. 2008. Evolution of the Amazonian frontier: Land values in Rondônia, Brazil. *Land Use Policy*, *26*(1): 55–67.

Soler, L. de S., and Verburg, P. H. 2010. Combining remote sensing and household level data for regional scale analysis of land cover change in the Brazilian Amazon. *Regional Environmental Change*, *10*(4): 371–386.

Southgate, D. 1990. The causes of land degradation along "spontaneously" expanding agricultural frontiers in the Third World. *Land Economics*, *66*(1): 93–101.

Stern, N. 2007. Stern review on the economics of climate change. London UK: UK Cabinet Office - HM Treasury. London.

St-Laurent, G.P., Gélinas, N., Potvin, C., 2013. REDD+ and the agriculture frontier: Understanding colonists' utilization of the land. Land Use Policy 31, 516–525.

Sunderlin, W. D. 2011. The global forest tenure transition: Background, substance, and prospects. In T. Sikor and J. Stahl (Eds.), *Forests and people: Property, governance, and human rights* (pp. 19–32). Earthscan. London.

Sunderlin, W. D., Angelsen, A., Belcher, B., Burgers, P., Nasi, R., Santoso, L., and Wunder, S. 2005. Livelihoods, forests, and conservation in developing countries: An Overview, *33*(9): 1383–1402.

Swallow, B. M., Kallesoe, M. F., Iftikhar, U. A., van Noordwijk, M., Bracer, C., Scherr, S. J., et al. 2009. Compensation and Rewards for Environmental Services in the Developing World: Framing Pan-Tropical Analysis and Comparison. *Ecology and Society*, *14*(2).

Swallow, B. M., Meinzen-Dick, R. S., and van Noordwijk, M. 2005. Localizing demand and supply of environmental services. International Food Policy Research Institute (IFPRI). Washington D.C.

Swenson, J. J., Young, B. E., Beck, S., Comer, P., Cordova, J. H., Dyson, J., et al. 2012. Plant and animal endemism in the eastern Andean slope: challenges to conservation. *Bmc Ecology*, *12*.

Thünen, Von, J. H. (1966). Der Isolierte Staat (The Isolated State; 1826). (C. M. Wartenberg, Trans.). Pergamon Press. New York.

Tole, L. 2004. A quantitative investigation of the population-land inequality-land clearance nexus. *Population and Environment*, *26*(2): 75–106.

UNCED. *The Rio declaration on environment and development* (pp. 1–19). United Nations Conference on Environment and Development.

Unruh, J. D. 2003. Land tenure and legal pluralism in the peace process. *Peace & Change*, *28*(3): 352–377.

Unruh, J. D., Cligget, L., and Hay, R. 2005. Migrant land rights reception and "clearing to claim" in sub-Saharan Africa: A deforestation example from southern Zambia. *Natural Resources Forum*, *29*(3): 190–198.

van der Werf, G. R., Morton, D. C., DeFries, R. S., Olivier, J. G. J., Kasibhatla, P. S., Jackson, R. B., et al. 2009. CO2 emissions from forest loss. *Nature Geoscience*, *2*(11): 737–738.

Vandergeest, P., and Peluso, N. L. 1995. Territorialization and state power in Thailand. *Theory and Society*, *24*(3): 385–426.

Varughese, G., and Ostrom, E. 2001. The contested role of heterogeneity in collective action: Some evidence from community forestry in Nepal. *World Development*, *29*(5): 747–765.

Verburg, P. H., Overmars, K. P., and Witte, N. 2004. Accessibility and Land-Use Patterns at the Forest Fringe in the Northeastern Part of the Philippines. *The Geographical Journal*, *170*(3): 238–255.

Verburg, R., Filho, S. R., Lindoso, D., Debortoli, N., Litre, G., and Bursztyn, M. 2014. The impact of commodity price and conservation policy scenarios on deforestation and agricultural land use in a frontier area within the Amazon. *Land Use Policy*, *37*, 14–26.

Veronesi, M., Reutemann, T., Zabel, A., and Engel, S. 2015. Designing REDD + schemes when forest users are not forest landowners: Evidence from a survey-based experiment in Kenya. *Ecological Economics*, *116*(C): 46–57.

Vhugen, D., and Miner, J. 2012. Carbon Rights in Mozambique: Harmonizing Land and Forest Laws to Conform with REDD. In L. Naughton-Treves and C. Day (Eds.), *Lessons about land tenure, forest governance and REDD+: Case studies from Africa, Asia and Latin America* (pp. 23–32). USAID.

Walker, R. 2003. Mapping process to pattern in the landscape change of the Amazonian frontier. *Annals of the Association of American Geographers*.

Weisse, M.J., Naughton-Treves, L.C., 2016. Conservation Beyond Park Boundaries: The Impact of Buffer Zones on Deforestation and Mining Concessions in the Peruvian Amazon. Environmental Management 1–15.

Wiebe, K. D., and Meinzen-Dick, R. (1998). Property rights as policy tools for sustainable development. *Land Use Policy*, *15*(3): 203–215.

Wollenberg, E., Merino, L., Agrawal, A., and Ostrom, E. 2007. Fourteen years of monitoring community-managed forests: learning from IFRI's experience. *International Forestry Review*, *9*(2): 670–684.

Wunder, S. 2001. Poverty Alleviation and Tropical Forests--What Scope for Synergies? *World Development*, *29*(11): 1817–1833.

Wunder, S. 2005. Payments for environmental services: some nuts and bolts. *CIFOR Occasional Paper*, *42*(1). CIFOR. Bogor, Indonesia.

Wunder, S. 2006. Are direct payments for environmental services spelling doom for sustainable forest management in the tropics? *Ecology and Society*, *11*(2).

Wunder, S. 2007. The Efficiency of Payments for Environmental Services in Tropical Conservation. *Conservation Biology: the Journal of the Society for Conservation Biology*, *21*(1): 48–58.

Wunder, S., The, B. D., and Ibarra, E. 2005. Payment is good, control is better: Why payments for forest environmental services in Vietnam have so far remained incipient. CIFOR. Bogor, Indonesia.

Wünscher, T., Engel, S., and Wunder, S. 2008. Spatial targeting of payments for environmental services: A tool for boosting conservation benefits. *Ecological Economics*, *65*(4): 822–833.

Young, K. R. 1996. Threats to biological diversity caused by coca/cocaine deforestation in Peru. *Environmental Conservation*, *23*(01): 7–15.

Zanella, M. A., Schleyer, C., and Speelman, S. 2014. Why do farmers join Payments for Ecosystem Services (PES) schemes? An Assessment of PES water scheme participation in Brazil. *Ecological Economics*, *105*(C): 166–176.

Zegarra, E. 1999. *El mercado de tierras rurales en el Perú. Volumen I: Análisis institucional* (pp. 1–114). Santiago, Chile: United Nations.

Zimmerer, K. S. 2011. “Conservation booms” with agricultural growth?: Sustainability and shifting environmental governance in Latin America, 1985-2008 (Mexico, Costa Rica, Brazil, Peru, Bolivia). *Latin American Research Review*, *46*, 82–114.

Chapter 2. Migration, land acquisition, and forest clearing in Peru's upper Amazon

2.1. Abstract

Migration patterns are important to determining how deforestation frontiers advance. In the upper Amazon of Peru, much frontier settlement is undertaken by migrants from other parts of the country–mostly Andean regions. In this study, I draw on 194 household interviews in three districts to examine past migration patterns, future migration intentions, and how migration relates to land acquisition and forest clearing decisions. I find that the majority of settlers have moved hundreds of kilometers from their districts of birth to their districts of residence and that the selection of migration destination areas is strongly mediated by social networks based in the areas of origin. I also find that although the most common age for individuals to migrate is in the early twenties–which is consistent with household life cycle models of migration–migration continues to be common for households through a wide range of ages. Once households have arrived in frontier communities, the amount of land that they acquire is best predicted by the financial assets they arrive with, the age of the household head, and whether or not the household head originated from the coastal part of Peru. Total amount of forest cleared was best predicted by the year of the household's arrival relative to the year when the frontier area began to be opened. For individuals living in developing frontier communities, more express an interest in moving to an urban area than express interest in moving further into the frontier. This suggests that the attraction of improved services in less remote areas is greater than the attraction to the opportunity for acquiring larger parcels of land in more remote areas. Households with higher agricultural income had a higher probability of

having considered migrating; additionally, households that had contemplated moving to urban areas tended to be better-off than households that considered moving in to the frontier. This finding partly supports and partly contrasts with predominant models of frontier migration: it does not support the notion that poverty is a primary driver of out-migration on the frontier. However, it does suggest that migrating to the frontier is a more accessible option to poorer households than migrating to urban areas.

2.2. Introduction

Rural migration plays a central role in deforestation in the Amazon and globally. Migration can have both positive and negative interactions with the rate of forest clearing: in-migration to areas of newly expanding agriculture drives the advance of deforestation frontiers (Carr, 2009; Carr et al., 2006; Parry et al., 2010a), while rural to urban migration can serve to reduce pressure on forests (Schelhas and Sánchez-Azofeifa, 2006; Wright and Muller-Landau, 2006). The relative importance of different types of migration has large implications for land use change, particularly in frontier areas. Various models have been proposed to describe patterns of migration on the frontier, of which each has different implications for the long-term sustainability of both land and communities (Caviglia-Harris et al., 2012). In areas where in-migration is the dominant component of demographic change–such as the upper Peruvian Amazon–examining the differences among migrants and among their motivations is important to predicting long-term patterns of land use change and community development (Fearnside, 2008; Parry et al., 2010a; 2010b). However, despite the wealth of literature on the determinants of household land use and decision-making processes, there is relatively little empirical work examining the potential effect of household origins and migration histories.

This chapter provides insight into the migration dynamics of a rapidly-changing region in Peru's upper Amazon and the implications for land acquisition and forest clearing in three frontier districts. My three study areas are relatively new frontiers: the oldest of the three was first settled in 1974 while the most recent saw its very first arrivals in 1998. As with many settlements in Peru's upper Amazon, my study districts are largely populated by migrants from the Andean *sierra*. I use life histories of migrant farmers to assess household patterns of migration and the spatial patterning of migrant origins. Following from a description of migration patterns, I evaluate how household origins and migration histories affect land acquisition and forest clearing on the frontier. Finally, I examine future migration intentions of respondents in order to evaluate patterns of who is likely to migrate and to where.

2.2.1. Migration on the frontier

Deforestation frontiers–places at the leading edge of agricultural expansion into forested areas–are the areas with the highest rates of forest loss in the tropics (Carr, 2004; Naughton-Treves, 2004; Rindfuss et al., 2007). They are, by definition, dynamic environments where land use, land cover, and demographics change rapidly (Rindfuss et al., 2007). In-migration is prevalent on frontiers, with smallholders or larger investors claiming or purchasing new land as they arrive. New arrivals clear forest both for agriculture and as a strategy for demonstrating rights over the land (Southgate, 1990; Angelsen and Kaimowitz, 1999; Fearnside, 2001; Brown et al. 2016). Depending on the state of development of the frontier, informal land markets may be active, and speculating on land for future resale is common (Imbernon, 1999; Fearnside, 2008).

Newly-opened frontiers provide opportunities for land acquisition at a much lower cost per area than locations that have been established for longer periods (Carrero and Fearnside, 2011; Chapter 3). This low cost of land is an important 'pull' factor for individuals to move to the frontier–or, framed differently, high prices elsewhere are a 'push' factor for people to move away from longer-established agricultural zones (Margulis, 2004). Migration to the frontier provides an alternative to migration in a different direction: as Bates and Rudel (2004) observed, out-migration from established rural areas in search of wage-labor opportunities–particularly in urban areas–is a common strategy for landless individuals to accumulate sufficient capital to purchase their own land. Cheap or free land on the frontier offers an alternative to this longer process of saving money for land purchase; individuals who would have spent a longer time climbing the "agricultural ladder" via wage-labor and tenant farming can quickly own land outright. However, in any given area these opportunities for inexpensive land acquisitions are fleeting as land prices rise quickly with in-migration and community development (Chapter 3).

The opportunity that the frontier provides for inexpensive land is counterbalanced by hardships both economic and personal. Economically, agricultural production in more remote areas of the frontier is less profitable because of increased transportation costs for products. Frontier life is difficult because of reduced access to social services such as health posts or schools and the expense acquiring those goods that a household cannot produce independently. The absence of schools has in certain areas been documented as a central driver behind out-migration from rural areas (Parry et al., 2010a). Indeed, the provision of education services has been discussed as a policy tool to stabilize rural populations (Parry et al., 2010a). The lack of services and other consequences of the frontier's remoteness are the primary 'push' factors encouraging people to migrate to urban areas or to longer-established agricultural zones.

There are four conceptual models of frontier migration of which Caviglia-Harris and colleagues (2012) provide an excellent summary. The models differ in their predictions of three aspects of frontier migration: who migrates, to where, and with what eventual impact on the region. Three of the four models suggest that individuals migrate in response to negative situations: either because of a failed farm or due to poverty. The fourth suggests that household lifecycles dominate the question and those who migrate are primarily young individuals households. In terms of destinations, the models are split between those that focus on migration to the frontier, while others allow for a combination of migration to both urban and frontier areas. The two models that describe farm failure as the most important driver of migration both predict that long-term degradation of the land left behind the advancing frontier.

Understanding the dynamics of rural migration is essential to predict long-term outcomes both for human welfare and for agricultural sustainability and land cover. Studies to date, however, have been limited in that they have primarily involved surveys of migrants at destination areas (Carr, 2009). Caviglia-Harris and colleagues (2012) are a rare exception as they were able to gather information on individuals who had migrated away from their long-term study location. Studies at destination areas only provide a partial sample of those individuals who consider migration–by definition, those who decide in the affirmative–and as such can only give a partial understanding of the factors that motivate decisions to migrate to the frontier. Carr (2009) therefore argues for the importance of surveys at origin areas in order to better understand rural-rural migration and who makes the decision to move to the frontier. With this in mind, I consider the study communities as both destination areas and origin areas of migration: I examine both household migration histories as well as their future migration intentions. Although a stated intention may be a less reliable indicator than actual migration events, I believe that it nevertheless provide a useful additional perspective on the factors that motivate migration.

2.2.2. Household origins and land use

In areas where demographic change is dominated by in-migration, examining the place of origin of households should be a research priority for an understanding of land use and land cover change (Parry et al., 2010a; Perz, 2001). However, despite the large number of empirical studies that have examined the role of household characteristics as predictors of land use decisions, very few have explicitly used the place of origin as a predictor variable. Kaimowitz and Angelsen (1998) provide a thorough overview of household-level empirical models of land use; none of those models included variables related to origin. While overall migration rate has often been included as a predictor variable in regional and larger-scale models of land use and deforestation, the potential role played by household-level differences among migrants based on their places of origin has been understudied. Newly-arrived migrants are sometimes blamed by longer-term residents as being responsible for larger shares of deforestation; this was found to be the case in Apui in Brazil (Carrero and Fearnside, 2011) and also seems to be occurring in my study region of San Martin, Peru where migrants from the *sierra* are often blamed by long-term Amazonian residents of agricultural practices that are too intensive to be sustainable. Beyond the sterotypes, there are reasons to believe that the place of origin may influence land use decisions on the frontier. Individuals from different places of origin will be familiar with different production systems and social structures and so may be expected to be manage land differently as a result (Parry et al., 2010a; Redo, 2011). It is also possible that actors from different places may have distinct motivations. Carrero and Fearnside (2011) described individuals who had arrived from wealthier southern parts of Brazil as being more oriented towards economic growth than individuals from states in the Amazon. Fearnside (2008) also describes certain sets of actors as associated with particular areas; individuals he describes as "landgrabbers" tend to come from the wealthier parts of the country and generally use their land differently than smaller-scale agriculturalists from poorer regions.

Of the small number of studies that have explicitly examine the relationship between place of origin and land use outcomes, some have focused on the distinction between long-term residents and new arrivals (Alvarez and Naughton-Treves, 2003; Fujisaka et al., 1996; Rudel and Horowitz, 1993). While this distinction is important, it does not differentiate among migrants based on their different origins. These studies did tend to find that migrants were likely to deforest a higher percentage of their land; however, in these cases this relationship was also entangled with the shorter timeframe of establishment of the migrants relative to the long-term residents.

Of studies that have examined regions of origin among migrants for its ability to predict land use, the results have not been conclusive. Carrero and Fearnside (2011) included place of origin in a regression tree model predicting extent of deforestation on household land parcels; however, origin was excluded from the final tree as other variables were stronger predictors. Murphy (2001) found that settlers who were born in the *sierra* earned more income from cattle than those who were originally from the Amazon; however, she did not specifically examine outcomes regarding forest cover. Caviglia-Harris and colleagues (2012) compare land use among three groups of people: those born in the study area, those who migrated early, and those who migrated later. They found little significant difference between the two groups of migrants, although both groups tended to have significantly larger holdings than locally-born individuals. None of these studies have yet shown a conclusive relationship between place of origin and land use at the household level. With this study, I will again evaluate this relationship, but in a frontier area of Peru that is more recently-established than the study areas used in three examples given above. In addition to forest clearing, I also focus specifically on the area of land that households acquire upon arrival. Parcel sizes have been shown to influence the percent of forest cover that is maintained, so the area of land that households initially acquire may have long-term effects on land cover in the area (D'Antona et al., 2006; Michalski et al., 2010).

2.2.3. Study location

The upper Amazon (*selva alta*) of Peru is an area of rapid population increase and rapid deforestation. The Region of San Martin in particular had the highest deforestation rate of any major administrative area in the Amazon basin in the second half of the 1980s–higher than any state in Brazil (Perz et al., 2005). During the decade from 2001 to 2011, San Martin lost more humid tropical forest than any other region in Peru (Potapov et al., 2014). There are many interconnected reasons for this rapid loss of forest in the region. Extensive logging and its associated road construction, the mid-1990s expulsion of the *Sendero Luminoso* and other violent revolutionary groups from the region, the completion in the late 1990s of two paved highway links to the Pacific coast, and extensive USAID-funded programs promoting coffee and cacao as alternatives to coca have all contributed to make San Martin relatively accessible to migrant agriculturalists and increasingly well-connected to markets. With this greater connectivity has come a steady flow of new arrivals to the region who have in turn worked to advance the frontier of agriculture further into the region's forests.

Migration from the *sierra* into the *selva* is not a new process. Large-scale land reforms in the mid-1970s led to the government of Peru launching a propaganda campaign encouraging people to move to the *selva* with promises of fertile land (Brack Egg, 1997); cited in (Schjellerup, 2000). This comparison was concurrent with large scale land reforms redistributing tenure from large latifundios to smaller producers (Ballantyne et al., 2000). More recently, Inge Schjellerup (2000) considered a case study of a small village in western San Martín that was established by migrants from the *sierra.* She found that word of mouth and social networks played a major role in attracting new colonists and rapidly populating the village. These findings pointing to the importance of social networks in driving migration are consistent with migration work elsewhere in Latin America (Carr, 2009).

2.3. Methods

2.3.1. Life histories and migration

I interviewed 194 landholding farmers in buffer zones of protected areas in three districts of the Region of San Martin, Peru. Those areas–in the Districts of Pardo Miguel, Shamboyacu, and Alto Biavo–have different histories of settlement. Colonization in all districts originated with homesteading (non-market land claims) that was a spin-off of infrastructure development and extractive activities (cf. Lambin et al., 2001)– either highway construction (Pardo Miguel) or logging activity (Shamboyacu and Alto Biavo). The timing of settlement can in part be understood by observing the timing of the establishment of the first primary school in each study community. In Pardo Miguel, all study communities had a primary school established within two kilometres of them by 1982. In Shamboyacu, one community was within two kilometres of a school by 1983 and a second by 1994; however, the remaining four communities have only had schools established nearby since 2001 to 2007. In Alto Biavo, the earliest primary school established in the area was in 2003, and other communities have only had within-two-kilometre access to a school since 2009 (DRE, 2013). I interviewed household heads in 13 communities among the three districts. In each community I tried to interview heads of either twenty households or–in the case of smaller communities– twenty percent of the households; I met this goal in 11 of the 13 communities while in two communities I fell somewhat short (18% and 14% of households) due to logistical constraints. To select households, I first walked each community on foot and drew a sketch map that located all of the dwellings. I numbered each dwelling systematically across the page and created a sequence of numbers by randomly selecting a starting point and proceeding by a fixed interval that would give me the desired number of households to sample (usually every fourth or fifth dwelling). Proceeding in this manner ensured that my sampling was stratified geographically across the community (in case of spatial stratification by wealth or family group) and that it was kept free of influence by my social contacts or by community leaders.

The semi-structured interviews each lasted between 45 minutes and two hours with the average being about 75 minutes. A large part of each interview was devoted to describing household land holdings, the household's history of land acquisition, and the household's crop production in the previous twelve months. Additionally, I asked each household head for their migration history–where they were born and each place they had lived prior to arriving in the study community–and the motivation for moving in each instance. Coffee is very labor intensive during its short harvest season; as a result, it is relatively common for individuals to have sought temporary wage labor in an area for the two or three months during the harvest but then to have returned to their previous location. Ionly counted moving events where the household head lived in an area for six months or more: this excluded these instances of temporarily moving to work a single harvest season. Because of the frontier nature of the study communities, very few of my respondents had been born in them (two household heads out of 194) and otherwise had moved at least once in their lifetimes. I also asked individuals to assess their future intentions regarding migration: whether or not they intended to move again in future or if they saw themselves still living in the same area in ten years and beyond. For those individuals who stated that they had considered moving, I asked to where they would consider moving. The answers to this question tended to group into one of three categories: individuals stated preferences for either (a) moving to a town or a city, (b) moving to a more remote rural area where land would be cheaper to acquire, or (c) moving to a less remote rural area where land would be more expensive but services such as health and education would be more readily available.

2.3.2. Migration in Peru–context from the Peruvian census

To provide a broader national context for life histories of my respondents, I looked to the Peruvian census. Peru's National Institute for Information and Statistics has completed 11 national censuses on population and household characteristics; the results of the most recent three–1993, 2002, and 2007–are available online at the level of district (INEI, 2014). The censuses provided information on total population in each district as well as the percent of residents who had lived in their current district five years previously (responses to the question, "*Hace 5 años - Vivía en este Distrito*"). I combined these values with district areas calculated from the shapefile in order to create maps (Figures 2-1 and 2-2) of population density, population change 1993-2007, and percent of residents who were new to the district within five years. The latter I take as a proxy for the intensity of migration into a given area. I merged this census data with a shapefile of Peru's districts form the GADM database of Global Administrative Areas version 2.0 (GADM, 2012). In the small number of cases where districts had merged or split between the census years, I summed values or took weighted averages as appropriate.

2.3.3. Modeling land acquisition and forest clearing

I modeled the relationship between household characteristics and migration history with land acquisition and forest clearing behavior. For this analysis, I only included those households where the household head arrived to the study district independent of his/her parents' household (n=156); households that were formed after arrival by individuals who arrived as children were excluded. I built household-level models with three distinct independent variables: (1) the area of land acquired in the first two years after arrival in the study community, (2) the total area of land acquired since arrival, and (3) the total area of primary forest cleared. In the case of land acquisition in the first two years (1) and the total area of forest cleared (3), values are zero-inflated; there is a significant number of respondents for whom the result is zero on both variables. Zero-inflation is not an issue in the total area of land acquired (2): all respondents interviewed were landholders so all had acquired at least some land in the past. Because of zero-inflation, I used censored regression (Tobit) models to generate robust estimates. The *censReg* package in R statistical software allowed me to run these models as well as to calculate marginal effects for each of the independent variables (Henningsen, 2013). Marginal effects in Tobit models depend on a linear function of all independent variables in the model (not simply on the predictor variable for which the effect is being calculated) which means that a representative value for each variable must be chosen

(Wooldridge, 2006). In this case, I present all marginal effects at the mean value for all indepdendent variables. The effects also assume that the dependent variable has a positive value (i.e., is not censored at zero).

Because I have information on the timing of land acquisition events (also see Chapter 3), I was able to model both the total amount of land that households acquired during their residence in the study district as well as the land acquired within a given time since arrival–in this case I selected a two-year window. This allows me to look at a household's longer-term decisions while focusing on those early-stage decisions that may be more sensitive to the context in which the household arrived in the district. Ideally I would have taken a similar approach to forest clearing by modeling both total forest clearing as well as clearing that a household undertook in its first years of residence. However, on this I was limited by respondents' recollections. Some respondents were indeed able to accurately remember the timing of forest clearing, but this was not always the case. I was consistently able to determine the total area of forest that a household had cleared during their tenure in the area, but only in some cases were the precise years known in which clearing happened. For this reason, I include the total area of forest cleared as one of the dependent variables, but cannot include a comparable variable for the forest cleared in a household's first years in an area.

My approach for each of the three dependent variables was to start with a minimal model including only three basic household characteristics–household head age, household size, and proportion of household of working age–that have been shown in many studies to affect land use decisions (Kaimowitz and Angelsen, 1998). From this starting point, I expanded the models through two sequential steps: first to add variables relating to the migration event that led to the household's arrival in the study district, and second to add variables relating to the prior origin of the household. The minimal model and the two sequential expansions refer to the 'a', 'b', and 'c' columns respectively in Tables 2-2 and 2-4. For each model I performed a likelihood ratio test (LRT) to evaluate its performance over the null model. For sequential steps two and three, I also performed an LRT on the model's improvement over the simpler model that it was an expansion of. LRTs are appropriate in this context given that each previous model is nested within the subsequent model that builds upon it (Wooldridge, 2006).

I added three variables relating to the migration event itself: whether or not the household had sold a house or land before moving to the study community, the distance they migrated, and the arrival year relative to a reference year for each district. The first of these–whether or not a household had sold land prior to arrival–was included as an indicator of the financial assets that the household brought to the frontier. More available income could enable the household to invest further in their land: either through a larger acquisition or with through more intensive land management. Financial assets may also allow greater investment in household land through indirect means by reducing the need for household members to engage in off-farm labor that would take them away from on-farm work. Next, I included a variable for the distance that a household migrated from their previous district of residence. This value is the straight-line distance between the district centroids of their previous district of residence and the study district. I included this variable because the distance migrated could serve both as an indicator of the resources that a household was able to bring to finance the move–longer moves involving more expense–but also as an indicator of the degree to which the study district would have represented an area to which the household had little previous connection. Moving longer distances may indicate that household members sought information on a broad spectrum of possible destination areas before selecting the area to which they would migrate. A higher level of selectivity and planning may indicate households that are better-equipped to manage their land in ways that maximize economic returns.

The third variable in the set of characteristics describing the migration event is the year of migration relative to a reference year for each study district. Using a year relative to a reference year gives me a proxy for the level of development in each study distrcit. As briefly mentioned above, the three study districts have different histories of settlement and settlement happened in different times for each. My study areas in Pardo Miguel were settled in the mid-1970s, those in Shamboyacu primarily in the mid-1990s (in some Shamboyacu communities, there was earlier settlement in the 1980s that was later reversed following coca eradication), and those in Alto Biavo in the late-1990s and early-2000s. I decided to use the date of the first land sale in the area–information that I have from a database of more than 300 land transactions that I developed for another part of this study (Chapter 3)–as an indicator of the timing of the early stages of development of the district. The years this yielded were 1976, 1996, and 2001 for Pardo Miguel, Shamboyacu, and Alto Biavo, respectively. A household's arrival year relative to that reference year in the district is a good indicator of the level of development in the district at the time of arrival.

The last sequentially-added set of variables in my model are those that relate to the background of the household head prior to migration: what part of the country the household head is from and whether or not he/she has ever lived in an urban area in past. Among many longer-term Amazonian residents, there are stereotypes about people from other parts of the country–particularly those from the *sierra*–regarding how they use land (the stereotype being that they farm land too intensively and degrade it). Whether or not this is true, different farming systems do exist in the *sierra* and on the coast, and experience with one or the other may influence how a household manages newly acquired land in an Amazonian district. For this variable, I classify a household head's birth district as beloning to one of the three zones of Peru–coast, *sierra*, or Amazon–based on whether its average elevation is above 2000m (*sierra*) or below and if it below 2000m whether it is in the Atlantic (Amazon) or Pacific (coast) drainage basin (Figure 2-10; supplementary). Lastly, I include as a dummy variable whether or not the household head has ever lived in an urban area. Experience with non-agricultural economic opportunities may affect the household head's underlying orientation towards longer-term maintenance of land productivity as opposed to shorter-term financial return on investment.

2.3.4. Predicting future migration intentions

I asked all household heads whether they had considered moving to a new area in the future. Of all of the questions I asked during these interviews, this one was the most likely to engender suspicion on the part of the respondent and to provoke an evasive answer ("*sólo Dios sabe*" or "only God knows" was an answer I heard on multiple occasions). It is likely that this occasional suspicion was at least partly because of the author's (TGH) position during interviews as a foreigner in an area where the great majority of land holdings have no legal title. Rumors (and no doubt some examples) of foreigners dispossessing farmers of their land are relatively common in this area. In cases where it became clear that a respondent did not want to answer questions about his/her future intentions, I did not press the matter. This meant that I had to exclude some households from my analysis of migration intentions: whereas I interviewed 194 landholders overall, 168 are included in this part of the study, a 13% attrition rate.

I evaluated migration intentions at two levels: first, the household intention to migrate or not and second, the planned destination. Using a probit model, I examined the effect that various household characteristics had on the likelihood that a household head had considered migrating away from their current district of residence. I built the models using the *glm* function of the core *stats* package of R and calculated marginal effects using the *maBina* function in the *erer* package (Sun, 2014). The marginal effects are what I report in the results section. For comparison, I ran equivalent logit models for each of the probit models. Results from the logit models were qualitatively similar and in this chapter I include only the probit results. The explanatory variables in these models include household age, size, and working age proportion:

all factors that have been shown to affect land use decisions and on-farm productivity (Perz, 2001). The lifecycle stage of a household will likely affect the "pull" factors influencing migration (Carr, 2009; Parry et al., 2010a; Walker et al., 2002): a larger household with children moving into adulthood will have more labor available to cultivate larger parcels of land further towards the frontier. However, children approaching adolescence also give the household an incentive to move towards larger population centers that provide better access to secondary schools, drawing a household away from the frontier. The working age proportion variable–coupled with the household size–provides an indicator for the lifecycle stage of a household and therefore may indicate some of the pull factors that it faces.

Variables describing total land holdings and the percentage of land remaining in forest reflect a household's potential for agricultural production in their current area of residence, as well as their potential for further expansion of agricultural land by clearing new forest. A household's income from crops in the previous twelve months provides information on past production. Combining these variables provides an indication of the "push" incentives for migration: the less opportunity a household has for agricultural production in their current area, the more likely they will be to look for other options (Carr, 2009; Caviglia-Harris et al., 2012). As two further predictors of a household's likelihood of intending to migrate, I included a dummy variable representing whether or not a household had adult children who had left the home and were now living outside the community. I hypothesized that family members in other areas would make a household head more likely to consider leaving their current area of residence. I also included a dummy variable indicating whether or not a household head had in past lived in a city or town. In these rural areas where most people's work experience is exclusively in agriculture, I hypothesized that previous experience in urban areas could affect an individual's familiarity with other types of economic opportunities and may in turn affect their willingness to migrate away from the rural study districts.

2.3.5. Impact of la roya: 2012-2013

All of the interviews in Shamboyacu took place in mid-2012 while those in Pardo Miguel and Alto Biavo took place in mid-2013. It is important to highlight this difference in timing because of events that transpired during those two years: beginning in 2012, but peaking in early 2013, there was a large-scale outbreak of *Hemileia vastatrix,* the coffee rust fungus that in Spanish is known as *la roya*. This outbreak affected most coffee-producing countries from Central America to Andean South America and Peru was no exception. Estimates by the National Coffee Board (*Junta Nacional del Café*) in February of 2013 were that 130,000 ha of coffee plantation in Peru–32% of the national total–was affected by the *roya* and that this had an impact on 53,000 coffee-producing households (JNC, 2013). Overall coffee production in Peru, after increasing by 64% between 2009 and 2011, fell by 17% in 2012 and by a further 20% in 2013 and 2014 (ICO, 2015). The majority of landholders I interviewed (>90%) derived most of their cash income from coffee growing, meaning that many of them were greatly affected by this outbreak. Unsurprisingly, optimism regarding future farm revenue was much lower among farmers I interviewed in 2013 than among those I interviewed in 2012. Because of this change in context, I think it is reasonable to expect that landholders' intentions regarding future migration may in some cases have changed between 2012 and 2013. For this reason, when I evaluate my data on migration intentions I compared districts individually as well as in combination.

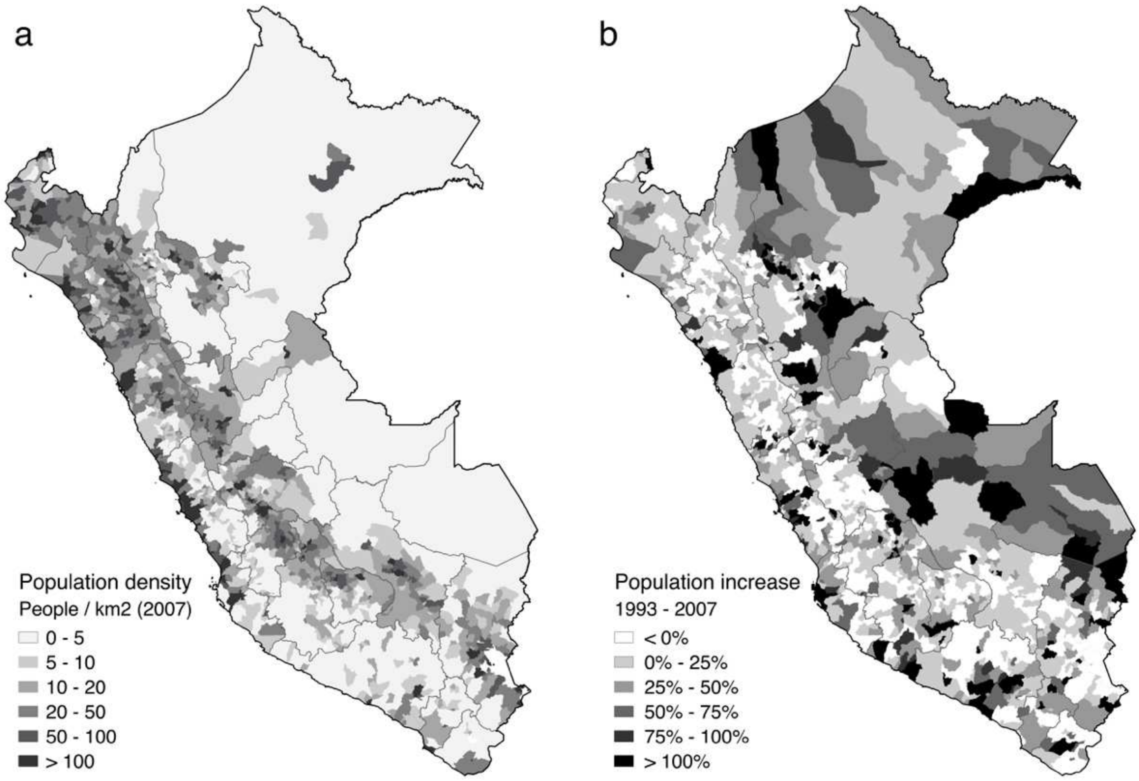

Figure 2-1: Population density in 2007 (left) and percent population increase between 1993 and 2007 (right) in Peruvian districts.
Districts are the smallest of the three levels of administrative division in Peru. Data are from the 1993 and 2007 Peruvian censuses (INEI); maps created by the author.

2.4. Results

Population in Peru is densest on the coast and along the length of the Andean *sierra*. Data from the 2007 Peruvian census illustrate this pattern when population per square kilometer is mapped for each district in the country (Figure 2-1a). Amazonian districts are generally more sparsely populated than districts in either the coast or the *sierra*; however, they have recently seen higher rates of population increase than districts in the two latter zones (Figure 2-1b). In the years between 1993 and 2007, districts in the *selva* had average rates of population increase of 37.5% (σ=57.8%; n=213). This is nearly three times higher than the average rate of increase of 13.0% in the *sierra* (σ=51.7%; n=1308) and is also higher than the rate of 29.1% in coastal districts (σ=45.1%; n=286). The overall rate of population growth (i.e., for the population as a whole rather than averages by district) in the *selva* was 39.5% as compared to 22.1% in the *sierra* and 38.0% on the coast.

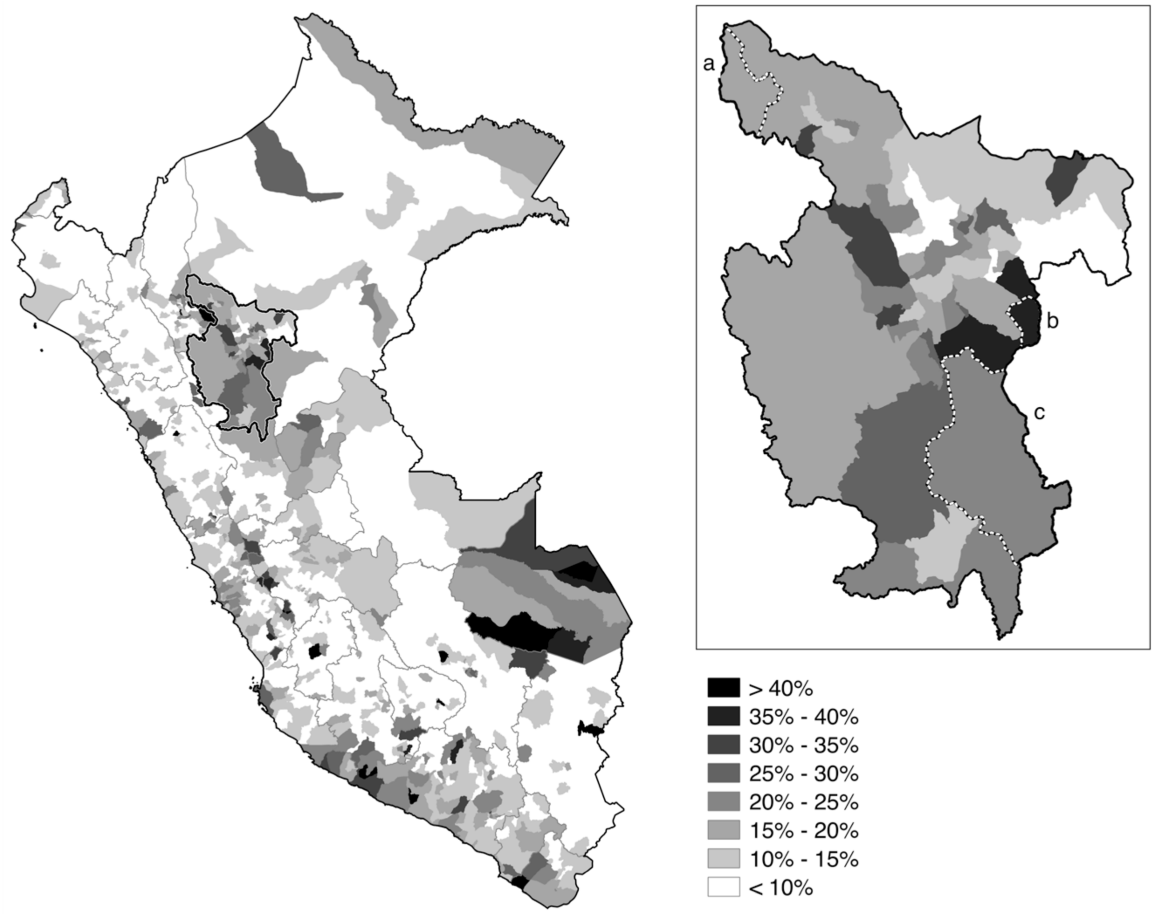

Figure 2-2: Percent of population in 2007 reporting that they did not live in their current district of residence five years previously (i.e., in 2002). Peru and San Martin. San Martin is indicated by the outline in the main map and by the inset. The three study districts are indicated by dotted lines on the inset map of San Martin and by letters: a) Pardo Miguel, b) Shamboyacu, and c) Alto Biavo. Districts are the smallest of the three levels of administrative division in Peru. Data are from the 1993 and 2007 Peruvian censuses (INEI); maps created by the author.

Migration to the Amazon from the *sierra* and the coast is a large part of the reason that population in Amazonian districts has increased rapidly in recent decades. Answers to the census question "did you live in this district five years ago?" illustrate the prevalence of in-migration to the Amazon. In Amazonian districts, 13.1% of individuals responded in 2007 that they were new arrivals to their district of residence in the previous five years. This compares with 9.8% in the *sierra* and 15.4% on the coast. Certain regions particularly stand out as areas of prevalent in-migration. Of Peru's 24 regions, the two with the highest percentage of new arrivals were two Amazonian districts: Madre de Dios (27.2%) and San Martin (19.1%). These compare to an overall Peruvian average of 13.4%. The third and fourth regions in Peru when ranked according to prevalence of new arrivals were Arequipa (19.0%) and Lima (18.8%), the regions that are home to Peru's two largest cities. In San Martin, more than 30% of people in seven out of 77 districts responded that they had arrived since 2002 (Figure 2-2). This included Shamboyacu, one of the study districts, with 35.2%; the two other study districts–Pardo Miguel and Alto Biavo–stood at 20.6% and 19.1% of new arrivals respectively (Figure 2-2 inset).

2.4.1. Migration trajectories

Of the 194 household heads I interviewed, only two were born in their district of current residence (~1%). The rest had moved at least once in their lives, with the majority having been born in other regions of Peru. The average time of residence in the study communities ranged from an average of 7.8 years (σ=4.3) among respondents in Alto Biavo to an average of 16.1 years (σ=10.7) in Pardo Miguel (Table 2-1). More than half of my respondents–54.6%–were born in Cajamarca, a region that lies mostly in the *sierra*. A further 21.6% were from Piura, 8.2% were born in Amazonas, and 8.2% were born in the region of San Martin itself. Smaller percentages of respondents were born in Ancash, Lambayeque, and Loreto (Figure 2-3). General trends–for example the large number of people originally from Cajamarca–were relatively consistent among study districts and among study communities. However, there were community-specific patterns that came to light when I examined the district of birth of interviewees. In total, respondents were born in 67 different districts split among the seven regions mentioned above. Some birth districts were common to observe in several communities: for example, I encountered individuals who had been born in Jaen–the capital district of Cajamarca–in six of my 13 study communities. However, there were other birth districts that were very common in some communities while being rare or absent in others. The district of Pacaipampa in Piura, for example, was the birth district of 41.7% of respondents in one community but I did not encounter a single person from Pacaipampa in any of the other 12 communities. Similar patterns can be seen in Figure 2-4; it shows the distribution among study communities of individuals from the ten most common birth districts in my sample. In several cases I see the same birth district appear very frequently in a small number of communities while in the rest of the communities it is largely absent.

Although most of the household heads I spoke to had moved only one or two times in their life, 12.9% had moved three or more times. The largest number of moves was seven by one individual who arrived in a study community in 1999. In my sample, individuals had averaged 0.5 cumulative moves by the age of twenty, 1.2 by the age of thirty, and 1.9 by the age of fifty (Figure 2-7). The most common age for household heads to have moved is in their teens and early twenties: 35.3% of household heads moved at least once between the ages of 21 and 25–the highest value for any five-year sliding window on the migration-age data. However, the peak is quite broad and respondents continued to migrate in the thirties and forties with a relatively high frequency. At least 20% or more of the sample moved in every five-year age range between 15-19 and 40-44 (Figure 2-8). I did not encounter any individuals who had migrated after their mid-sixties, although the number of people in my sample who were older than that was very small (only eight individuals over 65).

Table 2-1: Descriptive statistics for three districts and for all districts taken together. Values for continuous variables are averages with standard deviations in parentheses. Binary variables are shown as percentages.

	All districts	Shamboyacu	Pardo Miguel	Alto Biavo
Household head age				
At interview	40.03 (12.1)	38.95 (11.73)	41.67 (12.66)	39.79 (12.04)
When arrived*	31.67 (10.76)	30.90 (10.48)	30.29 (8.71)	33.82 (12.37)
Household members				
At interview	4.75 (1.93)	4.83 (2.02)	4.38 (1.77)	5.02 (1.94)
When arrived*	4.06 (2.28)	3.86 (2.14)	4.37 (2.66)	4.12 (2.19)
Household working age prop.				
At interview	0.57 (0.22)	0.56 (0.22)	0.61 (0.24)	0.53 (0.21)
When arrived*	0.66 (0.28)	0.68 (0.28)	0.65 (0.27)	0.64 (0.28)
Years residing in community	10.92 (9.21)	9.19 (9.02)	16.10 (10.68)	7.79 (4.29)
Have children living outside of community	27%	22%	36%	23%
Lived in urban area in past	10%	6%	17%	9%
Birth district				
Selva	48%	62%	51%	32%
Sierra	34%	33%	30%	41%
Coast	16%	5%	18%	27%
Sold land or a house at previous location of residence	38%	43%	33%	35%
Distance migrated from previous location to current district (km)	235.49 (151.28)	246.86 (158.12)	127.55 (95.58)	333.6 (113.21)
Earnings from crops in previous 12 months (USD)	1778.46 (2463.4)	2559.87 (3193.7)	710.18 (1015.4)	1834.64 (1947.97)
Total land acquired (ha)	16.49 (24.24)	12.40 (13.25)	11.98 (15.6)	27.02 (37.36)
Total land acquired within two years of arrival (ha)	11.77 (15.87)	8.89 (10.97)	7.50 (13.68)	20.12 (20.23)
Total land holdings (ha)	15.16 (23.51)	10.91 (12.23)	10.92 (15.58)	25.63 (36.23)
Forest area cleared (ha)	4.55 (5.92)	4.05 (4.99)	3.65 (6.31)	6.12 (6.48)
Total holdings in forest (ha)	8.45 (19.11)	4.26 (7.3)	4.21 (9.3)	18.82 (30.98)
n	194	78	60	56

* Values for the time of arrival were only calculated for those households where the household head arrived in the community independently (i.e., not as a part of his/her parents' household).

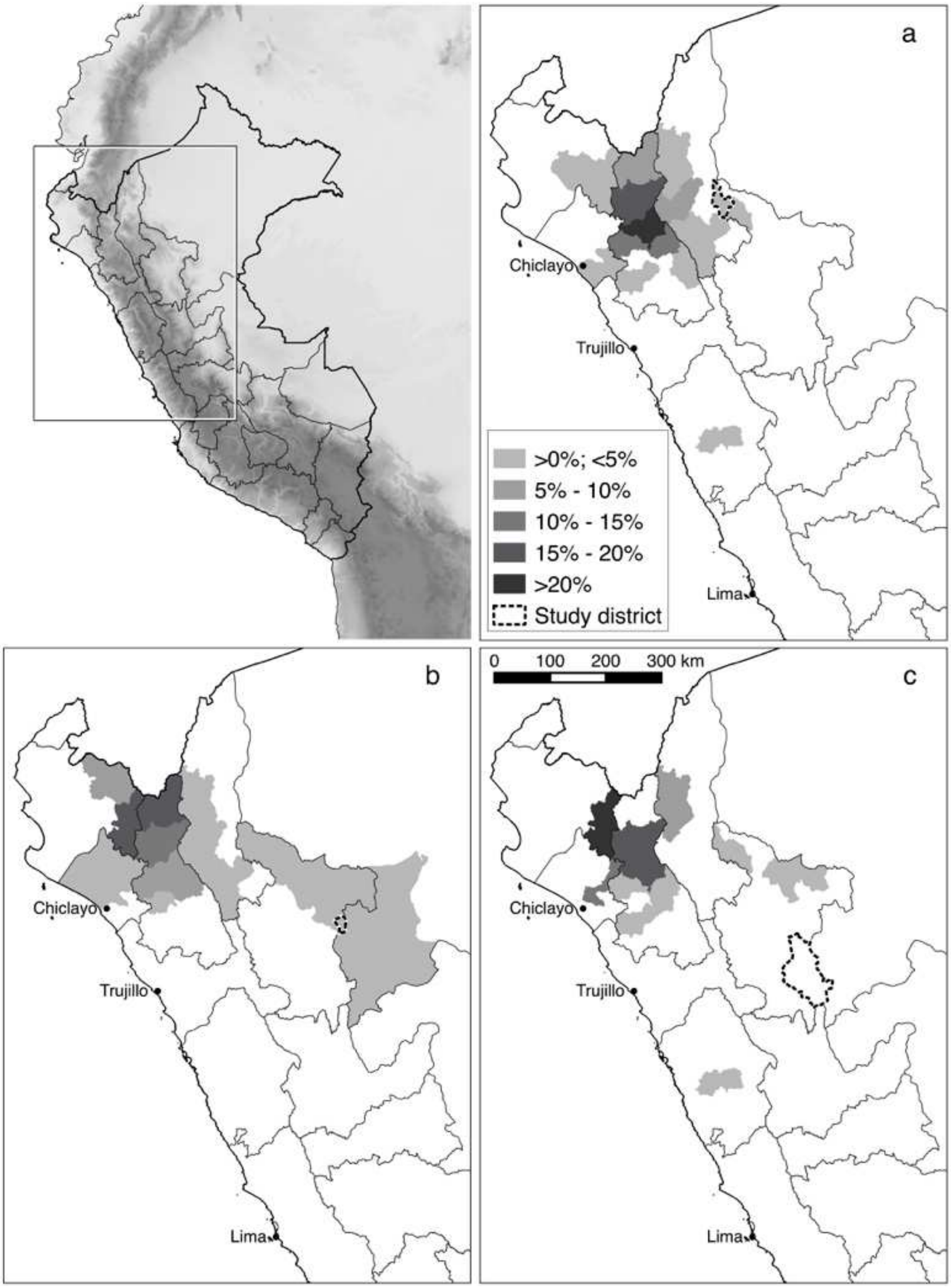

Figure 2-3: Province of birth of interviewees in each district.
Provinces are the administrative division between region (largest administrative division) and district (smallest).

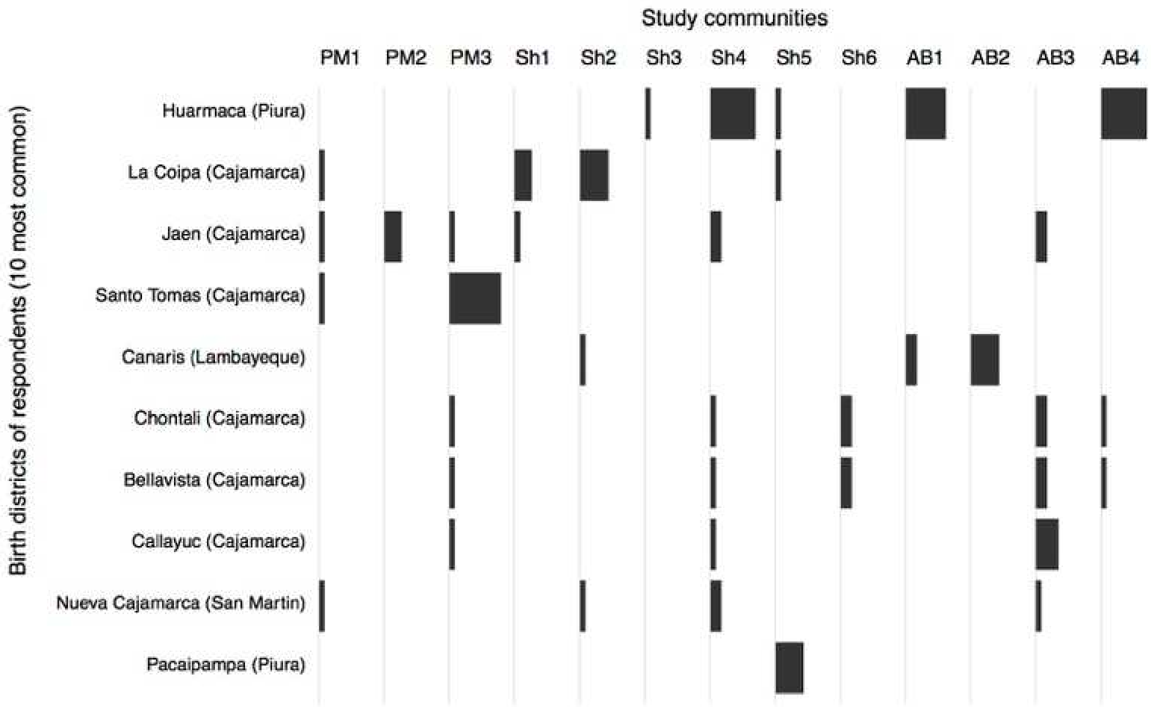

Figure 2-4: Distribution among study communities of individuals born in the ten most frequently-encountered birth districts in the sample.
Includes districts in which were born five or more respondents. The width of the thinnest bars represents one individual.

The location of the most recent residence prior to arrival in the study districts followed generally similar patterns to the location of birth districts (Figure 2-5). Nearly half of respondents–47.9%–had moved only one time in their life, meaning that they moved to the study district directly from their birth district. For this half of my sample, there is no difference between the district of most recent residence and the district of birth. For the other half of the sample there was some number of moves before the move that brought the respondent to their current community of residence. In a few cases, these moves were to Trujillo, Chiclayo, or Lima–large coastal cities. In a larger number of cases, these earlier moves were to areas intermediate in location between birthplaces in the *sierra* and current communities. Many respondents on the eastern–and more recently developed–side of San Martin had previously lived in longer-established districts in the northwest of the region. The distances that households migrated before arriving in the study communities were often quite large (Figure 2-6). Measured using the straight-line distance between district centroids, the median distance from a household head's birth district and his/her district of current residence is 328 km (mean 282 km). From the most recent district of residence prior to the current one, the median distance is 192 km (mean 232 km).

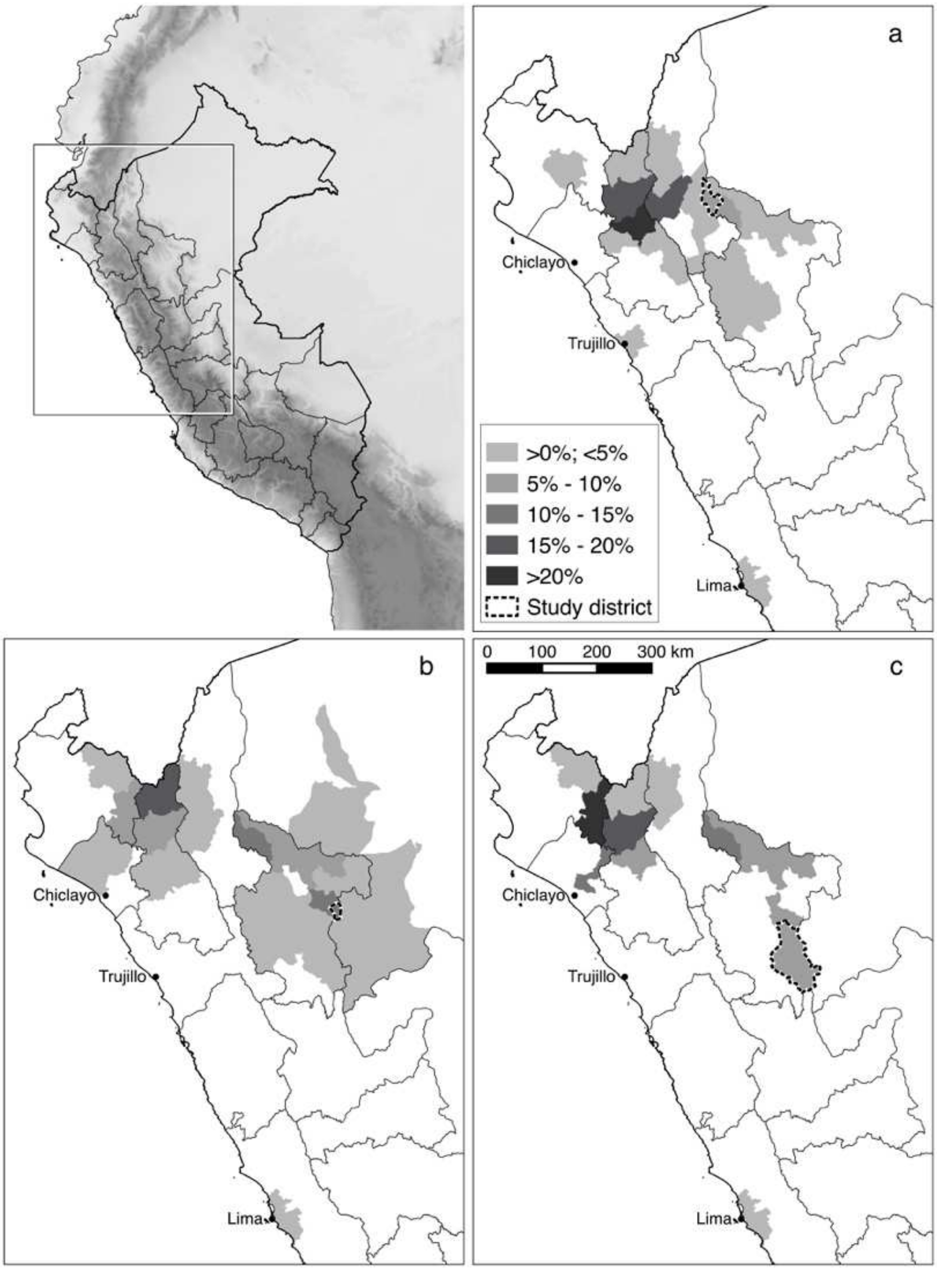

Figure 2-5: Province of residence of interviewees prior to first arrival in study district. Interviewees were found to have lived previously in the large coastal cities of Lima and Trujillo although none had been born there.

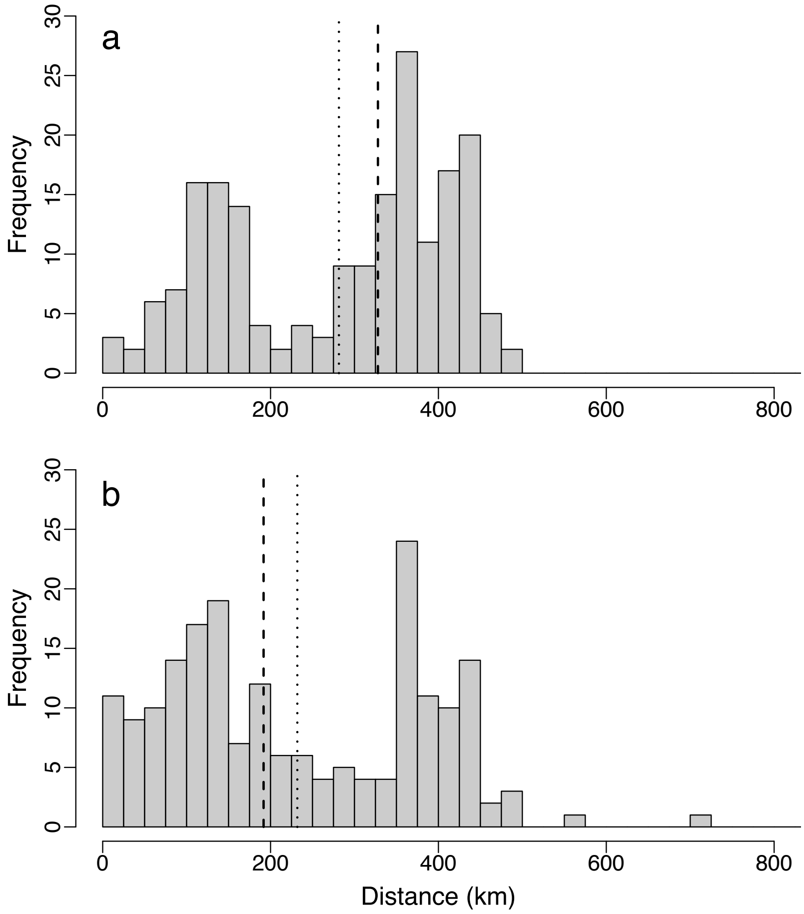

Figure 2-6: Distance moved by household heads (a) from their district of birth, and (b) from their last distance of residence (b).
Distances measured as the linear distance between the centroids of the two districts. For district of birth (a), means (281.5 km) and median (328.0 km) are indicated by the dotted and dashed lines respectively. The observations at zero represent the three household heads (1.5% of sample) who were born in their community of residence. (b) Distribution of distances from district where households lived most recently to their current one; measured as above. Mean is 231.9 km and median is 191.7 km. The 11 households (5.6%) shown at zero are the three households above plus eight more whose previous move was from a different community in the same district. The observations above 500 km–higher than the highest values seen in (a)–represent individuals who were born within 500 km of the study districts but who moved to the coastal cities of Chiclayo or Lima between the departure from their birth district and their arrival in the study district.

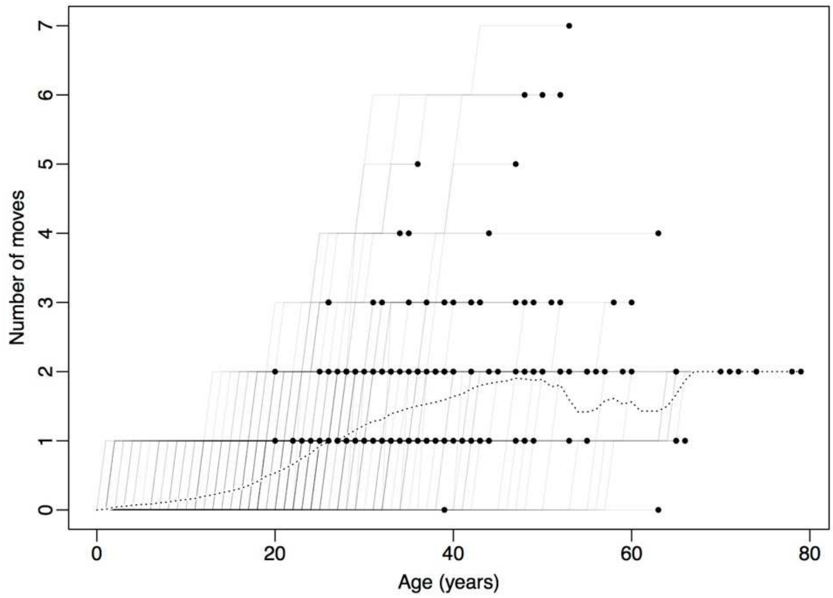

Figure 2-7: Cumulative moves as plotted for each household head.
Dots represent each household head at the time of interview in terms of the number of moves they had made to date and their age. Grey step-lines trace the path indicating the age at which each move happened. Lines are partly transparent so that darker lines represent multiple individuals making a move at the same age (for example lines are darkest around the age of twenty when many individuals moved for the first time). The dotted line is the average number of cumulative moves at each age for those respondents who were that age or older. Declines in that line above 50 are a sampling artifact as individuals with many moves drop out of the sample at higher ages.

2.4.2. Household land acquisitions

Tobit models that included study district dummy variables and basic household characteristics at the time of arrival in the district (household head age, number of members, and working age proportion) were able to predict both the amount of land that a household acquired within the first two years after their arrival as well as the total amount of land that they acquired up to the date of the interview. In both cases the model significantly outperformed the null model ($p<0.0001$ for acquisitions within two years; $p=0.0011$ for total acquisitions). The dummy variable for Alto Biavo study district–relative to a reference case of the Pardo Miguel study district–was a significant and positive predictor in both cases as was the household head's age at the time of arrival (Table 2-2).

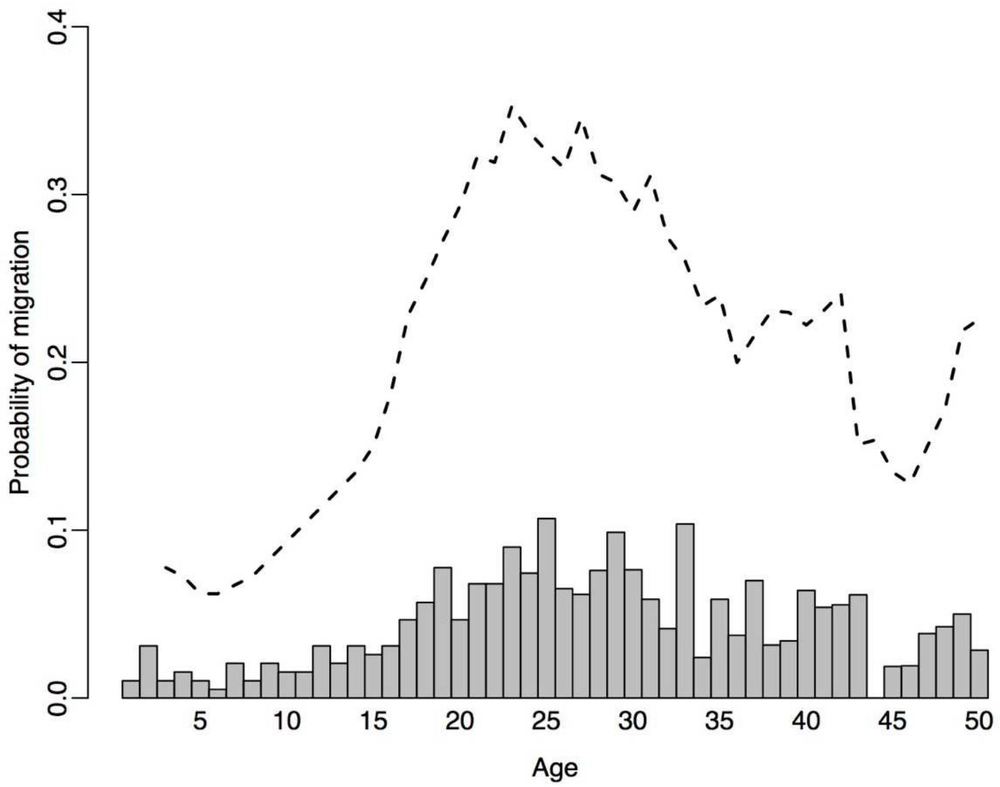

Figure 2-8: Probability of migration at a given age for household heads in the sample. Grey bars represent the probability of migration at each age, while the dashed line is a smoothed version of the same data that represents the probability of moving within sliding five-year age ranges. Only household heads above the age in question are included in the data for each age, meaning that values below 21 contain 100% of the sample (our youngest respondent was 21), age 35 contains 64% of the sample, and age 50 contains 20.7% of the sample. I have truncated this graph at age 50 as beyond that point less than 20% of my sample is included and variation increasingly becomes dominated by single individuals.

Table 2-2: Results from Tobit models with household characteristics as predictors of two aspects of land acquisition: the area of land acquired by the household within two years of arrival and the total area of land acquired by the household up to the date of interview.

	Land acquired within two years of arrival (ha)			*Total land acquired (ha)*		
	(a)	(b)	(c)	(a)	(b)	(c)
(Intercept)	-2.408 (8.162)	7.844 (8.79)	8.723 (8.615)	6.717 (12.444)	28.549 (13.324) *	28.674 (13.188) *
Household head age†	0.252 (0.127) *	0.179 (0.126)	0.164 (0.122)	0.436 (0.194) *	0.410 (0.192) *	0.398 (0.188) *
Household members†	-0.105 (0.860)	-0.215 (0.837)	-0.257 (0.813)	-1.355 (1.309)	-1.101 (1.264)	-1.24 (1.240)
H. working age prop.†	1.883 (6.711)	2.967 (6.444)	2.048 (6.269)	-6.336 (10.229)	-4.252 (9.772)	-5.016 (9.608)
Previously sold land		6.15 (2.654) *	5.442 (2.582) *		3.42 (4.029)	2.629 (3.954)
Distance migrated (km)		-0.014 (0.009)	-0.012 (0.009)		-0.025 (0.014) ∘	-0.023 (0.014) ∘
Arrival - years after ref.		-0.355 (0.192) ∘	-0.354 (0.188) ∘		-0.883 (0.290) **	-0.845 (0.287) **
HH born sierra			0.712 (2.753)			3.344 (4.235)
HH born coast			-8.955 (3.312) **			-10.463 (5.044) *
Previously urban			4.796 (4.039)			3.254 (6.190)
Dummy - Shamboyacu	2.583 (3.182)	-2.049 (4.753)	-0.555 (4.63)	1.703 (4.81)	-9.958 (7.187)	-8.23 (7.063)
Dummy - Alto Biavo	14.9 (3.415) ***	10.733 (5.62) .	12.451 (5.459) *	16.071 (5.188) **	3.618 (8.482)	5.729 (8.317)
Log(scale)	2.731 (0.059) ***	2.687 (0.059) ***	2.653 (0.059) ***	3.163 (0.057) ***	3.114 (0.057) ***	3.090 (0.057) ***
n; n censored at 0	156; 11	156; 11	156; 11	156; 0	156; 0	156; 0
Log likelihood	-611.45	-605.33	-599.97	-714.76	-707.17	-703.37
LRT - with null model	29.76 $_5$ ***	42.00 $_8$ ***	52.72 $_{11}$ ***	20.36 $_5$ **	35.52 $_8$ ***	43.13 $_{11}$ ***
LRT - with model to left	-	12.24 $_3$ **	10.72 $_3$ *	-	15.17 $_3$ **	7.61 $_3$.

Significance levels of p-values as follows: *** < 0.001 ** < 0.01 < * <0.05 < ∘ < 0.1.

† All household characteristics relative to status at time of arrival in district of residence.

When the models were made one step more complex ('b' columns in Table 2-2) by adding variables describing the most recent migration event–whether or not the household had sold land before migrating, the distance moved, and the year of arrival–the fit of the models improved significantly over the minimal model as measured by likelihood ratio tests. In these models, whether or not a household had sold land before leaving their previous district of residence was a significant positive predictor of how much land they acquired in their first two years in their new area of residence; however, it was not a significant predictor of the total land they had acquired up to the date of the interview. For the total land acquired, the two significant predictors in the model were the age of the household head at the time of arrival and the arrival year. Household heads who arrived at older ages were associated with larger amounts of total land acquired while arriving in more recent years was associated with smaller amounts.

In the last set of models ('c' columns in Table 2-2) I added variables that reflected the household head's background and origin–whether he/she was born in the sierra or on the coast, and whether he/she had previously lived in an urban area. According to the likelihood ratio test, this more complex model was a significant improvement over the previous model with respect to predicting the land a household acquired within their first two years; however, it gave only a marginally significant improvement with respect to predicting the total land acquired ($p=0.055$). In both models, households where the household head was originally from the coast acquired less land overall than those households headed by individuals from the Amazon. However, there was no significant difference between individuals born in the *sierra* and those born in an Amazon district. Whether or not an individual had sold land prior to moving was the only other significant predictor of the land a household would acquire in its first two years in the distrct. With respect to the total land acquired by a household, the age of the household head at arrival and the household's time of arrival relative to the district reference year were both significant predictors of the total land it had acquired by the time of being interviewed.

According to the marginal effects of those significant predictor variables, my models suggest that a household that sold land prior to moving to a study community was likely to acquire 4.4 ha more land in their first two years after arrival than would a household that did not sell land prior to arrival (Table 2-3). This estimate and other marginal effect estimates here assume a positive value for the outcome variable and are made at the mean of the predictor variables. This effect of selling land was smaller than the effect of a coastal birth by the household head: households headed by individuals born in coastal districts were associated with land acquisitions in the first two years that were 7.2 ha smaller than those who were born in the reference category–Amazonian districts. Lastly, new arrivals to the district of Alto Biavo tended to acquire slightly more than 10 ha more land than new arrivals in other districts in their first two years.

For the total amount of land acquired, the significant predictors were the household head age at arrival, the time of arrival relative to the district reference year, and whether or not the household head was born in a coastal area. Each additional year of age of the household head at arrival was associated by 0.31 additional hectares later acquired, while each year later a household established in the district was associated with 0.66 ha fewer hectares acquired. Whether or not a household head was born on the coast was again associated with a reduction in total land acquisition–in this case by 8.1 ha.

Table 2-3: Marginal effects from Tobit models of land acquired, forest clearing, and forest holding from tobit models. In each case, the model with all variables was used for calculating marginal effects–i.e., the (c) columns in Tables 2-2 and 2-4. Marginal effects are calculated assuming non-zero values of the dependent variable and at mean values of the explanatory variables.

	Land acquired within two years of arrival (ha)	Total land acquired (ha)	Total forest cleared from time of arrival (ha)
Household head age†	0.1324	0.3087 *	0.0688 *
Household members†	-0.2067	-0.9617	-0.3913 ∘
H. working age prop. †	1.6502	-3.8894	-2.5485
Previously sold land	4.3846 *	2.0384	-0.0747
Distance migrated (km)	-0.01	-0.0182 ∘	-0.0006
Arrival - years after reference	-0.2849 ∘	-0.6552 **	-0.3148 ***
HH born sierra	0.5735	2.5928	0.6927
HH born coast	-7.2153 **	-8.1131 *	-1.975 *
Previously urban	3.8641	2.523	-0.421
Dummy - Shamboyacu	-0.4469	-6.3811	-3.9237 **
Dummy - Alto Biavo	10.0318 *	4.4424	-2.4823

Significance levels of p-values as follows: *** < 0.001 ** < 0.01 < * < 0.05 < ∘ < 0.1.
† All household characteristics relative to status at time of arrival in district of residence.

Our models were able to predict the total amount of forest that households had cleared; likelihood ratio tests demonstrated that each of the three models was a significant improvement over the null model ($p < 0.01$; Table 2-4). The intermediate model that included characteristics of the migration event was a highly significant ($p < 0.001$) improvement over the more basic model that only included household characteristics, whereas the model including predictors characterizing the household head's background was a more modest improvement ($p < 0.05$) over the intermediate model. Of the basic household characteristics–household head age, number of members, and working age proportion–only household head age was significant and only in the final model. The year of arrival after the reference year was a highly significant negative predictor in both of the models in which it was included with later arrivals deforesting less than earlier arrivals. Households headed by individuals from coastal districts and households in Shamboyacu were both associated with lower levels of deforestation relative to the reference cases.

Table 2-4: Tobit model results of household characteristics as predictors of total forest clearing by households.

	Total forest cleared from time of arrival (ha)		
	(a)	(b)	(c)
(Intercept)	4.072 (3.228)	13.397 (3.224) ***	13.309 (3.166) ***
Household head age†	0.07 (0.05)	0.089 (0.046) ◦	0.091 (0.045) *
Household members†	-0.596 (0.339) ◦	-0.467 (0.305)	-0.516 (0.297) ◦
H. working age prop.†	-3.584 (2.66)	-3.243 (2.374)	-3.361 (2.315)
Previously sold land		0.104 (0.976)	-0.099 (0.952)
Distance migrated (km)		-0.002 (0.003)	-0.001 (0.003)
Arrival - years after reference year		-0.433 (0.07) ***	-0.415 (0.069) ***
HH born sierra			0.914 (1.016)
HH born coast			-2.605 (1.228) *
Previously urban			-0.555 (1.52)
Dummy - Shamboyacu	1.505 (1.275)	-5.463 (1.756) **	-5.175 (1.714) **
Dummy - Alto Biavo	4.514 (1.362) ***	-3.706 (2.046) ◦	-3.274 (1.991)
Log(scale)	1.783 (0.065) ***	1.662 (0.065) ***	1.63 (0.065) ***
n	156	156	156
n censored (at 0)	31	31	31
Log likelihood	-426.88	-408.06	-404.11
LRT - with null model	18.29_{5} **	55.92_{8} ***	63.82_{11} ***
LRT - with model to left	-	37.63_{3} ***	7.9_{3} *

Significance levels of p-values as follows: *** < 0.001 ** < 0.01 < * < 0.05 < ◦ < 0.1
† All household characteristics relative to status at time of arrival in district of residence

The marginal effect of the household head's age at time of arrival, although significant, was relatively small: each additional year of age was associated with only 0.07 ha of additional clearing–so an age difference of 14.5 years would correspond to a one-hectare difference

(Table 2-3). There is a larger effect of arrival time: each additional year later that a household arrived in the study area was associated with 0.32 ha less total forest clearing. Households with heads born on the coast were associated with 2.0 ha less forest clearing than households with heads born in the Amazon while households in Shamboyacu were associated with 3.9 ha less forest clearing than households in Pardo Miguel.

2.4.3. Migration intentions

Overall, 44.6% of respondents had considered leaving their community and moving to another area (Figure 2-9). This proportion was lowest in Alto Biavo–the most recently-settled district–where only 39.6% had considered moving. In Pardo Miguel and Shamboyacu, the figure was 50.9% and 43.3% respectively. A probit model using household variables performed relatively well at predicting whether or not a household had considered moving to another area. The overall model with all districts combined was a significant improvement over the null model by a likelihood ratio test ($p = 0.006$) and it had a 66.1% correct prediction rate. When the model was split by districts, the individual models for Shamboyacu and Pardo Miguel significantly outperformed the null models ($p = 0.033$ for both) and correctly predicted 82.0% and 71.2% of outcomes (Table 2-5). In Alto Biavo, my model did not significantly outperform the null model. In the three significant models–Shamboyacu, Pardo Miguel, and combined–the number of years that a household head had lived in a community was a significant negative predictor of that household head having considered migrating. Each additional year of residence was associated with a 2.1% lower probability of considering moving in Shamboyacu and a 3.5% lower probability in Pardo Miguel. In the overall model–with all districts combined–a household's earnings from crops in the previous year was significantly associated with a higher likelihood of considering migrating. In this case, each additional thousand dollars equivalent of income was associated with a 6.6% increased chance. In the Shamboyacu model, this value was marginally significant ($p = 0.051$) and in that case, each additional thousand dollars was associated with a 27.1% increase in the probability of the household having considered migrating.

Table 2-5: Marginal effects from probit model (with standard errors in parentheses) for the predictors of a household head having considered leaving current community of residence for a new area. Results are shown for for all districts combined as well as for each district individually. Year of sampling indicated after district name.

	All districts	Shamboyacu (2012)	Pardo Miguel (2013)	Alto Biavo (2013)
Intercept	0.154 (0.29)	-0.67 (0.676)	0.147 (0.474)	-1.166 (0.671) ◦
Household head - age	-0.001 (0.005)	0.009 (0.01)	-0.001 (0.009)	0.002 (0.011)
Household head - years established in community	-0.016 (0.006) **	-0.021 (0.010) *	-0.035 (0.014) *	0.034 (0.022)
Household - number members	-0.007 (0.030)	0.044 (0.068)	-0.001 (0.050)	0.057 (0.067)
Household - working age proportion	0.222 (0.254)	0.691 (0.604)	0.238 (0.419)	0.55 (0.568)
Household head - lived in urban area in past	0.021 (0.139)	-0.029 (0.22)	-0.098 (0.362)	0.198 (0.268)
Adult children living outside community	-0.003 (0.116)	-0.005 (0.249)	-0.238 (0.180)	0.307 (0.214)
Total holdings	-0.003 (0.003)	-0.013 (0.013)	0.007 (0.008)	-0.007 (0.006)
Percent of holdings in forest	-0.002 (0.002)	-0.006 (0.007)	-0.004 (0.003)	0.001 (0.004)
Earnings from crops in past 12 months (thousands USD)	0.066 (0.024) **	0.271 (0.140) ◦	0.042 (0.032)	0.096 (0.051) ◦
Shamboyacu (dummy)	-0.195 (0.117)			
Alto Biavo (dummy)	-0.106 (0.144)			
n	168	50	66	52
Log likelihood	-102.2	-25.5	-36.1	-29.7
McFadden's pseudo R^2	0.146	0.330	0.201	0.166
Likelihood ratio test with null model	26.04_{11} **	18.16_{9} *	18.23_{9} *	10.77_{9}
% correctly predicted	66.1%	82.0%	71.2%	75.0%

Significance levels of p-values as follows: *** < 0.001 ** < 0.01 < * < 0.05 < ◦ < 0.1

Of those individuals who expressed a clear preference, the most common plan for future destination was a town or a city area for 41.7%, 68.4%, and 81.3% of respondents in Shamboyacu, Pardo Miguel, and Alto Biavo, respectively (Figure 2-10). Household heads whose preference would be to move to more frontier areas–i.e., areas where settlement was more recent and available land was cheaper–represented 25.0%, 26.3%, and 12.5% in the same districts. It is worth noting that the lowest percentage is in Alto Biavo–the district that is most recently settled and where at the time of interviews land was still relatively inexpensive and available. The third category of destinations was rural areas that were less remote than respondents' current areas of residence. In most cases, this category included individuals who expressed a desire to move back to districts of origin in the *sierra*. In Shamboyacu, this represented one third of those individuals who stated a preference for a particular destination; however, in Pardo Miguel and Alto Biavo this was much lower–5.3% and 6.3%, respectively. This drop with the two districts sampled in 2013 is likely because of the *roya*: individuals believed–I assume correctly although I do not have independent confirmation–that the outbreak was even worse in the longer-established coffee growing zones of the *sierra* than it was in San Martin. The incentive to move back to that area for agriculture was therefore greatly reduced.

Individuals who express a preference to move to the frontier seem to be generally poorer than those who express a preference for migration to a town or city (Table 2-6). These differences are not statistically significant on any individual district-variable combination, but the pattern is consistent on nine combinations of three variables–earnings from agriculture in the last 12 months, total land holdings, or land holdings in crop and pasture–in three districts. In each district, values for those three variables–agricultural earnings, total land holdings, and land holdings in crop or pasture–were 1.2 to 3.0 times higher for household heads who expressed a preference for moving to urban areas than they were for those who were interested in moving to the frontier. Income from agriculture was two to three times higher on average within the urban preference group than within the frontier preference group in each of the three districts.

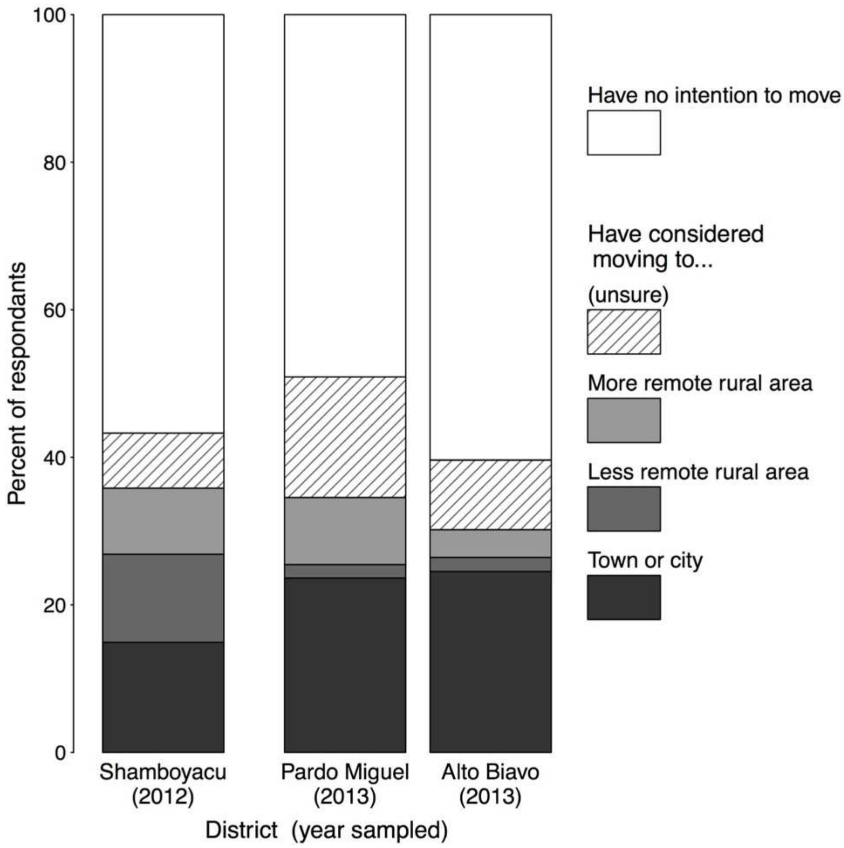

Figure 2-9: Percent of respondants in each district who reported having considered moving to another community (all non-white bars), and the percentage breakdown within those respondants who indicated a preference of moving to three categories of locations (or who were unsure about where they preferred to move).
'More remote' and 'less remote' rural areas were defined as areas where the respondent expected the land price per hectare to be respectively cheaper or more expensive than the district they currently resided in.

Table 2-6: Descriptive statistics of household data grouped by stated migration preference.

Variable	District	Have not considered migrating	Unsure or other	Frontier preference	Urban preference	Urban-Frontier difference p-value	Urban / Frontier ratio
Age of household head	*Shambo-yacu*	40.8 (11.9)	36.1 (8.4)	39.5 (6.6)	33.3 (12.2)	0.210	0.84
	Pardo Miguel	41.2 (11.9)	42.2 (9.5)	41.4 (15.4)	37.0 (10.1)	0.584	0.90
	Alto Biavo	38.3 (12.7)	41.1 (8.4)	40.0 (18.3)	39.2 (7.1)	0.962	0.98
Number of household members	*Shambo-yacu*	4.9 (2.1)	4.5 (1.7)	5.1 (1.9)	4.0 (1.5)	0.243	0.77
	Pardo Miguel	4.5 (1.6)	4.5 (1.6)	4.4 (1.1)	4.2 (2.3)	0.842	0.96
	Alto Biavo	5.0 (1.6)	4.3 (2.2)	6.5 (3.5)	5.5 (1.6)	0.767	0.85
Earnings from agriculture - 12 months (USD)	*Shambo-yacu*	1926 (1624)	2533 (2641)	2122 (3155)	4561 (7113)	0.363	2.15
	Pardo Miguel	465 (475)	1043 (1720)	445 (512)	1237 (1260)	0.076 ◦	2.78
	Alto Biavo	1362 (1518)	2077 (1492)	957 (168)	2901 (2767)	0.027 *	3.03
Total land holdings (ha)	*Shambo-yacu*	11.5 (12.5)	11.5 (12.0)	6.8 (6.9)	13.3 (18.1)	0.331	1.95
	Pardo Miguel	14.6 (16.8)	6.8 (11.9)	3.5 (3.5)	5.1 (5.8)	0.475	1.48
	Alto Biavo	22.9 (25.5)	13.5 (8.5)	11.1 (12.5)	25.6 (17.0)	0.311	2.30
Land holdings in crop or pasture (ha)	*Shambo-yacu*	4.3 (3.9)	4.3 (3.2)	3.6 (2.7)	4.4 (4.2)	0.683	1.20
	Pardo Miguel	6.8 (7.0)	3.7 (5.1)	2.6 (2.5)	3.1 (2.4)	0.697	1.21
	Alto Biavo	5.2 (4.2)	4.5 (4.0)	2.6 (0.5)	5.4 (3.9)	0.027 *	2.11

Significance levels of p-values as follows: *** < 0.001 ** < 0.01 < * < 0.05 < ◦ < 0.1. Mean values with standard deviations in parentheses.

2.5. Discussion

The patterns of migration observed among 194 interviewees support the broad trends that are evident in the Peruvian census (INEI, 2014) and that have been documented by other authors (Imbernon, 1999; Schjellerup, 2000). The census indicates that in the districts of

Shamboyacu, Pardo Miguel, and Alto Biavo the percentage of residents in 2007 who had lived in a different district five years previously was 35.2%, 20.6%, and 19.1%, respectively. Among the study communities, I found that only two interviewees in sample of 194 household heads had been born in their community of residence (and a third in a different community in the same district). The average time of residence among my sample was 9.2, 16.1, and 7.8 years, respectively. As Schjellerup (2000) documented in a different area of San Martin, migrants are indeed overwhelmingly from the Andean *sierra* with more than half having been born in the Andean region of Cajamarca and most of the remaining household heads born in Piura and Amazonas–two additional regions situated partly in the *sierra*.

Migration events described by interviewees were commonly over distances of hundreds of kilometers. This was true of the distance between household districts of residence and the household heads' districts of birth (median 328 km) and was also true of the distance traveled by the household in their most recent migration event (median 192 km). About half of respondents had moved to the study communities from districts intermediate between them and their districts of birth. However, 47% of household heads had moved directly from their region of birth in the *sierra* to the study communities and about two percent had moved to the frontier after living for some years in the coastal cities of Lima and Trujillo. These moves seem to contrast with the narrative often associated with the hollow frontier hypothesis that new frontier areas are opened by poor agriculturalists moving incrementally further into forested areas after having sold previously failed farms (Rudel et al., 2002). The directness and distance of many of the migration events I observed suggests a high level of information gathering and consideration of the area of destination.

In confirmation of previous work by Carr (2009), Laurian et al. (1998), and Parry et al. (2010a), I found that family and social ties were very important to household migration decisions. This is illustrated by the strong clustering of birth districts by community in the sample (Figure 2-4). Several of the study communities had significant over-representation of people born in specific districts. Interviewees frequently reported that their motivation for moving to the study communities was because a family member was already there or because a friend from their district of origin had informed them of the opportunity for land. These networks–both of family connections and of information–are often the primary reason that households decide to move to the specific frontier community that they do. In some cases, these information networks are created intentionally as early arrivers to the frontier return to their districts of origin and actively recruit people to move to those communities they have established. For households in frontier communities, it is often to their advantage to encourage new people to arrive: as the local population increases, there are more potential buyers for land and there is an improved chance that the government will provide health, infrastructure, and education services to the area. The strong impact of networks suggests that in this area, the patterns of settlement in Amazonian districts are to a great degree determined by social processes hundreds of kilometers away in the *sierra*. Further research in communities in the *sierra*–particularly on the process of recruitment by early arrivals and on related social networks–may be promising avenues to better understand the colonization of Peru's upper Amazon.

As has been documented by many authors, family life cycles play an important role in the timing of household migration (Carr, 2009; Perz and Walker, 2002; Walker et al., 2002). Young families and young single adults are the most likely individuals to migrate. I did observe this in my data: more than one third of interviewees had moved residence at least once between the ages of 21 and 25. This was the highest probability observed for any five-year age range. However, despite rates of migration peaking in the early twenties, migration events remain quite common for a much broader period. The probability of individuals migrating remained at 20% or higher for every five-year sliding age window between the teens and the early forties.

This suggests that the life cycle model for migration, while certainly important, is not a sufficient explanation for migration patterns. Households continue to migrate with frequencies that decline only slightly through later decades.

2.5.1. Land acquisition and forest clearing

The financial assets a household brings to the frontier–indicated by whether or not they had sold land when leaving their previous area of residence–is a significant predictor of how much land that household acquires in their first two years after arrival. This supports previous work which found that those who had migrated with more resources at their disposal did tend to have higher incomes later (Murphy, 2001). In this study, the advantage of initial assets seems to not be long lasting: the same variable does not effectively predict the total amount of land acquired over a household's entire period of residence in the study district–only the early acquisitions. One explanation for this difference could be that the importance of an initial advantage in asset holdings declines over time: while those who sold land previously may be able to acquire more land sooner, other arrivals to the area are able to catch up over time through a slower acquisition process. Other studies have shown that larger land parcels tend to maintain a larger percentage of forest cover through time although are responsible for more total forest clearing than smaller parcels (D'Antona et al., 2006; Michalski et al., 2010). These differences in initial acquisitions will likely have an effect on the structure of remaining forest cover on the landscape: if more households acquire larger parcels, local percent forest cover may remain higher for a longer period of time. However, given the same population pressure, the frontier may expand further and result in more forest loss overall.

When I included indicators of the household head's origin–whether district of birth was coast, *sierra*, or Amazon and whether or not he/she had lived in an urban area in the past–our model's ability to predict rates of land acquisition did improve significantly. However, the only variable that was independently significant was whether or not the household head was born on the coast: those individuals acquired significantly less land than the reference case of individuals born in the Amazon. I do not have a conclusive explanation for why this would be the case; it could be because of familiarity with different production systems–agriculture in coastal Peru tends to more intensive than in the Amazon which is generally more extensive. It could also result from individuals on the coast being less likely to have good social networks in these areas that are primarily settled by individuals from the *sierra*.

The area of forest that a household cleared is best predicted by the age of the household head at the time of arrival in the study community, whether or not the household head is from the coast, and the timing of arrival relative to when the frontier began to be opened. For every year later that a household arrived to the frontier, the total amount of forest that they cleared was about 0.3 ha less. It is likely that this is largely a time effect: individuals who have been in an area longer have had more time to clear more forest. Early arrivals will also tend to acquire parcels that are more heavily forested to begin with, meaning that crop establishment will require more clearing (Carrero and Fearnside, 2011)(Chapter 3).

2.5.2. Migration and income

Households with higher earnings from agriculture were more likely to have considered leaving the study community for another location. This stands in contrast with several models of frontier development that suggest that either poverty or poor farm production is primarily responsible for out-migration in rural areas (Barbieri et al., 2006; Caviglia-Harris et al., 2012; Rudel et al., 2002). In Rondonia, Brazil, Caviglia-Harris and colleagues (2012) indeed showed empirically individuals who had migrated tended to be younger and tended to have fewer assets. There are various possible reasons for the differences between these results and mine. For one, my results involve a stated preference rather than observed migration behavior, so it is possible that the actual migration decisions of the interviewees in future will be different from their stated preferences now. At the same time, there are reasons to believe why households with more resources might be more likely to move. Migration and reestablishment of a household in a new location involves significant risk and transaction costs. The act of moving itself is an expense, and buying land in a less-known area puts an individual at risk of paying an unfair price. If a household is considering a move to an urban area, the cost of reestablishment is likely even higher because of higher housing costs in cities and the lessened ability of households to grow subsistence food. For individuals with limited income and financial assets, migration may therefore seem too large a cost to bear. There is a possibility that previous studies reporting more migration among individuals with fewer assets are actually observing a sampling artifact, i.e., if young adults are more likely to migrate (as has been established), and young adults also tend to have fewer assets as they have had less time to accumulate wealth, a negative correlation would exist between assets and migration frequency even if there were no causal link between them. By controlling for age and time established in the study community in the model of migration intention, I have reduced the chance that my model would be so affected.

2.5.3. Factors influencing destination choice for migration.

Many studies have described a dichotomy in rural migration choices between those individuals who migrate further towards the frontier versus those who choose to move to urban areas (Carr, 2009; Caviglia-Harris et al., 2012; Parry et al., 2010a). In a study of migration from a frontier area in Rondonia, Brazil, Caviglia-Harris and colleagues (2012) found that roughly similar percentages of mobile individuals left the Amazon region entirely (15%) as moved to other municipalities within the Amazon (13%). However, for those that stayed within the Amazon, the authors were not able to determine what portion had moved to new frontier areas and what portion had moved to larger towns or cities. Among respondents, about twice as many were interested in moving to urban areas as were interested in moving to more remote frontier areas. As discussed above, establishment in urban areas is likely more expensive than establishment of a new frontier homestead, so stated preferences may overestimate the true proportion of total migration that rural-urban migration is likely to contribute. However, it is clear that for many individuals, the better services that are available in urban centers and in less-remote rural areas exert a strong pull.

As discussed above, households with higher agricultural earnings were more likely overall to consider migrating in the future. This includes all households that might migrate and did not differentiate among the destinations that households considered. When I evaluated that difference, I found that households that had considered moving to urban areas tended to be better-off than households that would consider moving to the frontier. This was true in all three districts across three metrics: the household's total land holdings, their land holdings in crops or pasture, and their income from agriculture in the previous twelve months. These differences were not statistically significant, but given their consistency across variables and districts I believe this could merit further investigation with a larger sample size. Wealthier households may be more likely to choose to move to urban areas rather than the frontier because housing in towns is expensive, and establishing any kind of business–as many respondents stated was their desire if they moved to a town–requires initial financial investment. Moving to a newer frontier, on the other hand, is likely to be the one option available where migration could lead to a reduced financial burden. The sale of land in the current district of residence would allow the purchase of equivalent land for much cheaper at a more remote frontier location (Carrero and Fearnside, 2011) (Chapter 3). This pattern suggests a way to reconcile my findings with extant models of frontier migration. While most frontier migration models suggest that out-migration is driven by poverty or failed land, my results suggested that it was in fact households with higher earnings that are more likely to consider migrating. It may be that this difference in wealth increases the probability of migration to urban areas while having less effect or perhaps even the opposite effect on the probability of frontier migration.

2.6. Conclusions

Migration plays a central role in the expansion of settlement in Peru's upper Amazon. Given that this area has one of the highest rates of deforestation in the Amazon basin, understanding the process of migration and how it affects land use is essential to any potential forest conservation policy. In this study, I found that migration events tended to involve relatively long distances and were structured by social and family networks based in households' areas of origin. From my results, it was not clear that poverty was a primary driver of migration as some models of frontier migration have depicted; in fact, I found that households with higher crop incomes were more likely to have considered migrating to a new district. Households with more resources when they arrived on the frontier acquired more land within their first two years of arrival. Because of likely differences in the rates of forest clearing on parcels of different sizes, this difference in land acquisition may have important effects on the longer-term patterns of deforestation on the frontier.

Among the smallholder farmers I interviewed, rural to urban migration is likely to be as prevalent or more prevalent than further migration to the frontier. Many household heads are drawn to the services provided in towns and in less remote areas. Although moving further into the frontier provides an opportunity for inexpensive land extension, it seems that–having moved to a frontier area once already–fewer households are interested in migrating again to an area even more remote. If rural to urban migration does in fact increase, it may serve to reduce the rate of advance of this rapidly-moving frontier.

2.7. References

Alvarez, N.L., Naughton-Treves, L., 2003. Linking national agrarian policy to deforestation in the Peruvian amazon: a case study of Tambopata, 1986–1997. *AMBIO* 32: 269–274.

Angelsen, A., Kaimowitz, D., 1999. Rethinking the causes of deforestation: Lessons from economic models. *World Bank Res Obs* 14: 73–98.

Ballantyne, B., Bristow, M., Davison, B., Harrington, S., Khan, K., 2000. How can land tenure and cadastral reform succeed? an inter-regional comparison of rural reforms. *Canadian Journal of Development Studies/Revue canadienne d'études du développement* 21: 693–723.

Barbieri, A.F., Bilsborrow, R.E., Pan, W.K., 2006. Farm household lifecycles and land use in the Ecuadorian Amazon. *Popul Environ* 27: 1–27.

Bates, D., Rudel, T.K., 2004. Climbing the “agricultural ladder”: social mobility and motivations for migration in an Ecuadorian colonist community. *Rural Sociology* 69(1): 59-75.

Brack Egg, A., 1997. Pobreza y manejo adecuado de los recursos en la Amazonia Peruana. *Revista Andina* 15: 15–40.

Brown, D.S., Brown, J.C., Brown, C., 2016. Land occupations and deforestation in the Brazilian Amazon. Land Use Policy 54, 331–338.

Carr, D.L., 2004. Proximate Population Factors and Deforestation in Tropical Agricultural Frontiers. *Popul Environ* 25: 585–612.

Carr, D.L., 2009. Population and deforestation: Why rural migration matters. Progress in *Human Geography* 33: 355–378.

Carr, D.L., Suter, L., Barbieri, A.F., 2006. Population Dynamics and Tropical Deforestation: State of the Debate and Conceptual Challenges. *Popul Environ* 27: 89–113.

Carrero, G.C., Fearnside, P.M., 2011. Forest clearing dynamics and the expansion of landholdings in Apuí, a deforestation hotspot on Brazil’s Transamazon Highway. *Ecology and Society* 16(2).

Caviglia-Harris, J.L., Sills, E.O., Mullan, K., 2012. Migration and mobility on the Amazon frontier. *Popul Environ* 34: 338–369.

D’Antona, Á.O., VanWey, L.K., Hayashi, C.M., 2006. Property size and land cover change in the Brazilian Amazon. *Popul Environ* 27: 373–396.

DRE, 2013. Padrón de centros y programas educativos – 2013 (*Census of educational centres and educational programs – 2013*). Database. Provided to the author in electronic form. Dirección Regional de Educación (DRE) San Martin. Moyobamba.

Fearnside, P.M., 2001. Land-tenure issues as factors in environmental destruction in Brazilian Amazonia: the Case of Southern Pará. *World Development* 29: 1361–1372.

Fearnside, P.M., 2008. The roles and movements of actors in the deforestation of Brazilian Amazonia. *Ecology and Society* 13(1).

Fujisaka, S., Bell, W., Thomas, N., Hurtado, L., Crawford, E., 1996. Slash-and-burn agriculture, conversion to pasture, and deforestation in two Brazilian Amazon colonies. *Agriculture, Ecosystems & Environment* 59: 115–130.

GADM (Ed.), 2012. GADM database of Global Administrative Areas, 2nd ed. UC Davis. (accessed 12.23.14). Davis, CA.

Henningsen, A., 2013. Package "censReg." R project for statistical computing.

ICO. 2015. Exporting countries: total production. International Coffee Organization. (accessed 3.20.15). London.

Imbernon, J., 1999. A comparison of the driving forces behind deforestation in the Peruvian and the Brazilian Amazon. *Ambio* 28: 509–513.

INEI 2014. Redatam (database). Instituto Nacional de Estadística e Informática. INEI. URL http://censos.inei.gob.pe/Censos2007/redatam (accessed 12.1.14).

JNC, 2013. Más del 30% del área cafetalera peruana ha sido afectada por plaga de Roya. Junta Nacional de Café. Lima.

Kaimowitz, D., Angelsen, A., 1998. Economic models of tropical deforestation: a review. CIFOR. Bogor, Indonesia.

Lambin, E.F., Turner, B.L., Geist, H.J., Agbola, S.B., Angelsen, A., Bruce, J.W., Coomes, O.T., Dirzo, R., Fischer, G., Folke, C., George, P.S., Homewood, K., Imbernon, J., Leemans, R., Li, X., Moran, E.F., Mortimore, M., Ramakrishnan, P.S., Richards, J.F., Skanes, H., Steffen, W., Stone, G.D., Svedin, U., Veldkamp, T.A., Vogel, C., Xu, J., 2001. The causes of land-use and land-cover change: moving beyond the myths. *Global Environ Change* 11: 261–269.

Laurian, L., Bilsborrow, R.E., Murphy, L.L., 1998. Migration decisions among settler families in the Ecuadorian Amazon: the second generation. *Research in Rural Sociology and Development* 7: 169–195.

Margulis, S., 2004. Causes of Deforestation of the Brazilian Amazon. World Bank. Washington D.C.

Michalski, F., Metzger, J.P., Peres, C.A., 2010. Rural property size drives patterns of upland and riparian forest retention in a tropical deforestation frontier. *Global Environmental Change* 20: 705–712.

Murphy, L.L., 2001. Colonist farm income, off-farm work, cattle, and differentiation in Ecuador's northern Amazon. *Human Organization* 60: 67–79.

Naughton-Treves, L., 2004. Deforestation and Carbon Emissions at Tropical Frontiers: A Case Study from the Peruvian Amazon. *World Development* 32: 173–190.

Parry, L., Day, B., Amaral, S., Peres, C.A., 2010a. Drivers of rural exodus from Amazonian headwaters. *Popul Environ* 32: 137–176.

Parry, L., Peres, C.A., Day, B., Amaral, S., 2010b. Rural-urban migration brings conservation threats and opportunities to Amazonian watersheds. *Conservation Letters* 3: 251–259.

Perz, S.G., 2001. Household demographic factors as life cycle determinants of land use in the Amazon. *Population Research and Policy Review* 20: 159–186.

Perz, S.G., Aramburú, C., Bremner, J.L., 2005. Population, Land Use and Deforestation in the Pan Amazon Basin: a Comparison of Brazil, Bolivia, Colombia, Ecuador, Perú and Venezuela. *Environ Dev Sustain* 7: 23–49.

Perz, S.G., Walker, R.T., 2002. Household life cycles and secondary forest cover among small farm colonists in the Amazon. *World Development* 30: 1009–1027.

Potapov, P.V., Dempewolf, J., Talero, Y., Hansen, M.C., Stehman, S.V., Vargas, C., Rojas, E.J., Castillo, D., Mendoza, E., Calderón, A., Giudice, R., Malaga, N., Zutta, B.R., 2014. National satellite-based humid tropical forest change assessment in Peru in support of REDD+ implementation. *Environmental Research Letters* 9: 1–13.

Redo, D., 2011. The role of the individual producer in driving land change: the case of Santa Cruz, Bolivia, 1986–2006. *GeoJournal*: 10.1007/s10708-011-9432-8.

Rindfuss, R.R., Entwisle, B., Walsh, S.J., Mena, C.F., Erlien, C.M., Gray, C.L., 2007. Frontier land use change: Synthesis, challenges, and next steps. *Annals of the Association of American Geographers* 97: 739–754.

Rudel, T.K., Bates, D., Machinguiashi, R., 2002. A tropical forest transition? Agricultural change, out-migration, and secondary forests in the Ecuadorian Amazon. *Annals of the Association of American Geographers* 92: 87–102.

Rudel, T.K., Horowitz, B., 1993. Tropical Deforestation: Small Farmers and Land Clearing in the Ecuadorian Amazon. Columbia University Press, New York.

Schelhas, J., Sánchez-Azofeifa, G.A., 2006. Post-frontier forest change adjacent to Braulio Carrillo National Park, Costa Rica. *Human Ecology* 34: 407–431.

Schjellerup, I., 2000. La Morada. A case study on the impact of human pressure on the environment in the Ceja de Selva, Northeastern Peru. *Ambio* 29: 451–454.

Southgate, D., 1990. The causes of land degradation along "spontaneously" expanding agricultural frontiers in the Third World. *Land Economics* 66: 93–101.

Sun, C., 2014. Package "erer." R project for statistical computing.

Walker, R., Perz, S.G., Caldas, M., Silva, L.G.T., 2002. Land use and land cover change in forest frontiers: the role of household life cycles. *International Regional Science Review* 25: 169–199.

Wooldridge, J.M., 2006. Introductory Econometrics: A Modern Approach, Third Edition. ed. Thomson South-Western, Mason, OH.

Wright, S.J., Muller-Landau, H.C., 2006. The future of tropical forest species. *Biotropica* 38: 287–301.

2.8. Supplementary info

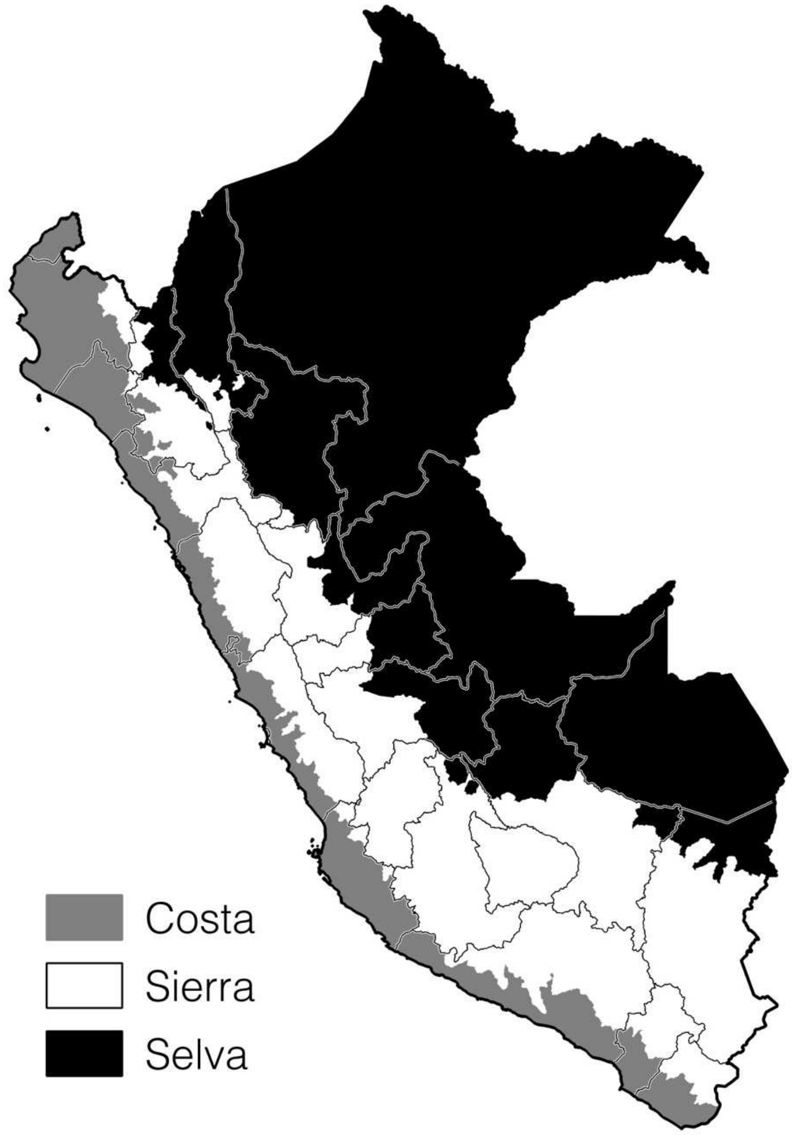

Figure 2-10 (supplementary): Map of the three district categorizations used in migration analysis (coast/*costa*; Andes/*sierra*; Amazon/*selva*).
These were defined using a 2000m threshold for average district elevation (determined from digital elevation model); above 2000m I classified the district as *sierra* while below it was classified as either *costa* or *selva*. Differentiation between *costa* and *selva* was determined based on whether the district was in the Pacific watershed (*costa*) or Atlantic watershed (*selva*).

Table 2-7 (supplementary): Equivalent table to Table 2-5, but presents results from logit model rather than probit model (as used in Table 2-5). Results qualitatively similar.

	All districts	Shamboyacu (2012)	Pardo Miguel (2013)	Alto Biavo (2013)
Intercept	0.136 (0.299)	-1.231 (0.697) ∘	0.112 (0.491)	-1.231 (0.697) ∘
Household head - age	0 (0.005)	0.002 (0.011)	-0.001 (0.01)	0.002 (0.011)
Household head - years established in community	-0.016 (0.006) **	0.038 (0.023)	-0.036 (0.015) *	0.038 (0.023)
Household head - lived in urban area in past	0.024 (0.144)	0.212 (0.275)	-0.11 (0.371)	0.212 (0.275)
Household - number members	-0.006 (0.031)	0.062 (0.069)	0.003 (0.053)	0.062 (0.069)
Household - working age proportion	0.237 (0.262)	0.596 (0.592)	0.271 (0.441)	0.596 (0.592)
Adult children living outside community	-0.002 (0.118)	0.351 (0.219)	-0.261 (0.171)	0.351 (0.219)
Total holdings	-0.003 (0.004)	-0.008 (0.007)	0.008 (0.008)	-0.008 (0.007)
Percent of holdings in forest	-0.002 (0.002)	0.001 (0.004)	-0.004 (0.003)	0.001 (0.004)
Earnings from crops in past 12 months (thousands USD)	0.066 (0.025) **	0.104 (0.056) ∘	0.044 (0.033)	0.104 (0.056) ∘
Shamboyacu (dummy)	-0.195 (0.119)			
Alto Biavo (dummy)	-0.107 (0.146)			
n	168	52	66	52
Log likelihood	-102.3	-29.5	-36.1	-29.5
McFadden's pseudo R^2	0.145	0.172	0.201	0.172
Likelihood ratio test with null model.	25.85_{11} **	11.21_{9}	18.24_{9} *	11.21_{9}
% correctly predicted	66.7%	75.0%	71.2%	75.0%

Significance levels of p-values as follows: *** < 0.001 ** < 0.01 < * < 0.05 < ∘ < 0.1.

Connecting statement: Migration to land acquisition

In Chapter two, I described broad patterns of migration in Peru from the Andes towards the upper Amazon. I studied migration trajectories of individual households in three districts in the Region of San Martin and examined how conditions of households' arrivals–where they came from, the financial resources they arrived with, and the timing of their arrival relative to the development of the area when they arrived–affected the amount land that they acquired and the extent of forest that they eventually cleared. In addition, I reported households' future migration intentions and explored differences between groups of people who were interested in moving further into the frontier and those who had interest in moving to cities and towns. In Chapter three, I move from the general discussion of migration trajectories and their implications and focus specifically on one aspect of migrants' establishment on the frontier: land acquisition. I will first evaluate how the process of land acquisition changes through time as it transitions from land claims to land purchases. Next, I examine land purchases and their characteristics in order to assess land price dynamics and to determine the implications of changes in land prices for the opportunity cost of conserving forest on the frontier.

Chapter 3. Evolving frontier land markets and the opportunity cost of sparing forests in western Amazonia

3.1. Abstract

Efforts aimed at sparing forests on tropical forest frontiers through REDD+, PES or other forest conservation initiatives rely on a limited understanding of the operation of land markets and their effects on the opportunity cost of forests as frontiers develop. In this chapter, we draw on a unique dataset of land transactions (n = 326 land acquisition events; n = 249 land sales) in three sub-montane frontier forest areas on the eastern slopes of the Peruvian Andes. We analyze reported land sales and purchases that took place between 1979 and 2013 among Amazonian frontier farmers and find highly active land markets in all three areas, often in the absence of formal land tenure. As frontiers developed, parcel size fell, as did the portion of remaining forest cover, and land prices rose, reflecting both forest clearing and general land price inflation as the areas became more populated and developed. Across three study districts in 2013, each hectare of forest cleared raised the price of land by US \$955 to \$1860. Importantly, this opportunity cost per hectare of frontier forest rose markedly over time: by \$86 to \$160 per year between 2003 and 2013, a rate of increase by 2013 of 11-26% per year. Forest conservation programs that rely on estimates of landholders' willingness to accept compensation for sparing forest need to take into account that these values change rapidly as frontiers develop.

3.2. Introduction

Conserving tropical forests requires an understanding of the economic incentives that operate on the agricultural frontier. Land markets play an important role in shaping the incentives faced by frontier actors: prices for land are a deciding factor in whether a frontier area is profitable to settle and they determine incentives for forest clearing (Bowman et al., 2012; Chomitz et al., 2005; Poffenberger, 2009). As land prices increase, the pressure to deforest intensifies as farmers bring more of their land into agricultural production in order to recoup the initial investment; forest left standing therefore represents a forgone opportunity to farmers. The opportunity cost of standing forest is important in the planning of forest conservation efforts, particularly for initiatives aimed at reducing emissions from deforestation and degradation (REDD) and for payments for ecosystem services (PES) schemes (Fisher et al., 2011b; Naidoo and Adamowicz, 2006; Plumb et al., 2012). A higher opportunity cost of standing forest increases the minimum payments that landholders would be willing to accept to conserve forests (Börner et al., 2010; Wunder, 2007).

Few studies to date have investigated land prices in tropical frontier areas. In newly-settled frontier areas, record-keeping on land transactions can be non-existent or spotty at best (Gould et al., 2006; Sills and Caviglia-Harris, 2008). In Latin America, studies on rural land markets have either focused on more developed non-frontier areas (Chomitz et al., 2005; Zegarra, 1999a) or used national surveys that lack information on individual land transactions (Deininger et al., 2003; 2004). To overcome the limitations imposed by scant data on land transactions, researchers have used landholders' stated perception of land value (Merry et al., 2008; Sills and Caviglia-Harris, 2008; Zegarra, 1999a). Alternately, land values have been estimated without reference to land markets by using net present value (NPV) estimates of future agricultural production (Börner and Wunder, 2008; Fisher et al., 2011b; Naidoo and Adamowicz, 2006).

In frontier Amazonia, several predictors of land price have been found consistently among previous studies. First, distance to market depresses prices because of the increased cost of transporting farm inputs and outputs. Second, farmer investment in land parcels in the form of forest clearing or pasture or crop establishment increases land value; forest coverage on land parcels is generally associated with lower prices per hectare (Chomitz et al., 2005; Merry et al., 2008; Sills and Caviglia-Harris, 2008). In one report from Pará, Brazil, pasture was reported to be five to ten times more valuable than the same area of forestland (Mertens et al., 2002). Total area of land parcels and slope have been shown to negatively affect the price per hectare (Chomitz et al., 2005; Sills and Caviglia-Harris, 2008). Merry and colleagues (2008) found that length of the landholder's residence time is positively associated with land price, but–perhaps surprisingly–holding definite title to the land did not affect landholder perceptions of value.

Land prices increase as frontiers advance, and this affects incentives for future land use and forest clearing (Sills and Caviglia-Harris, 2008). Expectations of rising land price encourage land speculation, leading individuals to acquire larger areas of land and clear more forest than they would considering only the productive potential of the land (Naidoo and Adamowicz, 2006; Poffenberger, 2009). Speculation thus plays a key role in accelerating the rate of frontier advancement and associated deforestation (Carrero and Fearnside, 2011; Fearnside, 2002; Kirby et al., 2006). The relative importance of speculative versus productive motivations may change through time as frontiers develop (Carrero and Fearnside, 2011; Fearnside, 2005). It is also important to note–particularly where land speculation is common–that land markets do not depend on the presence of formal land title. Indeed, land markets in Latin America have been described in areas where the proportion of individuals who hold formal title to their land ranges from 18% (Carrero and Fearnside, 2011) and 27% (Merry et al., 2008) to 71% (Alvarado, 1994) and 76% (Zegarra, 1999b).

Forest frontiers are advancing rapidly in many parts of the Amazon basin. The 'arc of deforestation' in the southeast of the basin is the locus of most deforestation; however, rates of deforestation in parts of the western Amazon, on the eastern slopes of the Andes, are just as high as rates in the southeast (Figure 3-1). Twenty percent of the deforestation in Amazonian countries between 2000 and 2012 took place in the five countries that span both the Amazon and the Andes–Bolivia, Colombia, Ecuador, Peru, and Venezuela (Hansen et al., 2013). Peru has the fourth-highest volume of above-ground carbon of any country in the world (Saatchi et al., 2011) and land use change in Peru is estimated to contribute 0.8 gigatonnes of carbon to the atmosphere in the next decade (Asner et al., 2014). Forest loss in the western Amazon is also of great concern for biodiversity: the eastern slopes of the Andes are very species-rich and have one of the highest levels of species endemism on Earth. The eastern slopes are consistently identified as a priority area for biodiversity conservation (Brooks et al., 2006; Swenson et al., 2012).

The processes driving forest loss on either side of the Amazon basin are distinct. Large-scale soya and pasture–responsible for much of Brazilian deforestation–are far less prevalent on the Andean slope (Bradley and Millington, 2008; Eakin et al., 2011; Gay et al., 2006; Morton et al., 2006). Coffee and coca are better adapted to the higher elevations of the Andes than the lowland Amazon and both play an important role in the development of the region (Muschler, 2001; Schroth et al., 2009; UNODC ICMP, 2007). Population composition in the western Amazon also differs from that in the southeast; colonization by Andean migrants who move eastwards into Amazonia is a common dynamic documented in Bolivia (Killeen et al., 2008; Müller et al., 2011; Paneque-Gálvez et al., 2013), Colombia (Sanchez-Cuervo and Aide, 2013), Ecuador (Pichón, 1997; Rudel and Horowitz, 1993) and Peru (Bebbington and Bury, 2009; Ichikawa et al., 2014; Shanee et al., 2015). The high proportion of Andean migrants among frontier colonists in the western Amazon creates a distinct cultural context which may influence land use; place of origin and cultural background are important determinants of agricultural practices (Parry et al., 2010; Redo, 2011). Differences in crops, agricultural scale, and demographic patterns between the western Amazon and the Brazilian Amazon require an understanding of the processes of land cover change that is particular for each region. Importantly, we know much less about land use change and the drivers of deforestation in the western Amazon than we do about the Brazilian Amazon. This is particularly true in Peru where most field-based research along the eastern slopes of the Andes was halted for more than a decade due to political instability and violence in the 1980s and 1990s (Kent, 1993).

This study analyzes land acquisitions–primarily purchases–that occurred between 1968 and 2013 in three frontier areas on the eastern Andean slopes of Peru. Few published studies as yet report data on individual land transactions in rural Latin America, and to our knowledge this is the first study for a recently-settled frontier. We use land purchase data to evaluate land holding changes through time and identify the determinants of land prices using a hedonic pricing model. We then combine these two elements of our analysis–the evolution of parcel characteristics and the pricing model–to assess the changing opportunity cost of forest sparing in each of the three frontier areas. Our findings advance understanding of the economic incentives driving frontier deforestation, particularly in the Andean Amazon, and inform the design of forest conservation and PES programs.

3.3. Study Area

The study was conducted in three frontier districts of San Martin, a region of Peru that borders the Amazonian Regions of Ucayali and Loreto, and the Andean Regions of Huanuco, La Libertad, and Amazonas. San Martin encompasses 51,253 km^2 of territory and elevations range from over 4000m asl on the western border down to 200m asl near Yurimaguas in the lowland Amazon (NASAJAXA, 2009). San Martin had a population of 806,452 in 2013, of which 23.7% lived either in Tarapoto, the largest city and commercial center, or in Moyobamba, the regional capital (INEI, 2013). The region has a Y-shaped network of principal highways with the northeastern branch connecting to the river-based transport of the Amazon while the northwestern and southern branches lead to cities on the coast (Figure 3-1). The first road to connect San Martin to the coast is the northwestern route that was completed in 1974.

The flat, central valleys of San Martin were settled by agriculturalists more than a century ago; in these areas rice and corn are the most widespread crops. Indigenous communities–particularly *Awajún*–exist throughout the region and are concentrated in its north and east; Indigenous land claims do not overlap with community lands of any of the 13 communities discussed in this study. Cattle raising occurs throughout the region, but ranching in San Martin is less economically important than agriculture: producers earn 10.6 times as much from growing coffee in San Martin than they do from selling beef (MINAGRI, 2013; MINAGRI, 2014). At higher elevations, coffee is the dominant crop. San Martin is the second-largest producer of coffee in Peru after the Region of Junin, producing 22% of the national total in 2012 (MINAGRI, 2013). Coffee in San Martin is most prevalent in the upper parts of the secondary valleys that branch from the region's central valleys and principal roadways (Figure 3-1). Coffee–particularly the higher-quality *arabica* variety–performs poorly at low elevations; peak yields have been reported at 1500m in Mexico, while in most areas production below 700m is significantly compromised relative to higher elevations (Muschler, 2001; Schroth et al., 2009). These higher-elevation zones are the focus of most frontier expansion in San Martin and have the highest rates of forest loss in the region. Overall, deforestation rates in San Martin have been very high–on the order of 1.12% or 574 km^2 per year during the late-1980s–a higher rate than any Brazilian state (Perz et al., 2005). My analysis of more recent deforestation data published by Hansen and colleagues (2013) indicate that from 2000 to 2012, San Martin had the third-highest proportion of its land area deforested of all first-level administrative areas in the Amazon basin after the Brazilian states of Rondonia and Mato Grosso (Table 3-5).

Frontier expansion in San Martin is closely linked to migration from other parts of Peru, as migrants move from more heavily populated areas in the Andean *sierra* in search of cheaper, more abundant land in the Amazon (MINAGRI, 2013; Schjellerup, 2000). In the 1970s, agrarian reform programs actively encouraged Andean farmers to colonize parts of San Martin (Schjellerup, 2000); no such government policies exist today, but rates of in-migration to San Martin remain high. In 2007, 19% of the population of San Martin had moved from another region within the previous five years; this was the third-highest rate of in-migration among Peru's 25 regions (INEI, 2014).

For this study, we worked in three areas of San Martin that were settled at different times: the districts of Pardo Miguel, Shamboyacu, and Alto Biavo (Figure 3-1). The study areas are similar to each other in two respects. First, they all overlap with the buffer zone of one of two protected areas, the Alto Mayo Protected Forest in the case of Pardo Miguel and the Cordillera Azul National Park in the cases of Shamboyacu and Alto Biavo. Second, coffee is the predominant cash crop in the three areas: 93% of interview respondents in this study reported growing coffee, and for 41%, coffee was their only source of cash income. The three districts have different histories of settlement and development, but all three were first settled after infrastructure establishment: highway construction in Pardo Miguel in the mid-1970s and logging activities in Shamboyacu and Alto Biavo in the mid-1990s and 1998-2003, respectively.

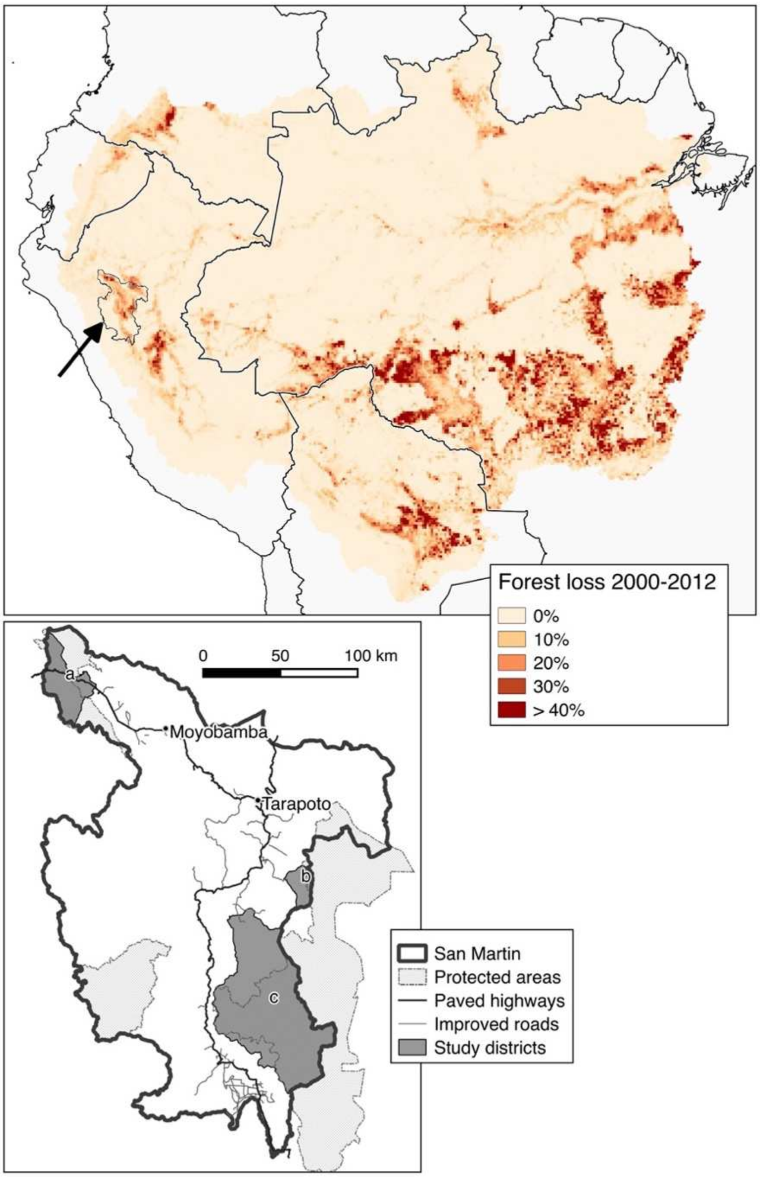

Figure 3-1: (Upper) Deforestation in the Amazon basin between 2000 and 2012 mapped at six minutes (0.1 degree) resolution. (Lower) San Martin with highways and study districts indicated.
Deforestation mapping uses data from Hansen and colleagues (2013). Colors in legend indicate total forest loss as a percentage of land area over the 2000-2012 period. San Martin indicated by arrow on upper map and shown in detail in lower map. Study districts are (a) Pardo Miguel, (b) Shamboyacu, and (c) Alto Biavo. "Improved roads" are any roads that have a non-dirt (generally gravel) surface. Region-wide data on seasonal dirt roads is not available.

Early settlers in each of these areas on the frontier acquired land through land claims. Peruvian law allows an individual to claim possession of state-owned rural land if he/she has made economic use of the land for at least one year prior. Individuals can also claim legal rights of possession to land that was previously privately owned; however, in this case the putative land holder has to demonstrate economic use over five years (*Ley del registro de predios rurales–Decreto legislativo No. 667;* 1991, modified 1996, 1997, 1998, 1999, 2006) (FAO, 2014; cf. Brown et al. 2016). In addition to formal land rights, a well-established cultural convention gives customary rights to *posesionarios*: individuals who bring previously uncultivated land into agricultural or livestock production. This convention can be more important than the law itself in frontier areas where the Peruvian state and regional government agencies have limited monitoring and enforcement capacity.

Approximately 30% of agricultural land in San Martin is held by registered land title (Conservation International, 2011; Gobierno Regional de San Martín, 2009; ProCeja, 2011). However, most formally-titled land is found in the large central valleys and in our recently-settled study areas land title is much less common. In land transactions where no formal land title is involved, purchase agreements (*documentos de compra-venta*) define the land parcel and the selling price. These documents are signed by both buyer and seller as well as by a community authority–the municipal agent or the lieutenant governor–or a justice of the peace. The documents are generally kept by purchasers and accumulate as land parcels pass through multiple owners with new purchase documents drafted for each transaction. In this way, the act of sale itself legitimates a claim by initiating a paper trail that establishes the land parcel as a legal entity.

NGO staff and regional government officials report that "land trafficking" (*trafico de tierras*) is common in San Martin. This is a particularly aggressive form of land speculation whereby well-connected individuals and groups claim large tracts of land that are generally beyond the administrative reach of local and regional governments (Conservation International, 2011; ProCeja, 2011). Speculators seek to profit by selling the land in smaller parcels to new migrants; in some cases, they actively recruit migrants from outside communities, often from distant districts in the *Sierra*.

3.4. Methods

We collected reports of land acquisitions that took place in three frontier districts of San Martin. The districts were selected following three criteria: that each be an area of active deforestation; that each be a site of active forest conservation efforts; and, that the districts collectively represent a range of settlement times. Interviews conducted in 2011 with NGO and government staff established that the districts best fitting these criteria were those bordering the Cordillera Azul national park in eastern San Martin, and those bordering on the Alto Mayo protected forest in the region's northwest. Information on the history of settlement of each district led me to select the District of Pardo Miguel in the northwest as an older frontier area–first settled in the mid-1970s–and the Districts of Shamboyacu and Alto Biavo along the Cordillera Azul as newer settlement areas. The upper valley of the district of Alto Biavo–an area separated from the rest of the district by a high ridge and lack of road links–was specifically identified by NGO and government staff as the most recent and active frontier area in San Martin with the fastest rates of in-migration and frontier expansion in 2012 and 2013. Shamboyacu has a settlement history that is intermediate between Pardo Miguel and Alto Biavo: the expansion of settlement peaked in Shamboyacu in the late-1990s and early-2000s. We interviewed landholders in three communities in Pardo Miguel, six in Shamboyacu, and four in Alto Biavo. We chose to work in communities within the protected area buffer zones that had active and community-specific forest conservation activities sponsored by one of two large NGOs working in the districts[2]. In all three districts, we defined a "community" as a

[2] The primary NGOs managing conservation programs in these two areas are Conservation International in the Alto Mayo Protected Forest and the Centro de Conservación, Investigación y Manejo de Areas Naturales (CIMA) in Cordillera Azul National Park.

cluster of households with a government-funded school and at least one teacher. In the upper valley of Alto Biavo and in the district of Pardo Miguel, we worked in communities situated inside the protected area buffer zone but outside the protected area itself, i.e., four and three communities, respectively. In Shamboyacu, the official buffer zone of the protected area is exceptionally large–it extends beyond the border of the district to include areas that have been dedicated to commercial farming for several decades. We therefore restricted our sampling to the area in the district that was a higher priority for local conservation efforts: the side closest to the National Park. The district is situated in a river valley with one side of the valley sloping upwards to the Park border. We worked in six of the seven communities on the park-side slope (in one community, authorities declined participation), but not those in the valley bottom or on the opposite slope.

3.4.1. Household interviews and land transaction data

Reports of land acquisitions were extracted from semi-structured interviews with 194 randomly-selected households in 13 communities in our study districts. One individual did not want to disclose information on land transactions, so data in this chapter is based on the remaining 193. To select households, we first mapped all occupied homes within a 30-minute walk of each community center. We systematically numbered houses on the map and used a regular increment from a random starting point to ensure that sampling was geographically representative across each community. We sought to interview either twenty percent of the households in each community or twenty households in the more populous communities where twenty percent would have required an unrealistically large number of interviews. We met this sampling goal in 11 out of 13 communities and fell slightly short in two communities (i.e., 17 households, 14%; 14 households, 18%–see Table 3-4).

Land transactions reported by respondents were of four types: (1) land claims; (2) land grants from community authorities or regional government (Alto Biavo only); (3) land purchases; and, (4) inheritances or gifts from family members. With our focus on the lands surrounding study communities, we excluded land acquisitions that were more than a 60-minute walk from the community center; this left 326 land acquisition events of which 261 were land purchases (the remainder being claims, grants, or inheritances). Of those 261 land purchases, 249 took place after 1991 when Peru's present currency–the Nuevo Sol–was introduced. For our analysis of land prices, only these 249 are included. We asked landholders to report details on each land parcel they had acquired or sold since arriving in the community. For each land parcel acquired or sold, landholders reported, the total area, the composition by land cover type, the year of the transaction, and in the case of land purchases, the sale price. Landholders also described the location of the land parcel using local landmarks and travel times. For each parcel, we calculated the travel time to the nearest paved road (in all cases, the nearest paved road was the principal regional highway) in the year of each land acquisition. These calculations were based reported travel times on footpaths and on GPS-tracked distances for all roads. We adjusted these travel times to reflect what they would have been in the year of land acquisition by using information from long-time community residents on dates of road construction and road improvement. We mapped approximate parcel locations using descriptions from landholders and GPS data on local footpaths and waypoints that we created in the field. Because locations are not precise, we assigned each land parcel to one of 39 different clusters; we then calculated average elevation and slope within a one-kilometer buffer as a proxy for the elevation and slope on individual parcels. We used digital elevation maps with 30m resolution (NASAJAXA, 2009) to calculate slope and elevation metrics.

Boom-and-bust development patterns have been suggested on Amazonian frontiers (Rodrigues et al., 2009, although see Weinhold et al. 2015), suggesting that land price increases may decelerate or even reverse as time progresses. In order to evaluate potential non-linear effects of the year of sale on land prices, we included a quadratic term for the year of the land sale. Because of the different histories of settlement in our three frontier areas, we would expect that if a boom-and-bust pattern were present in the land price trends, any price peak would happen in different years in different districts. In order to account for this difference in timing, we include the year of sale relative to the year of the first land sale reported in each district in our dataset, i.e., 1979, 1996, and 2001 in Pardo Miguel, Shamboyacu, and Alto Biavo, respectively. As an additional indicator of the level of social development in the area surrounding each land parcel, we also account for the distance between land parcels and the nearest primary school in the year of the land sale. To evaluate access to education, we obtained data from San Martin's regional education directorate on the location and date of establishment of every school in the region and then used GIS to evaluate the Euclidean distance to the closest primary school for each parcel at the time of sale.

3.4.2. Estimating determinants of land price

Factors that affect land price differ in the extent to which they change through time as well as in the degree to which landholders are able to influence them. Elevation and parcel location are both time-invariant. Other factors change through time but in a manner over which landholders have little or no control; these include commodity prices, travel time to market, and the level of development of communities in the area (e.g., access to educational or health services). Commodity prices vary internationally in a way that is largely unpredictable to landholders whereas travel time and community development tend to evolve unidirectionally and somewhat predictably as the frontier develops: travel times shorten as infrastructure improves and communities usually accrue more services as populations increase. The final set of factors that affect land price, over which landholders do exert control, are those relating to land cover on the parcel. With sufficient labor and/or capital, landholders can clear forest and convert land either to agricultural crops or pasture.

We used two different statistical approaches to evaluate the relative importance of factors determining land price following hedonic pricing theory which stipulates that the price of a good–in this case land–results from both the characteristics of that good and from external factors such as market characteristics (Rosen, 1974). We first used a set of regression models that we compare for fit with R^2 and for parsimony (as well as fit) with the Akaike information criterion (Akaike, 1974; Burnham, 2004; Mac Nally, 2000). Land parcels are spatially clustered; slope and elevation are calculated as averages for the locale around parcel locations rather than individually for each parcel. To avoid biased standard errors that may arise with OLS regressions (Moulton, 1990), we used robust regression modeling with clustering. As an additional test for spatial dependence in our models, we evaluated the Moran's I for model residuals. The seven regression models we use build on each other sequentially and generally follow the structure used by Sills and Caviglia-Harris (2008) in their evaluation of rural land prices in Rondonia, Brazil. We compare models with each other using a Wald test to test for significant improvements in goodness-of-fit with sequential additions of variables because likelihood-ratio tests are not appropriate when robust regression techniques are being used (Wooldridge, 2006). Following regression modeling, we use hierarchical partitioning to evaluate the individual contribution of each independent variable to the explained variance in price per hectare. Hierarchical partitioning considers all possible model constructions given a set of variables, and therefore is not sensitive to the ordering of model construction as a stepwise approach would be. We conducted our regression analysis with clustered standard errors in Stata version 14.1, our assessment of Moran's I in GeoDa version 1.6.7, and our hierarchical partitioning analyses in the 'hier.part' package of R version 3.2.2.

Studies of rural land values in the Amazon have used the total price of land parcels as the dependent variable (Merry et al., 2008) or both the total lot price and the price per hectare (Sills and Caviglia-Harris, 2008). Price per hectare is preferable to total price because it evaluates prices relative to a constant quantity of land; using price per hectare is also consistent with studies of rural property values in the USA (Bastian et al., 2002; Snyder et al., 2008; Xu et al., 1993) and with comparable Latin American studies (Chomitz et al., 2005; Zegarra, 1999a). We used log-transformed land price per hectare as our dependent variable. We corrected all land prices for inflation. In the late 1980s and the early 1990s, Peru went through a period of hyperinflation that peaked in 1990 at an annual rate of 7482%. Peru twice replaced and devalued its currency, first in 1985 and later in 1991. Likely as a result of the extreme inflation, prices of land sales in our dataset from 1991 and earlier are very irregular even when corrected for annual inflation rates and for currency devaluations. We therefore restricted our analysis of sale prices to those sales that occurred after the current currency, the Nuevo Sol, was established in 1991. For those 1992-2013 sales (n = 249), we corrected all prices ($US) for inflation to a 2013 base year using annual inflation data recorded by the Central Reserve Bank of Peru (IMF, 2012).

3.4.3. Model selection

We evaluated seven regression models, each with a more complete specification. In all cases, the values of each variable represent the value at the time of sale. In all seven models we include dummy variables for districts Shamboyacu and Alto Biavo (the reference case is the district of Pardo Miguel). For each model, we evaluated the spatial autocorrelation of the residuals in order to assess the need to use a spatially-explicit regression. We calculated Moran's I of the residuals of our models using a weights matrix based on a threshold distance. Because we have no a priori theoretical reason to select a particular threshold distance within which neighboring parcels may be correlated with each other, we evaluated Moran's I for our fully specified model using a range of different threshold distances in order to determine the threshold distance at which we observe the maximum level of spatial correlation or dispersion (Dubé and Legros, 2014). The set of distances we tested included the minimum distance for which each observation would have at least one neighbor (5.56 km) and each 10 km increment from 10 km until 100 km, at which point a land parcel would be considered a "neighbor" of every other land parcel in its district. We found that the highest absolute value for Moran's I at a threshold distance of 10 km; however, at no distance was the spatial autocorrelation or dispersion statistically significant ($p \leq 0.05$) (Figure 3-6; supplementary). Using the 10 km threshold where the maximum absolute Moran's I value was observed in our fully specified model, we also evaluated Moran's I of the residuals for each of the partially-specified models. We report these Moran's I values below in our regression tables; however, none are statistically significant. Our diagnostic tests indicate therefore that it is appropriate to use regression models that are not spatially explicit.

Our first model of land price, following Sills and Caviglia-Harris (2008), estimates the sale price of a parcel of land simply as a function of travel time to market. This reflects the theory of Von Thünen that travel time is central to land prices, land use, and rural landscape differentiation. In our case, we used travel time to the nearest paved road; we chose this metric instead of travel time to a specific market because agricultural goods are sold in different towns. The paved highways in San Martin are in good condition, meaning that the most significant differences in transport expense are from farm to highway rather than on the highway itself.

The second model incorporates commodity prices, which have been shown to influence land use and rates of forest clearing (Barona et al., 2010; Verburg et al., 2014). The combination of commodity prices and travel time to paved road lets me evaluate the extent to which land prices can be explained by market conditions and market access alone. We included inflation-corrected prices for coffee and cattle in our models as these commodities are the ones most relevant locally: our respondents reported anecdotally that land prices increased in years when the price of coffee was high. Our data on live cattle prices are specific to San Martin and come from the Peruvian Ministry of Agriculture and Irrigation (MINAGRI, 2014)[3]. MINAGRI data on San Martin coffee prices are incomplete and so we use international arabica coffee prices as a proxy (IMF, n.d.). For the years during which there is overlap between the San Martin and the international coffee price data, the correlation between the two is high ($r = 0.97$. $p<0.001$), so the latter serves as a reasonable proxy.

In our third and fourth models, we added information on land parcel characteristics: the total size of the land parcel, the percent covered in primary forest, and the average elevation and slope of the surrounding land (within a buffer of one kilometer). We used percent cover in primary forest to reflect farmer investment in the land parcel, i.e., less forest cover corresponding to greater investment. These characteristics–parcel size, land cover, slope, and elevation–are known to have significant effects on land price (Casetti and Gauthier, 1977; Chomitz et al., 2005; Merry et al., 2008; Sills and Caviglia-Harris, 2008; Busch and Vance, 2011).

In our fifth, sixth, and seventh models, we evaluate how land prices change with the level of development in a district after controlling for market and land parcel characteristics. Access to education is an important indicator of frontier development as it is highly valued by households in rural Peru (Gertler and Glewwe, 1990) and has been shown to play a role in decisions to migrate to and from agricultural frontiers (Carr, 2009). Model five includes the distance from land parcels to the nearest primary school as an indicator of the level of service development in the district. In model six and seven, we add the year of the sale itself relative

[3] Cattle prices from 2005 to 2013 are online (MINAGRI, 2014), while historical data starting from 1991 were provided to us via correspondence with MINAGRI staff. These data are available from the author upon request.

to the first sale in the district to account for changes through time in districts that are not captured by differences in access to educational services.

3.5. Results

3.5.1. Land markets

Land markets in the three frontier areas arose only once there was little or no remaining land available for claiming (i.e., within one-hour's walk from community). The maximum amount of time during which land claims and land purchases occurred contemporaneously in a given community was four years. In seven of 13 communities, the period of overlap between land claims and land purchases in our sample was one year or less. Combining all of the study communities within a given district–with communities separated by up to 40 km–the maximum period of overlap between land claims and land purchases was eight years. Once land markets were established, land purchases or inheritances became the only way people acquired land. The transition from claims to purchases had occurred by 1980 in Pardo Miguel, by 2001 in Shamboyacu, and by 2009 in Alto Biavo (Figure 3-2).

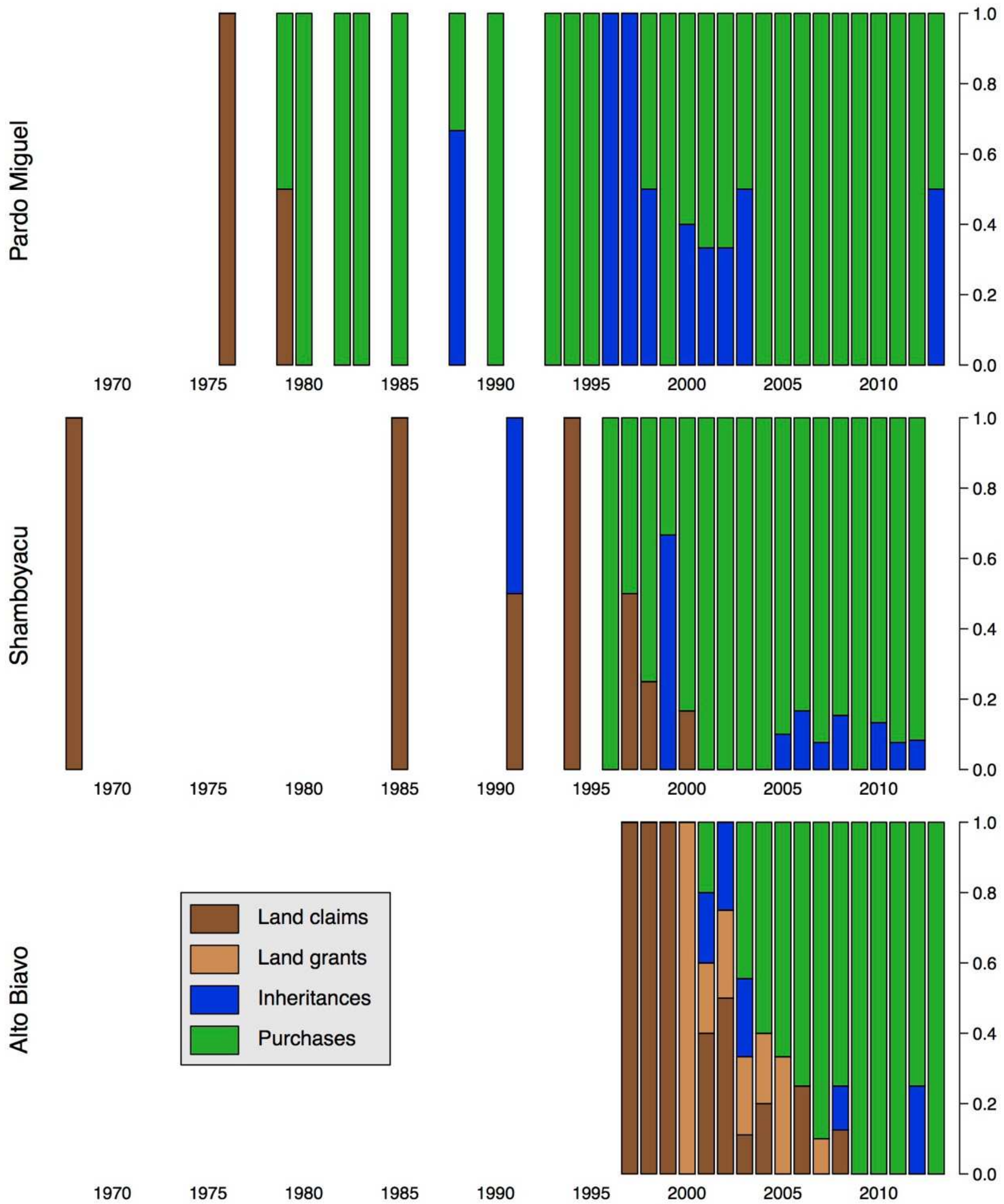

Figure 3-2: Proportion of different types of land acquisition through time in each of the three districts.
This includes all land acquisitions events (non-market land claims, land grants, inheritances, and purchases) that took place within a one-hour walk of study communities (n = 326).

More than half of the individuals in our sample (52.8%) reported participating in land markets in the five years prior to being interviewed. A large majority had participated in land markets (86.4%) at some point since their time of arrival in the study community. Participation in land markets in the previous five years ranged from a high of 60.3% in Shamboyacu to a low of 47.5% in Pardo Miguel (Table 3-1). In all districts, at least twice as many households had purchased land as had sold land. This difference was even more pronounced in the more recently-settled Districts of Shamboyacu and Alto Biavo: 56.4% and 42.9% of households had purchased land in the previous five years, respectively, whereas only 7.7% and 7.1% of households had sold land in the same time period (Table 3-1).

3.5.2. Forest coverage and parcel size

Land parcels that survey respondents reported claiming or being granted tended to be larger than average holdings and were typically covered entirely by primary forest. Of recorded land claims (n = 26) and land grants (n = 10), 78% were land parcels of twenty hectares or more (mean = 23.6ha, σ = 13.6ha). Parcel size of claimed land and granted land was broadly consistent across the three study districts with sample means of 31.0 ha (σ = 41.0ha), 21.7 ha (σ = 14.9ha), and 23.8 ha (σ = 10.8ha) in Pardo Miguel, Shamboyacu, and Alto Biavo, respectively. Regarding the coverage by primary forest, excluding one event that involved claiming three hectares of fallow land following coca eradication in Shamboyacu, the remaining 35 parcels had greater than 90% coverage in primary forest; the balance of 10% (or less) comprised small patches of fallow land created by farmers who had later abandoned the land. Parcel sizes and forest coverage in the parcels that were claimed were significantly higher than averages among parcels that were bought or sold (cf. Table 3-1).

Table 3-1: Household participation in land markets and characteristics of land parcels bought or sold. Values in parentheses are standard deviations. Only post-1991 land sales are included in this table (n=249) as those are the only ones for which reliable price data is available.

Unit	Variable	Pardo Miguel	Shamboyacu	Alto Biavo
Households (n=193)		*n=59*	*n=78*	*n=56*
	% who in the previous five years…			
	purchased land	37.3%	56.4%	42.9%
	sold land	15.0%	7.7%	7.1%
	purchased or sold land	47.5%	60.3%	48.2%
	% who since arriving in community…			
	purchased land	79.7%	85.9%	64.3%
	sold land	21.7%	15.4%	10.7%
	purchased or sold land	86.4%	88.5%	67.9%
Land parcels bought or sold post-1991 (n=249)		*n=68*	*n=125*	*n=56*
	Travel to paved road (minutes)	35.9 (19.0)	180.9 (33.5)	312.8 (66.9)
	Elevation (masl)	1258.6 (147.6)	810.5 (175.4)	914.2 (127.3)
	Number of sales recorded by decade			
	1992-1999	8	9	0
	2000-2009	37	80	41
	2010-2013	23	36	15
	Parcel size by decade (ha)			
	1992-1999	6.6 (7.4)	12.9 (21.8)	–
	2000-2009	2.7 (2.1)	6.8 (8.1)	13.3 (11.7)
	2010-2013	3.7 (5.7)	3.0 (2.8)	12.2 (11.2)
	Forest cover by decade (%)			
	1992-1999	52.9 (49.0)	80.0 (32.6)	–
	2000-2009	31.2 (42.2)	76.3 (33.9)	93.6 (17.7)
	2010-2013	15.7 (27.3)	38.1 (44.1)	71.9 (40.7)
	Coffee plantation by decade (%)			
	1992-1999	3.0 (4.4)	11.1 (33.3)	–
	2000-2009	38.9 (41.7)	10.4 (23.9)	1.4 (6.3)
	2010-2013	45.9 (39.3)	25.7 (38.0)	23.0 (41.1)
	Price per hectare (2013 USD)*			
	1992-1999	433.3 (265.0)	130.9 (172.1)	–
	2000-2009	1188.8 (1254.4)	499.4 (908.3)	275.7 (539.7)
	2010-2013	1595.8 (733.5)	1340.4 (1111.0)	670.6 (862.5)

*Adjusted for inflation to equivalent of 2013 US dollar values. Calculated from price in Peruvian Nuevo Soles (PEN) at the time of sale, converted to 2013 PEN value using Peruvian annual inflation rates (IMF, 2012), converted to USD using the 2013 average exchange rate (1.00 USD = 2.71 PEN).

Over time, purchased parcels became progressively smaller and less forested. This occurred in the transition from land claims to land purchases, but also during the period when only land purchases occurred. The year of sale and the percent of forest cover overall are negatively correlated in the three districts (Pearson's $r = -0.19$; $p = 0.001$) as well as individually in the Districts of Pardo Miguel ($r = -0.46$; $p < 0.001$), Shamboyacu ($r = -0.33$; $p < 0.001$) and Alto Biavo ($r = -0.25$, $p = 0.06$). In Pardo Miguel, the average proportion of forested land on each land parcel sold declined from 52.9% in the 1990s to 31.2% in the 2000s to 15.7% in the period from 2010 to 2013. Shamboyacu and Alto Biavo showed similar declines on a decadal comparison although they started from higher average levels of forest cover (Table 3-1). Most forest cover loss has been due to the expansion in the area of coffee plantations (Table 3-1; Figure 3-3). Pasture and non-coffee agriculture have also expanded at the expense of forest; however, these land covers represent less than one third of the extent represented by coffee plantations in each district, and in many cases represent much less.

As with forest cover, the size of parcels decreased through time across all three districts. The year of sale and parcel size (log transformed) were negatively correlated, i.e., Pardo Miguel ($r = -0.48$; $p < 0.001$), Shamboyacu ($r = -0.34$; $p < 0.001$), and Alto Biavo ($r = -0.29$; $p = 0.02$). In Pardo Miguel, the average parcel sold was 6.6 ha in the 1992 and 1999, 2.7 ha in the 2000s, and 3.7 ha between 2010 and 2013. In Shamboyacu this decline was from 12.9 ha to 6.8 ha to 3.0 ha while in Alto Biavo there was a slight drop from 13.3 ha to 12.2 ha between the 2000s and 2010s (Table 3-1). With declines in both parcel size and the proportion of forest, the total area of forest on each parcel sold declined through time in all districts (Figure 3-5I).

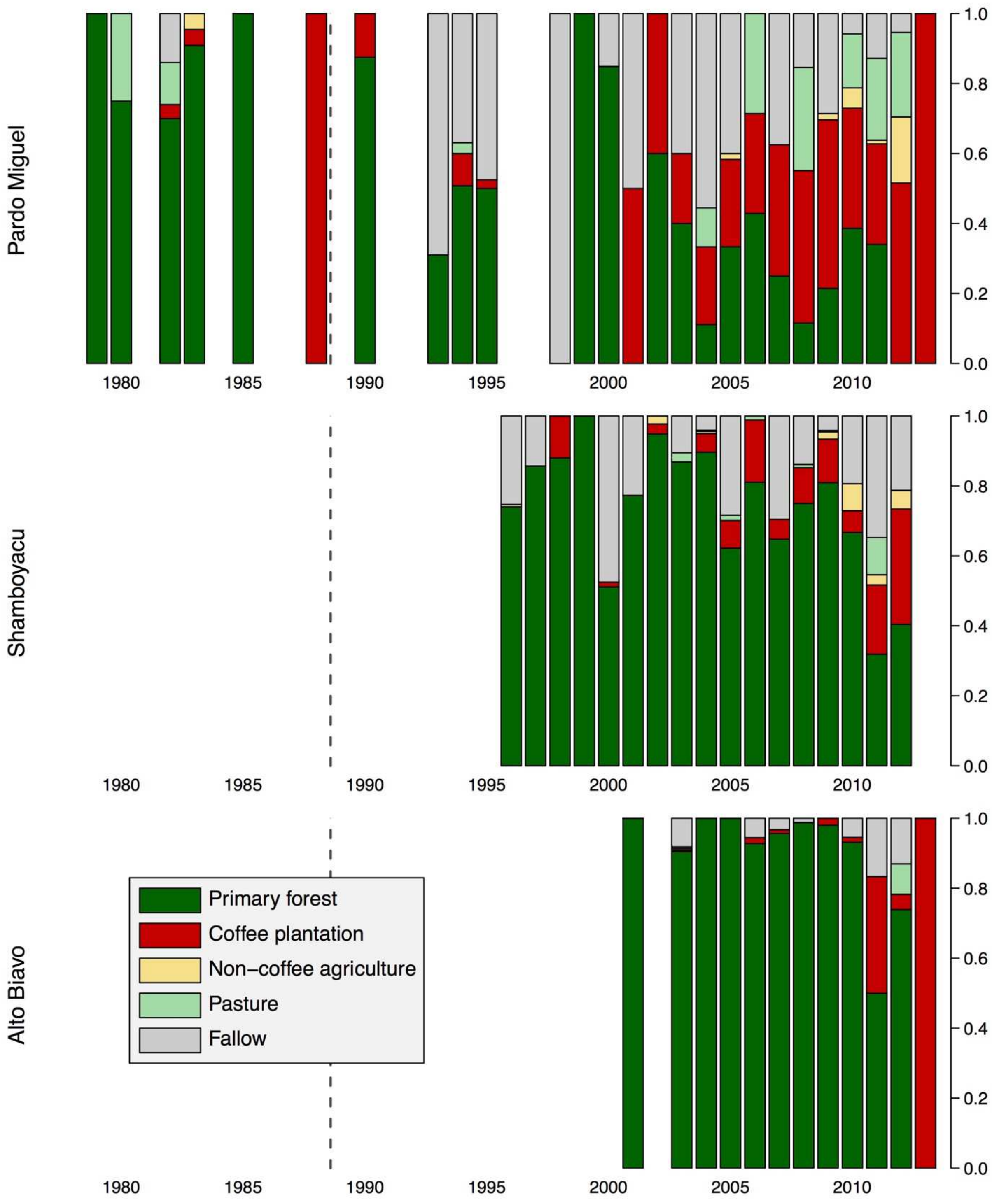

Figure 3-3: Proportion of the total amount of land sold in a given year that was covered by each land cover type.

Includes all reported land sales that occurred within a one-hour walk of study communities (n = 261). Sales that were included in land price models because they date from after the 1991 introduction of Peru's current currency (Nuevo Sol) are those to the right of the dotted line (n = 249).

3.5.3. *Estimates of sale price*

Reported land sales that took place between 2010 and 2013 had inflation-adjusted average prices of \$671 per hectare in Alto Biavo, \$1340/ha in Shamboyacu, and \$1596/ha in Pardo Miguel. These all reflected increases from the 1990s when prices in Shamboyacu and Pardo Miguel were \$131/ha and \$433/ha and land markets had not yet arisen in Alto Biavo (Table 3-1). The 12 variables used in our final estimation of land prices explain 71% of variance in the log-transformed price per hectare of land (R^2). Our first regression model simply tests the relationship theorized by Von Thünen that land further from market will be cheaper; the only independent variable included is the travel time to paved road which has a strongly significant ($p < 0.001$) and negative effect on land price. Travel time alone explains about 31% of the variation in land price per hectare. In order to account for changes in the market through time, we added prices of coffee and cattle as well (model 2)–which increases the explanatory power of the model by half to 45%. In this model, all three of the variables are significant, with travel time and cattle price being negatively associated with land price while coffee price is positively associated.

In models three and four, we evaluated parcel size, average local slope, average local elevation, and percent primary forest coverage (Table 3-2). In both models, parcel size, slope, and percent forest cover have strongly significant negative associations with land price per hectare while elevation has a significant positive association with price. Parcel characteristics–size, slope, elevation, percent forest cover–add more explanatory power to the model than do coffee and beef prices. Models two and three are both significant improvements over model one (Wald tests comparing models two and one: $F_{2, 38} = 27.8$, $p < 0.0001$; comparing models three and one: $F_{4, 38} = 35.7$, $p < 0.0001$); however, model three explains 15% more of the variance in price per hectare than does model two. When both parcel characteristics and commodity prices are included at the same time (model four), the explanatory power of the model increases by an additional 6.5% over model three and there is a significant improvement in goodness-of-fit relative to model two ($F_{4, 38} = 32.9$, $p < 0.001$) and to model three ($F_{2, 38} = 19.3$, $p < 0.0001$). The signs of all of the terms are consistent among these first four models.

Model five adds a proxy for the level of development in the area surrounding each parcel: the distance to the nearest primary school in the year that the sale took place. As expected, the sign of the coefficient of the school distance variable is negative–with land being cheaper where it is farther away from services–however, the variable is not statistically significant. A Wald test also indicates no significant improvement in goodness-of-fit between model four and model five ($F_{1, 38} = 0.38$, $p = 0.542$). Adding variables that account for the year itself, however, does significantly improve our ability to explain land prices. Adding a linear term for the number of years elapsed since the first recorded land sale in the district significantly improves the fit of the model (comparison of models five and six: $F_{1, 38} = 30.36$, $p < 0.0001$) while including years-squared makes a further improvement (comparison of six and seven: $F_{1, 38} = 9.54$, $p = 0.004$). In both cases, the coefficient of the linear year term is positive, whereas the quadratic (year-squared) term has a negative coefficient. Model seven, our most fully specified model, explains 71% of the variance in the inflation-corrected price per hectare (log10) as measured by the R^2 value. The Akaike information criterion–lowest in model seven–also suggests that the seventh model is the preferred model for parsimony and explanatory power. In model seven, all of the predictor variables are statistically significant ($p \leq 0.05$) with the exception of the two commodity price variables and the distance to a primary school. Signs of coefficients of all significant variables are consistent through all models.

Table 3-2: OLS models with robust standard errors for 2013 sale price per hectare (log10-transformed US dollars.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
(Intercept)	3.1037*** (0.0594)	2.8154*** (0.1765)	2.5527*** (0.1853)	2.3652*** (0.2063)	2.3003*** (0.1970)	1.1401** (0.3555)	1.2133*** (0.2996)
Travel time to paved road (minutes)	-0.0049*** (0.0011)	-0.0044*** (0.0010)	-0.0027** (0.0008)	-0.0028*** (0.0007)	-0.0027*** (0.0006)	-0.0029*** (0.0007)	-0.0031*** (0.0007)
Coffee price (arabicas; USD / tonne)		0.0002*** (0.00003)		0.0002*** (0.00002)	0.0002*** (0.00003)	0.00004 (0.00003)	0.00005 (0.00002)
Cattle price (USD / tonne)		-0.0003** (0.0001)		-0.0002* (0.0001)	-0.0002* (0.00007)	0.00002 (0.0001)	0.00001 (0.00009)
Size of land parcel (ha)			-0.0167*** (0.0026)	-0.0137*** (0.0027)	-0.0138*** (0.00282)	-0.0113*** (0.0028)	-0.0095** (0.0033)
Primary forest (% cover)			-0.0069*** (0.0008)	-0.0060*** (0.0007)	-0.0060*** (0.0007)	-0.0050*** (0.0007)	-0.0050*** (0.0007)
Elevation (masl)			0.0008*** (0.0001)	0.0008*** (0.0001)	0.0008*** (0.00013	0.0007*** (0.0002)	0.0006*** (0.0002)
Slope			-0.0140* (0.0063)	-0.0149** (0.0051)	-0.0137** (0.0048)	-0.0129* (0.0052)	-0.0139* (0.0054)
Distance to primary school					-0.0086 (0.0140)	-0.0033 (0.0131)	0.0023 (0.0136)
Years after first recorded sale in district						0.0443*** (0.0081)	0.0745*** (0.0121)
Years after first recorded sale in district (squared)							-0.0010** (0.0003)
District: Shamboyacu	0.30782 (0.18107)	0.2183 (0.1549)	0.5638*** (0.1250)	0.5025*** (0.1129)	0.5165*** (0.1261)	1.2348*** (0.1781)	1.0907*** (0.1668)
District: Alto Biavo	0.57299 (0.3453)	0.4106 (0.2971)	0.7637** (0.2081)	0.6666** (0.1826)	0.6490** (0.1752)	1.5564*** (0.2390)	1.4880*** (0.2281)
R^2	0.312	0.450	0.600	0.662	0.663	0.703	0.714
F-statistic	36.5 $_{3, 38}$***	53.3 $_{5, 38}$***	94.0 $_{7, 38}$***	109.2 $_{9, 38}$***	99.5 $_{10, 38}$***	135.3 $_{11, 38}$***	89.1 $_{12, 38}$***
Moran's I of residuals	0.006 (ns)	0.009 (ns)	-0.015 (ns)	-0.011 (ns)	-0.011 (ns)	-0.015 (ns)	-0.016 (ns)
AIC	369.803	314.403	243.176	204.769	206.249	176.903	169.642

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Log-likelihood	-180.901	-151.201	-113.588	-92.385	-92.125	-76.452	-71.821

Significance levels of p-values as follows: *** < 0.001 < ** < 0.01 < * < 0.05.

We compared the effect in model seven of a one standard deviation change in each significant predictor variable (Table 3-3). A one standard deviation increase in travel time (106.3 minutes), parcel size (9.4 ha), percent forest cover (43.4%), or slope (4.0%) was associated with, respectively, 53.5%, 18.6%, 39.5%, and 12.1% decreases in the price of land per hectare (percentage changes presented here because dependent variable is log-transformed). Conversely, a one standard deviation increase in elevation would raise land prices by 41.6%. The terms relating to the year of sale indicate that land prices increasing most rapidly in the early years after the establishment of land markets, followed by slowing increases and eventually a possible decline, i.e., following a quadratic function. The coefficients predicted by the model suggest a peak in land prices 37 years after the first land sale in the district. The model was also tested using interaction terms and the results are included in supplementary materials (Table 3-6). With the main effects from model seven (12 variables) included as well as the 26 possible interaction terms involving the district and the year of sale, the R^2 value improved slightly from model 7 (Table 3-2) to 0.754; however, the Akaike Information Criterion was higher (184.3), suggesting a less parsimonious model.

We used hierarchical partitioning to determine the relative contribution of each variable to the overall variance in land price per hectare (Figure 3-4). This technique compares the independent contributions of each variable, independent of model selection (Mac Nally 2000). Hierarchical partitioning indicated that the largest contributor to the variance in land price was the percent forest cover of each land parcel; it was responsible for 16.8% of the independent effects in the model with more forest associated with lower prices. The second- and third-largest contributors were the year of sale and year of sale squared, which explained 14.2% and 11.3%, respectively. When both terms are considered, as a quadratic function, the year of the sale–represented as the number of years after the first sale in the district–accounts for 25.5% of the variance explained by independent effects in the model. The fourth- and fifth-largest contributors to explained variance were the size of a land parcel (11.0%) and the travel time to a paved road (10.9%).

Table 3-3: Effects on land price per hectare of each significant predictor variable as estimated by coefficients of model 7 in Table 3-2. The increment of change in each independent variable is equal to one standard deviation of the distribution in that variable in the overall sample.

Variable	Increment (One σ)	Predicted effect on land price per hectare
Travel time to paved road (minutes)	106.3	-53.46%
Size of land parcel (ha)	9.4	-18.60%
Primary forest (% cover)	43.3	-39.50%
Elevation (masl)	247.1	41.63%
Slope	4.0	-12.07%
Years after 1st sale	9.2	382.11%
Years after 1st sale (squared)	84.1	-17.04%

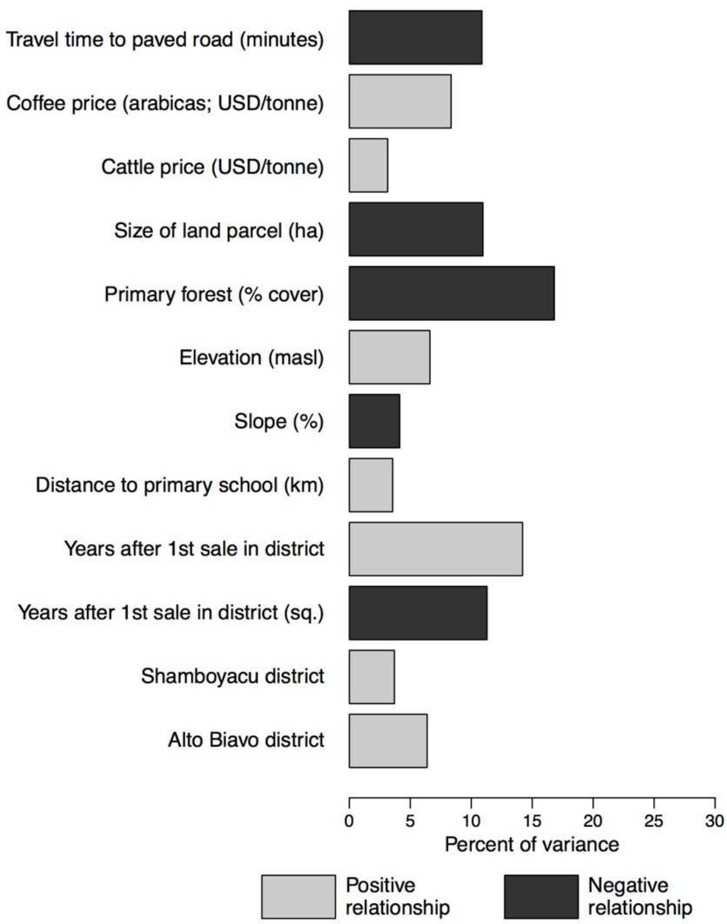

Figure 3-4: Results of hierarchical partitioning on the prediction of land price per hectare (inflation corrected; log10 transformed) showing the proportion of all independent effects that can be attributed to each variable.
All variables from model 7 (Table 3-2) are displayed. Color-coding of bars indicates whether the relationship between the variable and land price is positive or negative in the regression model, while values on the horizontal axes are the independent effect of each variable expressed as a percentage of total variance explained in the model by independent effects.

3.5.4. Predicting the effect of forest clearing on land price

Of 249 land sales analyzed in our regression models and hierarchical partitioning, 179 were of a parcel that had some amount of forest cover (Figure 3-5I). For these land parcels, we predicted how the sale price would have increased if the parcel had one hectare less of forest (this value was scaled if there was less than one hectare to begin with). Using data from each land sale and coefficients from our saturated linear regression model (model seven, Table 3-2), we predicted the expected price of each sale and compared it with a hypothetical expected price after one additional hectare of forest clearing (Figure 3-5II). In any given year, the potential gain in price from clearing one additional hectare of forest was greatest in Pardo Miguel and least in Alto Biavo. In 2013, the predicted increase in land sale price for each additional hectare of forest cleared was \$1860, \$1821, and \$955 in Pardo Miguel, Shamboyacu, and Alto Biavo, respectively. We found that in all three districts, the expected increase in land price from one additional hectare of cleared forest was itself increasing through time, curvilinearly. Wald tests indicated that the quadratic function had significantly better goodness-of-fit than did the linear function ($F_{1,176} = 10.82$; $p = 0.0012$). Examining these relationships in each district for the decade from 2003 to 2013, we found that the increase in land price expected from an additional hectare of forest clearing itself increased at an average annual rate of between \$86 and \$159. In Pardo Miguel, the expected price increase per additional hectare of forest cleared rose from 672\$ in 2003 to \$1860 in 2013 (adjusted $R^2 = 0.54$; $p < 0.001$), or by \$119 per year. Over the same period, expected price increases in Shamboyacu and Alto Biavo rose from \$226 and \$95 per hectare to \$1821 (\$159 per year; adjusted $R^2 = 0.76$; $p < 0.001$) and \$995 (\$86 per year; adjusted $R^2 = 0.22$; $p < 0.001$), respectively.

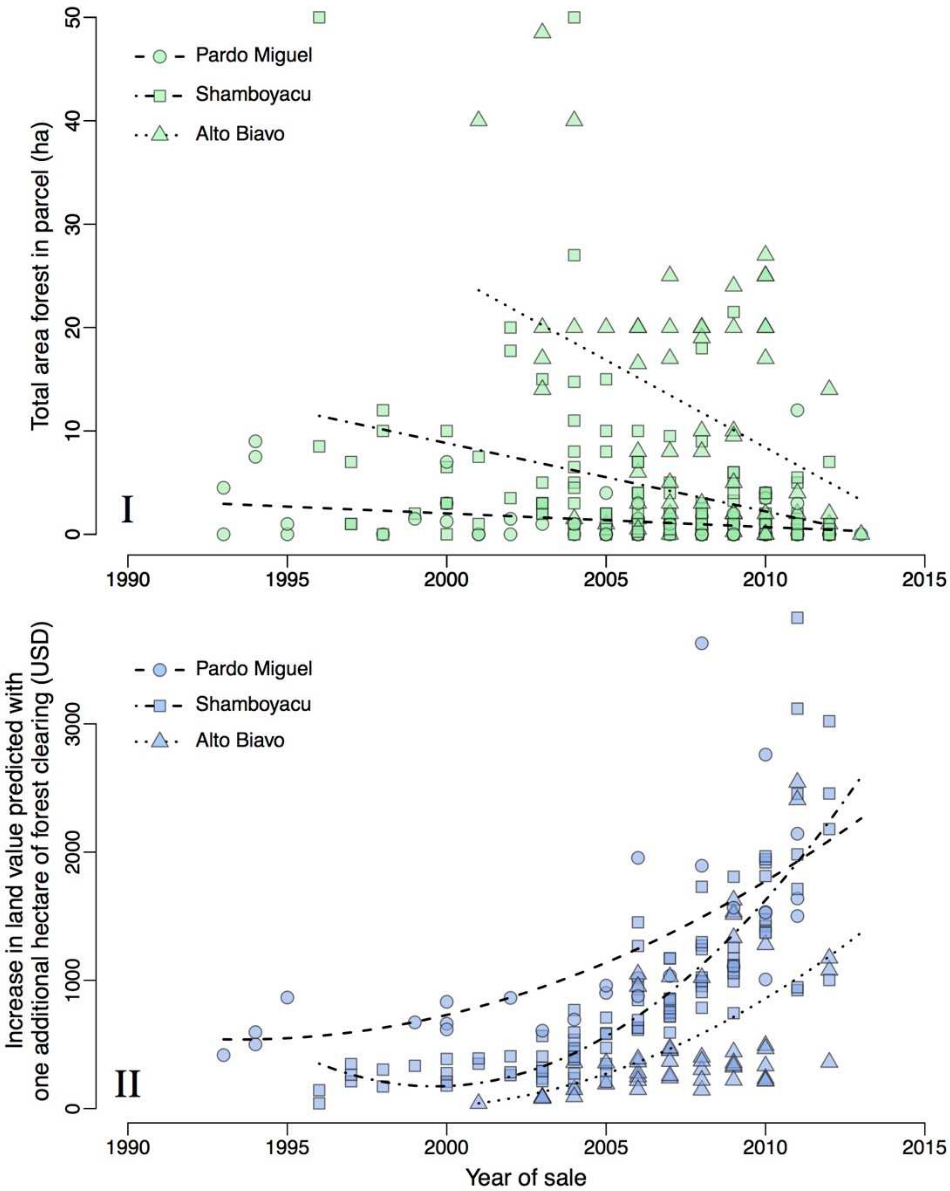

Figure 3-5: (I) Total amount of forest cover on land parcels sold through time. (II) The opportunity cost of forest sparing as indicated by the expected increase in the price of a land parcel that would be associated with the clearing of one additional hectare of land. In upper plot (I), points with zero forest cover (shaded grey in color figure) indicate sales of land parcels that contain no forest; these are excluded from plot II. Expected increase values in II are modeled using the coefficients of model 7 in Table 3-2. The opportunity cost increases through time in all three districts but is generally higher in the longest-settled district (Pardo Miguel) and lowest in the most recently-settled district (Alto Biavo). Quadratic best-fit lines for the relationship between opportunity cost and the year of sale suggest that opportunity costs in Pardo Miguel, Shamboyacu, and Alto Biavo have increased by \$119/year, \$159/year, and \$86/year respectively during the decade from 2003 to 2013. Values in 2013 would have been \$1860, \$1821, and \$955 (same order). All dollar values are US and inflation-corrected to 2013.

3.6. Discussion

We analyzed land acquisitions in three frontier areas of San Martin, Peru and found that transacted land parcels became smaller and less forested over time. The reduction in the total amount of forest on land parcels, coupled with increasing land prices, has meant that the financial incentive for forest clearing has increased steadily as these areas have developed. These patterns were consistent across three study districts, with a considerable lag between the earliest settled District of Pardo Miguel and the most recently settled District of Alto Biavo: average values for forest cover and parcel size for the years 2010-2013 in Alto Biavo were at levels seen in Pardo Miguel prior to 1990 (Table 3-1). Similarly, the predicted increase in land sale price from clearing one hectare of forest–an indicator of the opportunity cost to a land seller of leaving forest standing–was US $955 in Alto Biavo in 2013, similar to the price increase expected in Pardo Miguel in 2006 or in Shamboyacu in 2009. In 2013, the expected increase in sale price from clearing forest was $1860 per hectare in Pardo Miguel and $1820 per hectare in Shamboyacu.

3.6.1. Active markets in the absence of formal tenure

Participation in land markets in our study communities–even in the absence of formal land title–was higher than reported in previous studies of rural land market participation elsewhere in Latin America. In the five years prior to interviews, 46.6% of respondents in our study communities had bought land and 9.8% had sold land (Table 3-1). No other study we could find of rural land markets in Latin America reported rates of market activity as high as those we observed. Studies from Colombia, Nicaragua, and coastal Peru found five-year participation rates in land markets that ranged from 1.1% to 13.5% (Alvarado, 1994; Deininger et al., 2003; 2004). The striking difference in land market participation between our study and previous work is likely due to the high proportion of newly-arrived individuals in these frontier communities: 92% of our respondents were born elsewhere in Peru and 60% had arrived in their communities in the previous ten years. The high level of land market activity in these areas–and in other areas that are similarly dominated by in-migration and rapid demographic change–indicates that land prices and land price changes play a particularly important role in landholder decision-making. Land market dynamics deserve close attention in the design of programs and policies seeking to influence land use decisions–particularly regarding forest clearing–in developing forest frontier areas.

Formal land title is not a pre-requisite for active land markets. In our study, we found high levels of participation in land markets despite only 2% percent of respondents holding registered title. Formal land title may make markets more efficient and encourage the entry of different actors into land markets (Fearnside, 2005), but the absence of title does not prevent land transactions. Rather than inhibiting land markets, the lack of formal title in our study may in fact have provided additional incentive for transactions to take place. Because purchase agreements between buyer and seller often represent the first legal document relating to a land parcel, the act of selling can itself improve the security of the land holding by establishing a paper trail that proves a financial investment in the land. There are thus advantages to both the original claimant and to the person to whom they sell the land: the initial claimant will have made a quick financial return with the sale while the first purchaser improves future tenure security.

This study provides additional support to previous findings that rural land values are negatively affected both by standing forest cover and by travel time to market in Amazonia (Merry et al., 2008; Sills and Caviglia-Harris, 2008). Our results indicate larger effects than those found in the Brazilian Amazon. Whereas Sills and Caviglia-Harris (2008) report coefficients suggesting that a 25% decrease in forest cover would result in a price increase of 8.5 to 9.9%, we find that such a decrease corresponds to a 33.3% increase in land price. Our models indicated the fastest rates of land price increase in the first years of market establishment, after which rates of increase gradually declined. The maximum rate of increase, 17.9% in the first year after market establishment, was somewhat higher than the range of annual land price increases of 3-15% reported by Carrero and Fearnside (2011) from Brazil. This pattern of rapid initial increases suggests that the timing of land acquisitions matters most early in the development of a frontier area, i.e., who arrives first and is able to acquire their land earliest. As the frontier develops, the issue of timing becomes less important and characteristics of the land parcel–characteristics that the landholder can modify through investment of time and money–become more important in determining land value. Rapid early returns mean that incentives for land speculation are highest in the first years after frontier establishment, suggesting that policy efforts to reduce deforestation during the early years of frontier establishment would do well to prioritize the reduction of speculation. Fearnside (2005), while describing high rates of land speculation in the Brazilian Amazon in the 1970s and 1980s that declined in the 1990s, suggested specific taxation regimes to deter land speculation. In San Martin, there is broad recognition among NGOs and government agencies of the role that land speculation plays in frontier expansion. However, efforts to reduce speculation and land trafficking have been relatively unsuccessful, in some cases as because of the reportedly direct involvement of municipal-level officials in land trafficking (ProCeja, 2011).

3.6.2. The cost of not clearing forest

As parcels became smaller, less forested, and more expensive per hectare, the opportunity cost of standing forest increased. Higher total expenditures at the time of land purchase make it more difficult for households to recoup their investment in land without expanding their crops or pasture further into the remaining forest. By showing the expected increase in land price resulting from one additional hectare of cleared forest, our models provide a proxy for the opportunity cost of forest sparing. Our estimates reflect the expected return to a land buyer who purchases a parcel of land, clears one hectare of forest, and then re-sells the parcel under the same market conditions of purchase (Figure 3-5II). This does not include the cost to the landholder of forest clearing, so it should not be taken as the direct gain from clearing a hectare of forest; however, given relatively constant costs of forest clearing through time, increases in the expected price increase after forest clearing indicate higher opportunity costs of forest sparing. Our estimates show average annual increases in the opportunity cost of forest sparing of US $119, $159, and $86 per hectare of forest over the decade of 2003-2013 for Pardo Miguel, Shamboyacu, and Alto Biavo, respectively.

Whereas we have used land transaction data to estimate the opportunity cost of forest sparing, most studies have determined these costs by calculating the net present value (NPV) of future returns to agriculture. Despite differences in method, our estimates of US $955 to $1860 per hectare are in a similar range to reported NPV-based values. In Tanzania, in a context of small-scale agriculture and charcoal production, the opportunity costs of forest sparing ranged between $1000 and $7000 per hectare with a median value of about $1700 (Fisher et al., 2011b). Studies in Brazil, Ecuador, and Bolivia have shown NPVs based on agricultural production range from $300/ha to $1100/ha for different crop types with one outlier of more than $3000/ha for soybean in Brazil (Börner and Wunder, 2008; Ferraro and Kiss, 2002; Grieg-Gran, 2008; Knoke et al., 2009; Vosti et al., 2002; Wunder, 2007).

One challenge of NPV-based methods for opportunity cost estimation is the fact that NPV is very sensitive to the discount rate used (Naidoo and Ricketts, 2006; Stern, 2007). Because our method follows a revealed-preference approach that focuses on the moment of land transaction, it does not depend on the selection of a discount rate. More importantly, by estimating the opportunity cost at one moment–as opposed to an NPV approach that estimates the value of land use over a long time frame–our approach allows us to track change in opportunity cost through time. This is an important contribution to land use and conservation planning, in particular for any program or policy operating in a fast-changing frontier environment. At the observed rate of change, the opportunity cost of sparing one hectare in the recently-settled District of Alto Biavo could catch up in six years to the cost observed in 2013 in the longer-settled District of Pardo Miguel. This rate of change illustrates how a conservation project that offers payments for avoided deforestation to landholders could be economically attractive to participants at the stage of project design but could cease to be attractive–and therefore effective–some years later as the frontier develops. This is of particular concern for programs that use direct forest-sparing contracts with farmers or market-based incentives (Ferraro and Kiss, 2002; Wunder, 2007).

Asner and colleagues 2014 estimate that the Alto Mayo Protected Forest (bordering Pardo Miguel) averages 57.9 tonnes of aboveground carbon per hectare while the Cordillera Azul National Park (bordering Shamboyacu and Alto Biavo) holds 92.0 tC/ha. These carbon densities would result in emissions of 211 and 336 tonnes of CO_2 per hectare in a scenario of clearing and complete conversion (converting from C to CO_2). Assuming that the forests in our study areas bordering these protected areas are of similar average quality to the forests within the protected areas, we can use these values to estimate the emissions from forest conversion. If a landholder in Pardo Miguel in 2013 could sell a parcel of land for $1836 more after forest clearing, and clearing released 211 tonnes of CO_2, then avoiding those emissions has an opportunity cost to the landholder of $8.82 per tonne, not accounting for the cost of forest clearing itself. In Shamboyacu and Alto Biavo those values would be $5.42 and $2.84. For comparison, the Stern Review (Stern, 2007) estimated that 50% of global deforestation could be avoided for a cost of about five dollars per tonne. Other reported values have been higher: from $8 per tonne for 90% of global deforestation (Strassburg et al. 2009), to $10-$21 per tonne for 50% of global deforestation (Kindermann et al., 2008) to above \$40 in areas where conservation competes with high value crops such as oil palm (Fisher et al., 2011a).

While the opportunity cost per tonne of avoided emissions may be sufficiently low to be promising, we caution proponents of market-based conservation strategies in forest frontier areas. Market-based incentives have the potential to incentivize in-migration to the target area which risks the perverse outcome of increasing local rates of deforestation (Engel et al., 2008). Although the scale of payments made under most PES schemes is unlikely to provide sufficient incentive to initiate migration, PES payments may exacerbate already rapid in-migration. Additionally, in the absence of formal land title, land ownership records and an integrated land registry, the potential for gaming of PES payments systems is very high. Although we do not have empirical data from our study area on compliance with forest conservation programs, this sort of gaming was common in one local PES effort where landholders received in-kind payments in exchange for agreeing not to clear new forest clearing. Landholders would abide by the agreement on one parcel of land while concealing additional landholdings where they cleared forest unabated, continuing to receive the payments for avoided deforestation. In addition, landholders would often strategically wait to enter into the PES program until that time when they had cleared enough forest to establish the maximum amount of coffee plantation that their household labour constraints could harvest effectively. In the absence of land registration, most incentive-based schemes are likely to experience similar problems with gaming and enforcement. Lastly, as we have shown with in this chapter, the opportunity cost of sparing forest increases rapidly through time on the frontier. Payment levels designed to be cost-effective at one stage of frontier development are likely to be insufficient at later stages of development.

3.7. Conclusion

In this chapter, we have shown that land markets can arise rapidly after the first settlement of colonists in a new frontier area and can be very active, even in the absence of formal land title. Land markets in the three frontier districts in Peru showed consistent patterns of change through time: land sales reported from later years involved parcels that were smaller, had a lower proportion of forest, and were more expensive per hectare. By using a hedonic model of land price, we estimated by how much additional forest clearing would increase the price of land and showed how that increase changed through time. Although frontier areas in distinct stages of development showed different opportunity costs for forest sparing, the opportunity cost over time increased rapidly in all three areas–by US $86-$159 per hectare per year or 11-26% per year–during the decade of 2003-2013. Conservation initiatives must consider the dynamic nature of opportunity costs of forest clearing and sparing if they are to be effective. Indeed, in newly-settled frontier areas, policies focusing specifically on addressing land speculation may be more effective in stemming forest loss than incentive-based forest conservation approaches.

3.8. References

Akaike, H., 1974. A new look at the statistical model identification. *IEEE Transactions on Automatic Control* 19: 716–723.

Alvarado, J., 1994. Transacciones de tierras y crédito en la pequeña agricultura comercial. *Debate Agrario* 20, 107–126.

Asner, G.P., Knapp, D.E., Martin, R.E., Tupayachi, R., Anderson, C.B., Mascaro, J., Sinca, F., Chadwick, K.D., Higgins, M., Farfan, W., Llactayo, W., Silman, M.R., 2014. Targeted carbon conservation at national scales with high-resolution monitoring. *Proc. Natl. Acad. Sci.* 111: E5016–22.

Barona, E., Ramankutty, N., Hyman, G., Coomes, O.T., 2010. The role of pasture and soybean in deforestation of the Brazilian Amazon. *Environmental Research Letters* 5: 024002.

Bastian, C.T., McLeod, D.M., Germino, M.J., Reiners, W.A., Blasko, B.J., 2002. Environmental amenities and agricultural land values: A hedonic model using geographic information systems data. *Ecological Economics* 40: 337–349.

Bebbington, A.J., Bury, J.T., 2009. Institutional challenges for mining and sustainability in Peru. *Proc. Natl. Acad. Sci.* 106: 17296–17301.

Bowman, M.S., Soares-Filho, B.S., Merry, F.D., Nepstad, D.C., Rodrigues, H., Almeida, O.T., 2012. Persistence of cattle ranching in the Brazilian Amazon: A spatial analysis of the rationale for beef production. *Land Use Policy* 29: 558–568.

Börner, J., Wunder, S., 2008. Paying for avoided deforestation in the Brazilian Amazon: from cost assessment to scheme design. *International Forestry Review* 10: 496–511.

Börner, J., Wunder, S., Wertz-Kanounnikoff, S., Tito, M.R., Pereira, L., Nascimento, N., 2010. Direct conservation payments in the Brazilian Amazon: Scope and equity implications. *Ecological Economics* 69: 1272–1282.

Bradley, A.V., Millington, A.C., 2008. Coca and colonists: Quantifying and explaining forest clearance under coca and anti-narcotics policy regimes. *Conserv Ecol* 13(1): 32.

Brooks, T.M., Mittermeier, R.A., da Fonseca, G., Gerlach, J., Hoffmann, M., Lamoreux, J.F., Mittermeier, C.G., Pilgrim, J.D., Rodrigues, A., 2006. Global biodiversity conservation priorities. *Science* 313: 58–61.

Burnham, K.P., 2004. Multimodel Inference: Understanding AIC and BIC in model selection. *Sociological Methods & Research* 33: 261–304.

Busch, C.B., Vance, C., 2011. The diffusion of cattle ranching and deforestation: Prospects for a hollow frontier in Mexico's Yucatán. *Land Econonomics* 87: 682–698.

Carr, D.L., 2009. Population and deforestation: Why rural migration matters. *Progress in Human Geography* 33: 355–378.

Carrero, G.C., Fearnside, P.M., 2011. Forest clearing dynamics and the expansion of landholdings in Apuí, a deforestation hotspot on Brazil's Transamazon Highway. *Ecology and Society* 16(2).

Casetti, E., Gauthier, H.L., 1977. A Formalization and test of the "Hollow Frontier" hypothesis. *Economic Geography* 53: 70–78.

Chomitz, K.M., Alger, K., Thomas, T.S., Orlando, H., Vila Nova, P., 2005. Opportunity costs of conservation in a biodiversity hotspot: the case of southern Bahia. *Environment and Development Economics* 10: 293–312.

Conservation International, 2011. Iniciativa de conservation del bosque de protection Alto Mayo. Conservation International. Lima.

Deininger, K., Zegarra, E., Lavadenz, I., 2003. Determinants and impacts of rural land market activity: evidence from Nicaragua. *World Development* 31: 1385–1404.

Deininger, K.W., Castagnini, R., González, M.A., 2004. comparing land reform and land markets in Colombia. World Bank Publications. Washington D.C.

Dubé, J., Legros, D., 2014. Spatial Econometrics Using Microdata, First. ed. John Wiley & Sons, Hoboken, NJ.

Eakin, H., Benessaiah, K., Barrera, J.F., Cruz-Bello, G.M., Morales, H., 2011. Livelihoods and landscapes at the threshold of change: disaster and resilience in a Chiapas coffee community. *Regional Environmental Change* 12: 475–488.

Engel, S., Pagiola, S., Wunder, S., 2008. Designing payments for environmental services in theory and practice: An overview of the issues. *Ecological Economics* 65: 663–674.

FAO, 2014. FAOLEX: Legislative database of FAO legal office. Rome.

Fearnside, P.M., 2005. Deforestation in Brazilian Amazonia: History, rates, and consequences. *Conservation Biology* 19: 680–688.

Fearnside, P.M., 2002. Can pasture intensification discourage deforestation in the Amazon and Pantanal regions of Brazil, in: Wood, C.H., Porro, R. (Eds.), Deforestation and Land Use in the Amazon. University Press of Florida, Gainesville, FL: 299–314.

Ferraro, P.J., Kiss, A., 2002. Direct payments to conserve biodiversity. *Science* 298: 1718–1719.

Fisher, B., Edwards, D.P., Giam, X., Wilcove, D.S., 2011a. The high costs of conserving Southeast Asia's lowland rainforests. *Frontiers in Ecology and the Environment* 9: 329–334.

Fisher, B., Lewis, S.L., Burgess, N.D., Malimbwi, R.E., 2011b. Implementation and opportunity costs of reducing deforestation and forest degradation in Tanzania. *Nature Climate Change* 1: 161-224.

Gay, C., Estrada, F., Conde, C., Eakin, H., Villers, L., 2006. Potential impacts of climate change on agriculture: a case of study of coffee production in Veracruz, Mexico. *Climatic Change* 79: 259–288.

Gertler, P., Glewwe, P., 1990. The willingness to pay for education in developing countries. Evidence from rural Peru. *Journal of Public Economics* 42: 251–275.

Gobierno Regional de San Martín, 2009. Las potencialidades y limitaciones del departamento de San Martín: Zonificación ecológica y económica como base para el ordenamiento territorial. Gobierno Regional de San Martín, Lima.

Gould, K.A., Carter, D.R., Shrestha, R.K., 2006. Extra-legal land market dynamics on a Guatemalan agricultural frontier: Implications for neoliberal land policies. *Land Use Policy* 23: 408–420.

Grieg-Gran, M., 2008. The cost of avoiding deforestation: update of the report prepared for the Stern Review of the economics of climate change. International Institute for Environment and Development (IIED), London.

Hansen, M.C., Potapov, P.V., Moore, R., Hancher, M., Turubanova, S.A., Tyukavina, A., Thau, D., Stehman, S.V., Goetz, S.J., Loveland, T.R., Kommareddy, A., Egorov, A., Chini, L., Justice, C.O., Townshend, J.R.G., 2013. High-resolution global maps of 21st-century forest cover change. *Science* 342: 850–853.

Ichikawa, M., Ricse, A., Ugarte, J., Kobayashi, S., 2014. Migration patterns and land use by immigrants under a changing frontier society in the Peruvian Amazon. *Tropics* 23: 73–82.

IMF 2012. World Economic Outlook. Washington D.C.

IMF no date. IMF Primary Commodity Prices. International Montetary Fund. URL http://www.imf.org/external/np/res/commod/index.aspx (accessed 11.12.14). Washington D.C.

INEI 2014. Redatam (database). Instituto Nacional de Estadística e Informática. http://censos.inei.gob.pe/Censos2007/redatam (accessed 12.1.14). Lima.

Kent, R.B., 1993. Geographical dimensions of the Shining Path insurgency in Peru. *Geographical Review* 83: 441–454.

Killeen, T.J., Guerra, A., Calzada, M., Correa, L., Calderon, V., Soria, L., Quezada, B., Steininger, M.K., 2008. Total historical land-use change in eastern Bolivia: who, where, when, and how much? *Ecology and Society* 13(1).

Kindermann, G., Obersteiner, M., Sohngen, B., Sathaye, J., Andrasko, K., Rametsteiner, E., Schlamadinger, B., Wunder, S., Beach, R., 2008. Global cost estimates of reducing carbon emissions through avoided deforestation. *Proc. Natl. Acad. Sci.* 105: 10302–10307.

Kirby, K.R., Laurance, W.F., Albernaz, A.K., Schroth, G., Fearnside, P.M., Bergen, S., Venticinque, E.M., da Costa, C., 2006. The future of deforestation in the Brazilian Amazon. *Futures* 38: 432–453.

Knoke, T., Weber, M., Barkmann, J., Pohle, P., Calvas, B., Medina, C., Aguirre, N., Günter, S., Stimm, B., Mosandl, R., Walter, von, F., Maza, B., Gerique, A., 2009. Effectiveness and distributional impacts of payments for reduced carbon emissions from. *Erdkunde* 63: 365–384.

Mac Nally, R., 2000. Regression and model-building in conservation biology, biogeography and ecology: the distinction between–and reconciliation of–‘predictive’and ‘explanatory’models. *Biodiversity Conservation* 9: 655–671.

Merry, F.D., Amacher, G., Lima, E., 2008. Land values in frontier settlements of the Brazilian Amazon. *World Development* 36: 2390–2401.

Mertens, B., Poccard-Chapuis, R., Piketty, M.G., Lacques, A.E., Venturieri, A., 2002. Crossing spatial analyses and livestock economics to understand deforestation processes in the Brazilian Amazon: the case of São Félix do Xingú in South Pará. *Agricultural Economics* 27: 269–294.

MINAGRI, 2014. Producción Pecuaria e Industrial Avícola. Ministerio de Agricultura y Riego; República del Perú. Lima.

MINAGRI, 2013. Producción Agrícola 2012. Ministro de Agricultura y Riego; República del Perú. Lima.

Morton, D.C., DeFries, R.S., Shimabukuro, Y.E., Anderson, L.O., Arai, E., del Bon Espirito-Santo, F., Freitas, R., Morisette, J., 2006. Cropland expansion changes deforestation dynamics in the southern Brazilian Amazon. *Proeedings of the National Academy of Sciences* 103: 14637–14641.

Moulton, B.R., 1990. An illustration of a pitfall in estimating the effects of aggregate variables on micro units. *The Review of Economics and Statistics* 72: 334–338.

Muschler, R.G., 2001. Shade improves coffee quality in a sub-optimal coffee-zone of Costa Rica. *Agroforestry Systems* 51: 131–139.

Müller, R., Müller, D., Schierhorn, F., Gerold, G., Pacheco, P., 2011. Proximate causes of deforestation in the Bolivian lowlands: an analysis of spatial dynamics. *Regional Environmental Change* 12: 445–459.

Naidoo, R., Adamowicz, W.L., 2006. Modeling opportunity costs of conservation in transitional landscapes. *Conservation Biology* 20: 490–500.

Naidoo, R., Ricketts, T.H., 2006. Mapping the economic costs and benefits of conservation. *PLOS Biology* 4: e360.

NASA, JAXA, 2009. ASTER Global DEM. http://gdex.cr.usgs.gov/gdex/. Washington D.C.

Paneque-Gálvez, J., Mas, J.-F., Guèze, M., Luz, A.C., Macía, M.J., Orta-Martínez, M., Pino, J., Reyes-García, V., 2013. Land tenure and forest cover change. The case of southwestern Beni, Bolivian Amazon, 1986-2009. *Applied Geography* 43: 113–126.

Parry, L., Day, B., Amaral, S., Peres, C.A., 2010. Drivers of rural exodus from Amazonian headwaters. *Population and Environment* 32: 137–176.

Perz, S.G., Aramburú, C., Bremner, J.L., 2005. Population, land use and deforestation in the pan Amazon basin: a comparison of Brazil, Bolivia, Colombia, Ecuador, Perú and Venezuela. *Environment, Development and Sustainability* 7: 23–49.

Pichón, F.J., 1997. Colonist land-allocation decisions, land use, and deforestation in the Ecuadorian Amazon frontier. *Economic Development and Cultural Change* 45: 730–744.

Plumb, S.T., Nielsen, E.A., Kim, Y.-S., 2012. Challenges of opportunity cost analysis in planning REDD+: a honduran case study of social and cultural values associated with indigenous forest uses. *Forests* 3: 244–264.

Poffenberger, M., 2009. Cambodia's forests and climate change: Mitigating drivers of deforestation. *Natural Resources Forum* 33: 285–296.

ProCeja, 2011. ProCeja: Plan Operativa Anual 2012. Gobierno Regional de San Martín (GORESAM). Moyobamba.

Redo, D., 2011. The role of the individual producer in driving land change: the case of Santa Cruz, Bolivia, 1986–2006. *GeoJournal* 78: 69–84.

Rodrigues, A.S.L., Ewers, R.M., Parry, L., Souza, C.J., Veríssimo, A., Balmford, A., 2009. Boom-and-bust development patterns across the Amazon deforestation frontier. *Science* 324: 1435–1437.

Rudel, T.K., Horowitz, B., 1993. Tropical deforestation: Small farmers and land clearing in the Ecuadorian Amazon. Columbia University Press, New York.

Saatchi, S.S., Harris, N.L., Brown, S., Lefsky, M., Mitchard, E.T.A., Salas, W., Zutta, B.R., Buermann, W., Lewis, S.L., Hagen, S., Petrova, S., White, L., Silman, M., Morel, A.C., 2011. Benchmark map of forest carbon stocks in tropical regions across three continents. *Proc. Natl. Acad. Sci.* 108: 9899–9904.

Sanchez-Cuervo, A.M., Aide, T.M., 2013. Consequences of the armed conflict, forced human displacement, and land abandonment on forest cover change in Colombia: a multi-scaled analysis. *Ecosystems* 16: 1052–1070.

Schjellerup, I., 2000. La Morada. A case study on the impact of human pressure on the environment in the Ceja de Selva, Northeastern Peru. *Ambio* 29: 451–454.

Schroth, G., Laderach, P., Dempewolf, J., Philpott, S., Haggar, J., Eakin, H., Castillejos, T., Moreno, J.G., Pinto, L.S., Hernandez, R., Eitzinger, A., Ramirez-Villegas, J., 2009. Towards a climate change adaptation strategy for coffee communities and ecosystems in the Sierra Madre de Chiapas, Mexico. *Mitig Adapt Strateg Glob Change* 14: 605–625.

Shanee, N., Shanee, S., Horwich, R.H., 2015. Effectiveness of locally run conservation initiatives in north-east Peru. *Oryx* 49: 239–247.

Sills, E.O., Caviglia-Harris, J.L., 2008. Evolution of the Amazonian frontier: Land values in Rondônia, Brazil. *Land Use Policy* 26: 55–67.

Snyder, S.A., Kilgore, M.A., Hudson, R., Donnay, J., 2008. Influence of purchaser perceptions and intentions on price for forest land parcels: A hedonic pricing approach. *Journal of Forest Economics* 14: 47–72.

Stern, N., 2007. Stern review on the economics of climate change. UK Cabinet Office - HM Treasury, London UK.

Strassburg, B., Turner, R.K., Fisher, B., Schaeffer, R., Lovett, A., 2009. Reducing emissions from deforestation—The “combined incentives” mechanism and empirical simulations. Global Environmental Change 19, 265–278.

Swenson, J.J., Young, B.E., Beck, S., Comer, P., Cordova, J.H., Dyson, J., Embert, D., Encarnacion, F., Ferreira, W., Franke, I., Grossman, D., Hernandez, P., Herzog, S.K., Josse, C., Navarro, G., Pacheco, V., Stein, B.A., Timana, M., Tovar, A., Tovar, C., Vargas, J., Zambrana-Torrelio, C.M., 2012. Plant and animal endemism in the eastern Andean slope: challenges to conservation. *BMC Ecol*. 12:1.

UNODC ICMP, 2007. Coca cultivation in the Andean region: A survey of Bolivia, Colombia, Ecuador and Peru. UNODC. Vienna.

Verburg, R., Filho, S.R., Lindoso, D., Debortoli, N., Litre, G., Bursztyn, M., 2014. The impact of commodity price and conservation policy scenarios on deforestation and agricultural land use in a frontier area within the Amazon. *Land Use Policy* 37: 14–26.

Vosti, S.A., Witcover, J., Carpentier, C.L., 2002. Agricultural intensification by smallholders in the western Brazilian Amazon: from deforestation to sustainable land use. International Food Policy Research Institute (IFPRI). Washington D.C.

Weinhold, D., Reis, E.J., Vale, P.M., 2015. Boom-bust patterns in the Brazilian Amazon. Global Environmental Change 35, 391–399.

Wooldridge, J.M., 2006. Introductory Econometrics: A Modern Approach, Third Edition. ed. Thomson South-Western, Mason, OH.

Wunder, S., 2007. The efficiency of payments for environmental services in tropical conservation. *Conserv. Biol.* 21: 48–58.

Xu, F., Mittelhammer, R.C., Barkley, P.W., 1993. Measuring the contributions of site characteristics to the value of agricultural land. *Land Econ* 69: 356–369.

Zegarra, E., 1999a. El mercado de tierras rurales en el Perú. Volumen II: Análisis económico. United Nations, Santiago, Chile.

Zegarra, E., 1999b. El mercado de tierras rurales en el Perú. Volumen I: Análisis institucional. United Nations, Santiago, Chile.

3.9. Supporting Information

Table 3-4 (supplementary): Community size and proportion of households interviewed.

District	Community	Households in community	Households interviewed	Percentage interviewed
Pardo Miguel	PM1	409	25	6.1%
	PM2	66	14	21%
	PM3	179	21	12%
Shamboyacu	Sh1	57	14	25%
	Sh2	43	11	26%
	Sh3	35	10	29%
	Sh4	47	17	36%
	Sh5	57	12	21%
	Sh6	76	14	18%
Alto Biavo	AB1	125	17	14%
	AB2	35	11	31%
	AB3	75	15	20%
	AB4	55	13	24%

Table 3-5 (supplementary): Deforestation rates in administrative regions of Amazon basin calculated from Hansen et al. (2013) data. Regions / States / Departments ordered within country on percent of area deforested. Countries ordered by total extent of deforestation in Amazon basin between 2000-2014.

Country	Region / State / Department	Area (km^2)	Percent forest cover (2000)	Percent of land area deforested (2000-2014)	Rank in % land deforested
Brazil	Rondonia	238 749	75.8%	13.6%	1
	Mato Grosso	906 226	56.0%	9.9%	2
	Para	1 256 815	89.5%	6.0%	6
	Acre	155 317	92.8%	5.5%	8
	Roraima	225 634	77.8%	2.0%	19
	Amapa	143 259	83.6%	1.5%	24
	Amazonas	1 578 885	95.5%	1.1%	28
Bolivia	Santa Cruz	361 230	68.0%	6.1%	5
	Cochabamba	54 396	46.7%	3.1%	14
	El Beni	220 641	55.0%	3.0%	15
	Pando	63 471	97.0%	2.7%	16
	La Paz	131 052	51.0%	1.2%	26
	Chuquisaca	51 144	33.5%	0.8%	31
	Potosi	119 535	0.1%	0.0%	44
Peru	San Martin	50 378	86.3%	8.2%	3
	Huanuco	37 069	56.0%	6.7%	4
	Pasco	23 955	67.3%	3.8%	11
	Ucayali	105 112	96.8%	3.3%	12
	Junin	44 603	49.1%	2.3%	18
	Amazonas	39 575	82.2%	1.7%	21
	Madre de Dios	84 868	97.3%	1.7%	23
	Piura	36 133	30.3%	1.2%	25
	Loreto	375 629	97.4%	1.1%	27
	Cajamarca	33 014	27.1%	1.0%	29
	Cusco	72 369	45.9%	0.7%	32
	Ayacucho	43 534	7.3%	0.3%	37
	Puno	73 244	20.1%	0.2%	40
	Apurimac	21 111	3.9%	0.1%	42
	Huancavelica	22 066	2.8%	0.1%	43
Colombia	Putumayo	24 026	91.1%	5.8%	7
	Caqueta	90 132	86.2%	4.5%	9
	Guaviare	55 700	94.4%	3.3%	13
	Vaupes	53 528	98.5%	0.6%	33
	Guainia	69 590	96.5%	0.3%	38
	Amazonas	107 833	98.3%	0.2%	41
Ecuador	Sucumbios	18 047	93.6%	4.4%	10
	Orellana	33 859	89.1%	2.3%	17
	Zamora Chinchipe	10 623	86.8%	1.7%	20
	Morona Santiago	24 104	89.9%	1.7%	22
	Chimborazo	6 508	23.6%	0.8%	30
	Pastaza	29 735	98.5%	0.5%	34
	Tungurahua	3 391	37.8%	0.4%	36
Venezuela	Amazonas	183 480	94.3%	0.4%	35
Guyana	Upper Dem.-Berbice	56 564	80.1%	0.3%	39

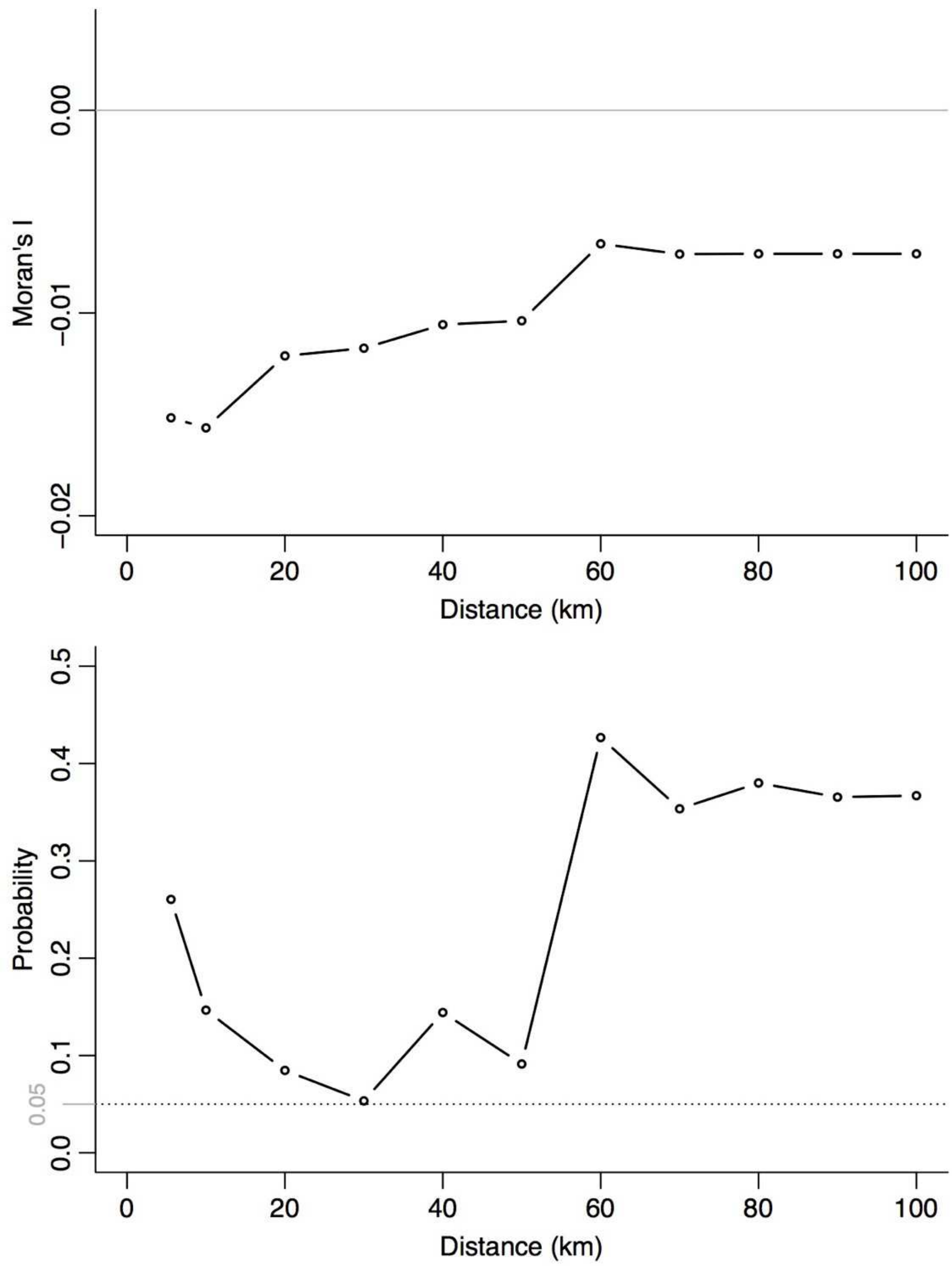

Figure 3-6 (supplementary): Moran's I of model residuals (model 7; top panel) and its probability (bottom panel) determined at different threshold distances for spatial association.

Distances used were 5.56 km (the minimum distance that ensures each observation has at least one neighbor) and every 10 km increment between 10 km and 100 km. The lowest value (i.e., largest absolute value) for the Moran's I was -0.0157 observed using a threshold distance of 10 km. Probabilities were determined using randomization (9999 iterations); p-values did not fall below the 5% critical value at any threshold distance; the value that came closest to the critical value was 0.053 observed at the 30 km threshold distance.

Table 3-6 (supplementary): Results of regression model with robust standard errors including primary effects form model 7 (Table 3-3) as well as all interaction terms involving district dummy variables or year of land sale. Note: it was not possible to use robust standard errors in this model because degrees of freedom were insufficient when all interaction terms were included.

Variable	β	Std. Error	t-value	p-value
Intercept	6.391	3.839	1.660	0.097
Primary effects				
Travel time to paved road (minutes)	-0.014	0.007	-2.000	0.047 *
Coffee price (arabicas; USD / tonne)	0.000	0.000	1.770	0.078
Cattle price (USD / tonne)	0.000	0.000	-1.070	0.286
Size of land parcel (ha)	0.029	0.020	1.450	0.149
Primary forest (%)	-0.010	0.004	-2.360	0.019 *
Elevation (masl)	-0.001	0.001	-0.920	0.361
Slope	-0.118	0.075	-1.580	0.116
Distance to primary school (km)	0.057	0.118	0.480	0.629
Years after first recorded sale in district	-0.117	0.223	-0.530	0.600
Years after first recorded sale in district (squared)	0.000	0.004	-0.090	0.925
District: Shamboyacu	-3.694	3.062	-1.210	0.229
District: Alto Biavo	-1.913	3.655	-0.520	0.601
Interactive effects				
Travel time * Alto Biavo	0.008	0.006	1.310	0.191
Coffee price * Alto Biavo	0.000	0.000	-1.280	0.203
Cattle price * Alto Biavo	0.000	0.000	0.320	0.750
Parcel size * Alto Biavo	-0.026	0.018	-1.480	0.140
Percent forest * Alto Biavo	0.004	0.003	1.070	0.286
Elevation * Alto Biavo	0.002	0.001	1.360	0.175
Slope * Alto Biavo	0.066	0.066	1.010	0.315
Distance to school * Alto Biavo	-0.046	0.106	-0.440	0.662
Years after 1st sale * Alto Biavo	0.027	0.176	0.150	0.879
Travel time * Shamboyacu	0.010	0.005	1.850	0.066
Coffee price * Shamboyacu	0.000	0.000	-1.210	0.226
Cattle price * Shamboyacu	0.000	0.000	1.040	0.301
Parcel size * Shamboyacu	-0.030	0.017	-1.750	0.082
Percent forest * Shamboyacu	0.002	0.003	0.930	0.353
Elevation * Shamboyacu	0.001	0.001	1.500	0.135
Slope * Shamboyacu	0.149	0.064	2.320	0.021 *
Distance to school * Shamboyacu	-0.045	0.090	-0.500	0.620
Years after 1st sale * Shamboyacu	0.023	0.134	0.170	0.867
Travel time * Year	0.000	0.000	1.520	0.131
Coffee price * Year	0.000	0.000	-1.400	0.163
Cattle price * Year	0.000	0.000	1.150	0.251
Parcel size * Year	-0.001	0.001	-1.980	0.049 *
Percent forest * Year	0.000	0.000	1.070	0.285
Elevation * Year	0.000	0.000	1.410	0.161
Slope * Year	0.003	0.002	1.410	0.161
Distance to school * Year	-0.002	0.004	-0.410	0.684
R^2	0.754			
F-statistic	$16.89_{38, 210}$***			
Akaike Information Criterion	184.3			

Significance levels of p-values as follows: *** < 0.001 < ** < 0.01 < * < 0.05.

Connecting Statement: Land acquisition to land distribution

In Chapters two and three, I examined the process of migration and the process of land acquisition on the frontier. In both cases, I assessed changes in these processes through time as the frontier areas develop by studying individual households and individual land parcels. In Chapter four, I will use the same set of information on land acquisitions and land holdings that was presented in Chapter three to assess the distribution of land among households in each district. I report the distribution of land among my respondent households and estimate how the level of equality or inequality in landholdings changed through time as the frontiers evolved. This study of frontier land distribution and its change through time has implications for an understanding of frontier dynamics as well as for the effectiveness of community-scale forest conservation regimes.

Chapter 4. The distribution of landholdings and land inequality evolution on a developing frontier in the Peruvian Amazon

4.1. Abstract

The distribution of land in frontier areas can affect land use decisions as well as the rate of out-migration to more distant frontiers and to urban centres. It can also affect the potential effectiveness of community-scale forest conservation efforts. In this chapter, I use historical landholdings reported by interview respondents to assess past trends in landholdings and in the level of equality of those holdings. I find that inequality increased in each of three study districts when using both of two different methods of assessment: the proportion of land held by the top quintile of landholders and the Gini index. Although inequality increased, the dynamics I observed are very different from the so-called "hollow frontier" pattern. Inequality increased when large numbers of new arrivals acquired relatively small landholdings while early-arriving larger landholders maintained their original holdings; this resulted in an overall decrease in land parcel size and an increase in overall population density–the opposite of the "hollow frontier.". This difference is likely due to the labour demands of coffee, the predominant crop in the area, and the way in which those labour demands act as a constraint on the size of coffee plantations that get established. I also find that the largest inequality in landholdings was in forestland whereas the inequality in coffee holdings was lower. This suggests that an important difference between the land-rich and the land-poor will be in their ability to pass land on to their children; this may mean that higher inequality is associated with higher rates of out-migration in future as the children of landholders with smallholdings become less able to stay in their area of origin and to make a living off their limited land

inheritance. This pattern of pronounced inequality in forestland may be particularly important to community-scale forest conservation efforts in the future as a larger proportion of standing forest is concentrated in the hands of fewer individuals.

4.2. Introduction

Land distribution is widely considered an important determining factor in landscape outcomes (Thiesenhusen 1991; Tole 2004; Takasaki et al. 2001) and in the welfare of settler farmers (Marquette 2006). Equality of income and of wealth more broadly is often implicated in the support for and the effectiveness of community institutions (Ostrom 2001; Milanovic 2005; Marquette 2006). The effectiveness of community institutions can in turn affect both the well-being of community members as well as the potential for the sustainable use and management of natural resources. In frontier areas of the Amazon, where land is often the most important asset held by settler farmers, understanding the distribution of land and how it changes through time as the frontier evolves is crucial to understanding the dynamics of landscape change and of settler welfare as the frontier expands.

As the population of an area increases, more land will be cleared and brought into agricultural production. This relationship–between population increase and the rate of land clearing–is in part mediated by the distribution of landholdings. In more unequal systems of land distribution, a given rate of population increase will tend to be accompanied by a higher rate of land clearing for agriculture (Tole 2004). Inequality has thus been described as decreasing the capacity of a landscape to absorb increasing population numbers (Thiesenhusen 1991; Tole 2004). By reducing the access to land and resources of poorer households, higher inequality also increases rates of out-migration from rural areas to expanding areas of the frontier (Carr 2004). Increased frontier migration will tend to raise rates of frontier expansion and of forest clearing. While migration to the frontier from urban areas is often driven primarily by exogenous policy changes and infrastructure expansion, migration within the frontier is often dependent primarily on household economies and lifecycles (Perz 2001; Caviglia-Harris et al. 2012). Relative levels of access to land and to resources are two key factors in determining frontier migration.

4.2.1. Inequality and resource management

The relationship between inequality and the sustainability of resource management has long been a subject of theoretical discussion, and relationships in both directions have been proposed. Mancur Olson (Olson 1965) suggested that higher inequality was likely to improve conservation outcomes because the control over resources was concentrated within a small group of people who also had the greatest incentive to keep resources in good condition in the long term; Olson hypothesized that this would avoid what later came to be called the "Tragedy of the Commons" (Hardin 1968)–the overexploitation of common resources that seemed inevitable when benefits of exploitation accrue to individuals but costs are shared collectively. Work by Elinor Ostrom and colleagues, however, made clear that in many cases the resources communities depended upon were not true "commons" (i.e., open access resources) but in fact were governed by various formal or informal institutions (Ostrom 1999). Those institutions governing resource use and access were often more effective when communities were more equitable, thus suggesting that inequality would in fact have a negative impact on the sustainability of community-managed resources (Ostrom 2001; Janssen and Ostrom 2001). Baland and Platteau (1999) have suggested that both positive and negative effects of inequality on management success can exist at the same time and that the net effect of inequality–whether it be positive or negative–will vary among communities depending on total levels of inequality and structures of management. The relationship between inequality and effectiveness of conservation regimes may be particularly important in frontier areas where social cohesion and political organization are often weak (Marquette 2006). Increased inequalities within frontier communities may make already-difficult conditions for community management even more so.

4.2.2. Determinants of total landholdings

The size of a household's landholdings often depends on the time of their arrival in a frontier area; earlier arrivals generally have larger holdings than those who arrived later (Chapter 2; Coomes et al. 2016). Additionally, migrant households who sell land in their areas of origin are generally able to translate the resulting financial assets into larger total holdings once they arrive in a frontier destination area (Chapter 2). These initial endowments of land have important implications both for future landholder income as well as for future land use and land clearing. More land is associated with higher incomes, higher levels of wealth (although in the case of wealth, the relationship with landholding likely has causality in both directions), with a larger cumulative stock of cleared land, and with higher rates of land clearing per year (Jones et al. 1995; Murphy et al. 1997; Walker et al. 2002).

Household land endowments interact with family lifecycles and with endowments of other assets to influence land use and land clearing. In the early years after establishment, households tend to clear land at a high rate as they establish claim over land and to begin producing crops (Jones et al. 1995; de Sherbinin et al. 2008). In later years, households tend to clear land at a slower rate than they do initially; however, they generally possess a larger cumulative total of cleared land (Walker et al. 2002; de Sherbinin et al. 2008). Household lifecycles can affect land use both at a local scale and at a distance through migration. Larger households–particularly households with larger numbers of working-age men–tend to be associated with higher rates of deforestation (Rudel and Horowitz 1993; Walker et al. 2002) while households with more children nearing adulthood lead to more rural-rural migrants as well as higher rates of deforestation on the forest frontier (Barbieri et al. 2006; Carr et al. 2006). As discussed by Tole (2004), the distribution of land–and the proportion of households who are land-poor–will affect the relationship between household lifecycles and migration: as land holdings become more unequal and a larger proportion of households are land-poor, a larger proportion of adult children will choose migration to the forest frontier while fewer will stay in their area of origin.

4.2.3. Trends in land distribution in the Amazon

Relatively high levels of inequality in land holdings have been observed across the Amazon, although there is also a considerable range. Gini index values–which range from a value of 0 at perfect equality to 1 at perfect inequality–of total landholdings in a ribereño community in the lower Peruvian Amazon varied between 0.23 and 0.45 during a 30-year period (Coomes et al. 2016). Communities bordering a protected area, also in the lower Peruvian Amazon, showed levels of land inequality that ranged from 0.31 to 0.58 with an inter-community mean of 0.53 (Takasaki et al. 2001). In Brazil, land distribution has historically been exceptionally high with Gini values up to 0.84 observed (Ludewigs et al. 2009). Land reform, however, in some cases drastically reduced the inequality of land distribution with values as low as 0.12 to 0.52 observed immediately following a land reform program.

To date, there is no general consensus on how land distribution is likely to change through time as frontiers develop (Caviglia-Harris et al. 2012). Two of the studies mentioned above demonstrated opposite trends through time in inequality. Ludewigs and colleagues (2009) found inequality increased through time through as the process of land market churn led to many small landholders selling their parcels to owners of large consolidated holdings. By contrast, Coomes and colleagues (2015) saw a decrease in the inequality of total land holdings as family inheritance led to land holdings being transferred from land-wealthier parents to land-poorer children in the same extended family. Understanding how the inequality in land distribution changes as frontier areas develop has important implications for projections of both forest cover outcomes and outcomes regarding settler welfare.

4.2.4. Study area

We evaluate trends through time in land distribution in three frontier districts of the San Martin Region in the upper Amazon (*selva alta*) of Peru. The districts have different settlement histories that range from initial settlement dates in the mid-1970s to initial settlement in 1998 and 1999. San Martin sits between the high Andes of the Regions of Cajamarca and La Libertad and the lowland Amazon of the Region of Loreto. Many of the newly-developing districts of San Martin are being settled by migrants from the Peruvian *sierra* (Schjellerup 2000; Shanee et al. 2015; Chapter 2). Among respondents, most had moved far from their district of birth; the median distance between district of birth and current district of residence of respondants was 328 km (Chapter 2).

The largest city in San Martin, Tarapoto, is 630 km northeast of Lima and 460 km southwest of Iquitos–the city often referred to as the capital of the Peruvian Amazon. Lands in San Martin range from a minimum elevation of 200 meters above sea level to a maximum of 4000 m.a.s.l. along the border of San Martin that abuts the Region of La Libertad. Landholdings of respondents varied in elevation from a minimum of 418 m to a maximum of 1659 m. Most respondents are coffee-growers; 93% had some portion of their land planted in coffee. Within the elevational band of the landholdings of respondents, higher elevation is as an advantage for production of the Arabica coffee that is grown in Peru. Peak Arabica yields have been observed at 1500m and higher while yields below 700m tend to be significantly lower (Muschler 2001; Schroth et al. 2009).

Our respondents hold their land almost exclusively with no formal title (>98%). Despite the lack of land title, however, land markets are very active in all three areas with 47.3% to 60.3% of respondents having either bought or sold land within the five years prior to field work (2012 in Shamboyacu; 2013 in Pardo Miguel and Alto Biavo). In 11 of 13 study communities, migrants in the early years of community settlement established tenure through land claims (in the remaining two communities, there were some limited government land allocation). In subsequent years, land markets were established and informal land claims were eventually eliminated. At the time of my field work, all land transactions took place either through an extra-legal market exchange or else through a gift / inheritance within a family.

4.3. Methods

We collected reports of land holdings, land acquisitions, land sales, and land losses among 191 smallholder households in the Peruvian upper Amazon (*selva alta*). I use these records to calculate the current distribution of landholdings and also to reconstruct historical landholding trajectories for the households in my sample. I gathered data during semi-structured interviews with 194 smallholders in 13 communities of three districts of San Martin. I chose the three study districts after consultation with NGO staff and government officials in order to meet three criteria: that each district be an area of active deforestation; that each contain areas targeted by forest conservation activities; and, that collectively the three districts represent a range of different settlement times. Within the three districts–Pardo Miguel, Shamboyacu, and Alto Biavo–we selected those communities that were targeted for conservation activities; in all cases, these were areas that fell within the buffer zones of protected areas. I excluded communities that were located inside protected areas themselves because in some cases (particularly in the district of Pardo Miguel), these communities within PAs have had contentious relationships with government agencies and PA management authorities; I was informed that the situation within some of these communities would make research difficult at best and dangerous at worst. In Pardo Miguel, there were three communities that were located outside the protected area (Alto Mayo Protected Forest) but within the marked buffer zone. In Shamboyacu, there were seven communities on the side of the district that sloped upwards towards the protected area–Cordillera Azul National Park–that was a particular conservation priority; I worked in six of these seven (in the seventh, community authorities were not interested in participating in the research project). In Alto Biavo, one valley is relatively separated from the rest of the district, but abuts the Cordillera Azul National Park and is therefore the target of most forest conservation activities in the district; I worked in the four communities in that valley. In each of these 13 communities (three, six, and four communities, respectively, in the three districts), I set a goal of interviewing the household head of either 20% of households in the community or else interviewing 20 households in larger communities where 20% would have been an impractically large number. I met this sampling goal in 11 of 13 communities and fell somewhat short in two communities (17 households representing 14% in one; 14 households representing 18% in the other). In total, I completed interviews with 194 households in the three districts. Three households were excluded because of inconsistencies in the land trajectory data described below, so 191 are included in the data reported in this study: 55, 78, and 58 households, respectively, in Pardo Miguel, Shamboyacu, and Alto Biavo.

With each household I conducted a semi-structured interview that generally lasted between 30 minutes and two hours (average about 75 minutes). Part of each interview was a full reporting of land holdings and the land cover breakdown of each parcel of land held. I also asked household heads for a full accounting of each land acquisition event (through purchase, inheritance, land claim, or land allocation) and land loss event (through sale, gift, or loss through conflict) with a description of the area and land cover type of the land acquired or lost and the year of the acquisition or loss. In each case, I cross-checked present land holdings with past acquisitions and land losses. In cases where the arithmetic was inconsistent, I followed up during interviews with household heads to reconcile differences. In three cases (mentioned above), I was unable to reconcile inconsistencies in the land holding trajectories, and so I excluded these cases.

With this record of land acquisitions and losses I am able to reconstruct a land holding trajectory for each household that indicates how many hectares each household held in each year since the year that the household arrived in the study community. With these trajectories for each household in my sample, I am able to estimate patterns in land holding through time. However, I note that my estimations of patterns of landholdings in past years should be treated with some caution: although I believe them to be accurate with regard to the individuals in my sample, they do not account for households who may have previously resided in the study communities but later left. As an example from my data presented below, the right panel in Figure 4-2 includes my full sample–systematically selected in each community–and can be considered representative and unbiased. However, the trends shown in the left panel in Figure 4-2 are not able to account for those individuals who may have left the study area.

Because field work took place in different years and the study areas having different histories of settlement, the ranges of years examined differ across districts. Measuring the relative distribution of land among households requires a certain number of households in order for the measure to be meaningful. I chose a threshold of 20 households; below that threshold, I did not attempt to calculate historical metrics of landholding and land distribution. Because Pardo Miguel is the longest-settled and has the longest average residence times (Chapter 2), I was able to go back furthest with the data: my threshold of 20 households allowed me to go back as far as 1998. In Shamboyacu, I reconstructed the historical data back as far as 2000, and in Alto Biavo I did so to 2003. In sum, the year ranges presented are 1998-2013, 2000-2012, and 2003-2013 for Pardo Miguel, Shamboyacu, and Alto Biavo, respectively.

4.3.1. Testing trends through time

We test for trends through time using the Mann-Kendall Tau statistic. This is a non-parametric statistic used to identify monotonic trends (Hirsch et al. 1982; Murtinho et al. 2013). At the sample sizes I have–with one observation per year over 11-16 years–it is more conservative than a Pearson correlation. In every case of a significant trend I report, the p-value from the equivalent Pearson correlation was lower (i.e., more significant) than the one I report from the Mann-Kendall test.

We examine determinants of total land holdings using an ordinary least-squares (OLS) model that includes terms expected to influence the total amount of land held: the household size, its lifecycle stage as indicated by the age of the household head and the working age proportion, and the length of time the household has been based in the study community. I further evaluate the influence of these variables on land holding by using hierarchical partitioning (Mac Nally 2000) to determine the percentage of independent contribution of each variable to the variance in total land holding.

4.3.2. Describing inequality

There are many ways of representing inequality and all have pros and cons. In this chapter, I use several different measures so as to present a fuller picture of land distribution. I begin by comparing landholdings of the top quintile with those of the bottom quintile. I report averages for each of these groups, the ratio of the holdings of the top quintile to the bottom quintile, and the proportion of land held by the top quintile. These metrics tend to co-vary, but an examination of them together gives the reader a more complete picture of the distribution pattern than any one on its own. I also present the Gini index as an overall measure of inequality. The Gini index is less intuitive than a comparison between quintiles; however, it has the advantage of providing a measure of inequality throughout the distribution rather than focusing only on the top and the bottom. The Gini index is calculated from the Lorenz curve, which plots the ranked cumulative distribution of the population on the x-axis and the cumulative distribution of land on the y-axis. The Gini ranges from a minimum value of 0 at perfect equality, where all individuals in the population have the same amount of land, and the Lorenz curve follows the 1:1 slope line. The maximum value of the Gini is 1 and would occur when all land is held by a single individual. In practice, a Gini value of 0.63 corresponds to the level of income inequality in a highly unequal country such as South Africa, while a value of 0.26 corresponds to the income distribution of a highly equal country such as Norway (World Bank n.d.). I calculate the Gini index within each district for landholdings of different types: coffee plantation, forestland, crops (including coffee) and pasture combined, and overall land. I also estimate trends through time in each district for the Gini index of total landholdings.

4.4. Results

We used household-reported landholdings and reported histories of land acquisitions, land sales, land gifts, and inheritances to recreate the trajectory of household landholdings through time. This allowed me to look at patterns of inequality in landholding in the present and also to estimate patterns of change in landholdings through time. I found that the majority of landholders (56.5%) I interviewed had acquired land in the study area only once–in a single land purchase, land claim, or inheritance event. A smaller number (28.3%) had acquired land twice, whereas only 15.2% had acquired land over three or more events. These values varied slightly between districts with the percentage of households that had only acquired once being 48.2%, 57.7%, and 63.6%, respectively, in Pardo Miguel, Shamboyacu, and Alto Biavo, whereas the percentages of those who had acquired land on three occasions or more was 15.5%, 20.5%, and 7.3%. Landholders tended to hold land that they acquired with only a minority seeing their holdings diminish over time as they sold land, lost it through conflict, or gave it to other family members: 81.7% of respondents had never parted with land, either voluntarily or otherwise (77.6%, 83.3%, and 83.6% among Pardo Miguel, Shamboyacu, and Alto Biavo, respectively), and only 4.7% (5.2%, 5.1%, and 3.6% in the districts, respectively) had done so two or more times. Plotting the area of land held through time for individual households illustrates this pattern of relatively few events of households parting with land relative to events where households acquire it (Figure 4-1).

An ordinary least squares (OLS) linear regression on the log (plus 1) of land holdings indicates that the number of years that a household has been established in a community is a significant predictor ($p = 0.0007$) of total land holdings (Table 4-1). The coefficient indicates that a household that had been established in the community for 15 years would be expected to have 17.8% more land than a household that had been established for only 10 years. Older household heads and larger working age proportions were both significantly associated with larger land holdings. A 50-year-old household head would be expected to have 21.5% more land than one who was 40 years old, whereas an increase in the working age proportion from 50% to 100% is predicted to be associated with a 60.6% increase in total land holdings. According to a hierarchical partitioning analysis, the length of time established in the community explains 11.1% of the variance in the model that can be attributed to individual effects. This compares to 17.5% of the variance explained by the age of the household head and 4.8% explained by the proportion of household of working age. The largest contributions to variance in land holdings are made by the two district dummy variables (65.2% total).

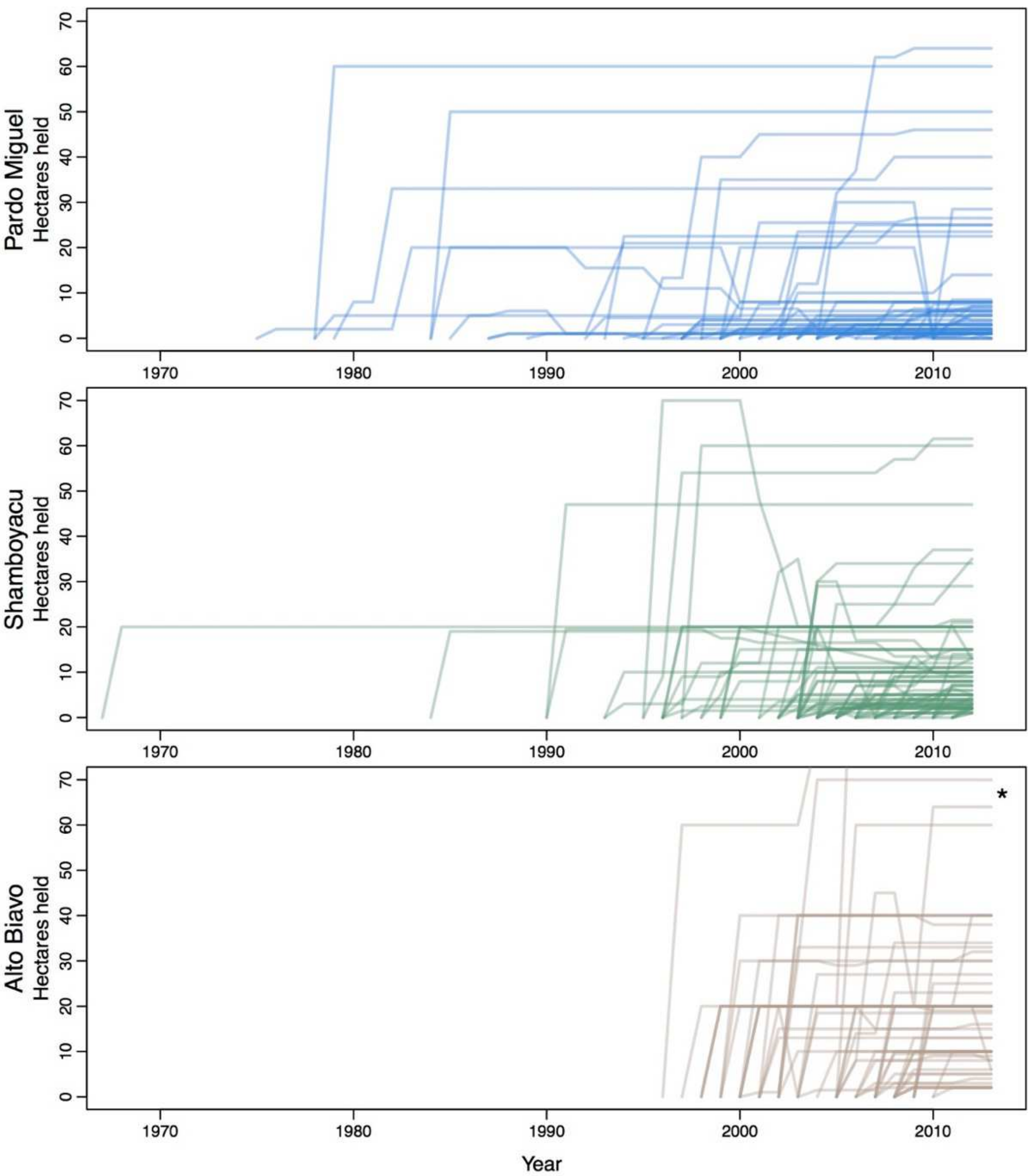

Figure 4-1: Land holding trajectories of individual households in each of the three districts: Pardo Miguel (top), Shamboyacu (middle), Alto Biavo (bottom). Each line represents a household and the total extent of its landholdings in the given year.
Trajectories were constructed from interviews that took place in 2012 (Shamboyacu) and 2013 (Pardo Miguel and Alto Biavo) where households were asked about all of the parcels of land that they had acquired and had lost, given away, or sold. The * indicates that the landholdings of two landholders are truncated from the bottom graph (Alto Biavo): those individuals had 80 ha and 200 ha respectively in 2013 (values were truncated to improve legibility and to maintain consistency with other districts).

Table 4-1: OLS model with independent variable of total land holdings by household (plus one; log-transformed). Right-most column represents percent independent contribution of each variable as determined by hierarchical partitioning.

	Coefficient	Standard error	Signif.	Percent independent contribution
Intercept	-0.0617	0.4169	ns	
Number of members of household	0.0528	0.0397	ns	1.4%
Age of household head	0.0163	0.0057	**	17.5%
Household working age proportion	0.8263	0.3449	*	4.8%
Years since established in community	0.0273	0.0079	***	11.1%
District: Shamboyacu	0.5523	0.1631	***	7.6%
District: Alto Biavo	1.3104	0.1802	***	57.6%
Adjusted R-squared	0.2663			
F-statistic	$12.49_{6, 184}$			
Model significance	$p < 0.001$ ***			

Significance levels of p-values as follows: *** < 0.001 < ** < 0.01 < * < 0.05.

4.4.1. Average holding size through time

The average size of land holdings in 2013 in Alto Biavo (24.3ha; σ = 29.8ha) was significantly higher–using Tukey's HSD test–than in either Pardo Miguel (10.6ha; σ = 15.3ha; $p = 0.0009$) or in Shamboyacu (12.2ha; σ = 10.9ha; $p = 0.0005$) (Figure 4-2). Using a historical reconstruction of landholdings based on past land acquisitions and past land sales and losses by respondents, I used Mann-Kendall's Tau as a test for trend and found evidence that the average size of holdings had declined in both Pardo Miguel ($\tau = -0.833$; $p < 0.0001$) and Shamboyacu ($\tau = -0.974$; $p < 0.0001$), while the median size of land holdings had declined in Shamboyacu ($\tau = -0.872$; $p < 0.0001$). I did not find evidence of a trend through time in either the mean or the median size of land holdings in Alto Biavo, nor in the median in Pardo Miguel.

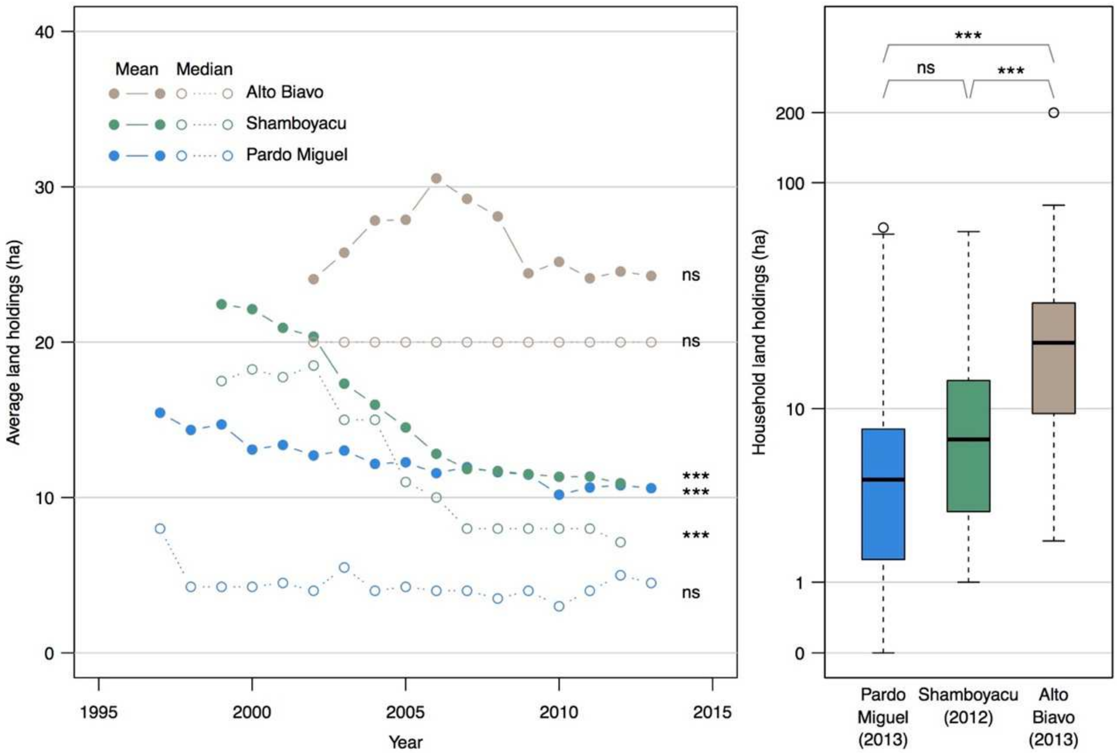

Figure 4-2: Land holding sizes through time in three districts.
Left: reconstructed timeline of average and median holding sizes in each district through time; created using reported landholdings of respondents. Years only included if 20 or more respondents could report data for that year. Significance of trends through time determined by Mann-Kendall trend test and indicated by stars to the right of each trend line. Right: boxplots of household land holdings at the time of interviews (2012 or 2013). Significant differences between districts indicated by brackets and stars above boxes (*** < 0.001 < ** < 0.01 < * < 0.05 < ns).

4.4.2. Inequality in land holdings

Inequality of land holdings was quite pronounced in all three districts. In Pardo Miguel, the area land held by the top quintile of respondents was 55.5 times greater than the total land held by the bottom quintile of respondents. The top quintile of landholders in Pardo Miguel held an average of 37.0 hectares of land while the average of the bottom quintile was only 0.7 ha. In Shamboyacu and Alto Biavo, the ratio between the total land holdings of the top and bottom quintiles was 16.8:1 and 18.0:1, respectively (Table 4-2). In Shamboyacu, the top quintile had an average of 29.7 ha while the bottom quintile had 1.8 ha. In Alto Biavo, the top quintile had an average of 64.2 ha while the bottom quintile had 3.6 ha.

Table 4-2: Metrics of inequality in land holdings and in income from crops. Data from 2012 for Shamboyacu and 2013 for Pardo Miguel and Alto Biavo.

		Average: bottom quintile	Average: top quintile	Ratio: top quintile total to bottom quintile total	Gini index
Pardo Miguel (n = 58)	Land: all cover types (ha)	0.7	37.0	55.5 : 1	0.64
	Land: crops and pasture (incl. coffee; ha)	0.5	15.9	29.8 : 1	0.57
	Land: coffee (ha)	0.1	6.9	91.9 : 1	0.53
	Land: forest (ha)	0.0	17.8	–	0.84
	Income from crops: annual (2013 USD)	3.4*	2210.5	646.4:1	0.60
Shamboyacu (n = 78)	Land: all cover types (ha)	1.8	29.7	16.8 : 1	0.51
	Land: crops and pasture (incl. coffee; ha)	1.1	10.8	9.8 : 1	0.44
	Land: coffee (ha)	0.8	6.0	7.8 : 1	0.39
	Land: forest (ha)	0.0	14.2	–	0.67
	Income from crops: annual (2013 USD)	71.9	6863.7	95.4:1	0.54
Alto Biavo (n = 55)	Land: all cover types (ha)	3.6	64.2	18.0 : 1	0.49
	Land: crops and pasture (incl. coffee; ha)	1.6	15.4	10.0 : 1	0.45
	Land: coffee (ha)	1.2	6.8	5.7 : 1	0.33
	Land: forest (ha)	0.9	59.4	68.6 : 1	0.60
	Income from crops: annual (2013 USD)	159.2	4797.8	30.1:1	0.50

*Several farmers in Pardo Miguel had lost their entire coffee crops from a fungal pathogen (coffee rust; *Hemileia vastatrix*) and so had zero income from crops in that year. Pardo Miguel has a more active labour market than the other two districts, so these farmers were supporting their families through wage labour (not included here).

The Gini index of land holdings ranged from 0.49 among respondents in Alto Biavo to 0.51 in Shamboyacu to 0.64 in Pardo Miguel (Table 4-2). The analysis also suggests that inequality of land may be increasing through time. Here I will note an important caveat: because my data were collected retrospectively, there were likely households with landholdings in the study areas who lived in the area for some time period and then left prior to sampling.

my data necessarily does not include any land held by those individuals. However, looking at past holdings of individuals I was able to interview in 2012 and 2013, the inequality of land holding among those respondents has increased through time by three different metrics. First, the proportion of land held by the top 20% of landholders increased significantly (as determined by Mann-Kendall test for trend) in all three districts (Figure 4-3). In Pardo Miguel, this increase was statistially significant ($\tau = 0.550$; $p = 0.003$) and represented an increase in the proportion of land held by the top quintile from 63.8% to 72.2% during the years that include 20 or more respondents (1998-2013)–an increase of 0.56% per year. In Shamboyacu, a significant trend ($\tau = 0.615$; $p = 0.004$) was observed over the time series (2000-2012) with an increase from 52.2% to 55.8% (0.30% per year). In Alto Biavo, the proportion increased ($\tau = 0.673$; $p = 0.005$) from 33.3% in 2003 to 52.9% in 2013, an increase of 2.0% per year.

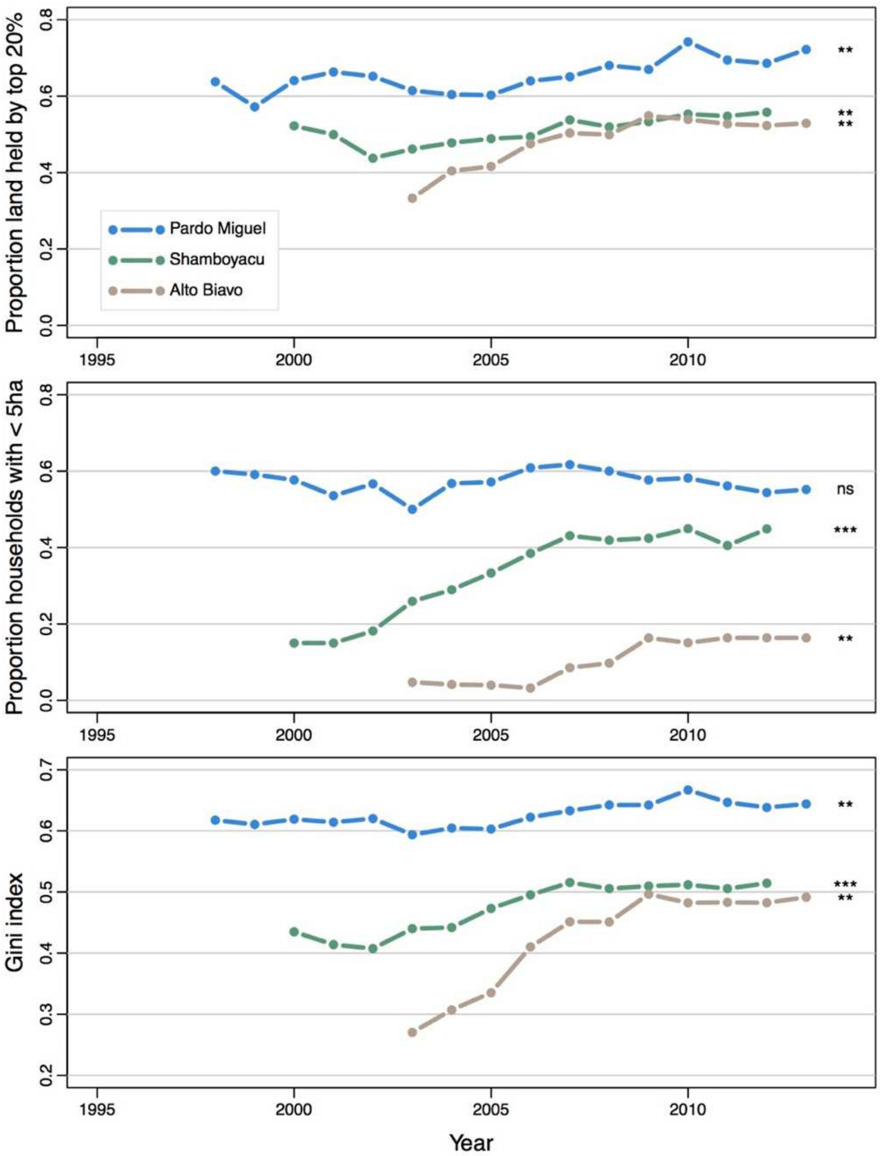

Figure 4-3: Trends through time in three metrics of land distribution: percentage of land held by top 20% of landholders (top); proportion of households with less than five hectares (middle); and the Gini index (bottom).
Significance levels indicated by stars (*** < 0.001 < ** < 0.01 < * < 0.05 < ns) are determined using the Mann-Kendall trend test.

While the proportion of land held by the largest landholders increased in all three districts, the proportion of households with small landholdings increased in two of the three districts (Figure 4-3). In Shamboyacu, the proportion of respondents who had fewer than five hectares of land was 15.0% in 2000 and rose to 44.9% in 2012 ($\tau = 0.813$; $p = 0.0002$). In Alto

Biavo, this value rose from 4.8% in 2003 to 16.4% in 2013 ($\tau = 0.711$; $p = 0.004$). In Pardo Miguel, there was no significant trend through time ($\tau = -0.135$; $p = 0.499$), but the percentage of respondents with less than five hectares was 60.0% in 1998 and 55.2% in 2013.

Given the increase both in the proportion of land held by the top quintile (in all districts) and in the proportion of households who have small holdings (in two out of three districts), it is not surprising that the Gini index–an indicator of overall inequality–increased through time in all three districts (Figure 4-3). In Pardo Miguel, the Gini increased through time ($\tau = 0.550$; $p = 0.003$) from a value of 0.62 in 1998 to 0.64 in 2013. In Shamboyacu, the increase ($\tau = 0.744$; $p = 0.0005$) was from 0.44 in 2000 to 0.51 in 2012, while in Alto Biavo, the increase ($\tau = 0.782$; $p = 0.001$) was from 0.27 in 2003 to 0.49 in 2013.

4.4.3. Lower inequality in cultivated land than in forested land

Inequality of forested land was consistently higher than inequality of cultivated land in general and inequality of coffee plantations in particular. In all three districts, the Gini of coffee holdings was lower (i.e., more equal) than the Gini of total landholdings, whereas the Gini of forest holdings was higher (i.e., more unequal) than that of total landholdings (Figure 4-4). In Pardo Miguel, the Gini for total landholdings of 0.64 compared with a Gini of coffee holdings of 0.53 and one of forest of 0.84 (Table 4-2). In Shamboyacu, inequality of forest holdings was 0.67 whereas inequality of coffee holdings was only 0.39. In Alto Biavo, Gini of forest land was 0.60 while that of coffee was 0.33. Because coffee production is the primary source of income for households in this area (94.2% of respondents have some area of coffee plantation, and for 40.7% of respondents coffee production is their only source of household income), the fact that coffee holdings are generally more equal than total land holdings could reduce the impact of land inequality on income inequality. Examining inequality of income from crop production, values are consistently more equal than forest landholdings, but consistently less equal than coffee landholdings. The Gini indices of crop production income in Pardo Miguel, Shamboyacu, and Alto Biavo are 0.60, 0.54, and 0.50, respectively.

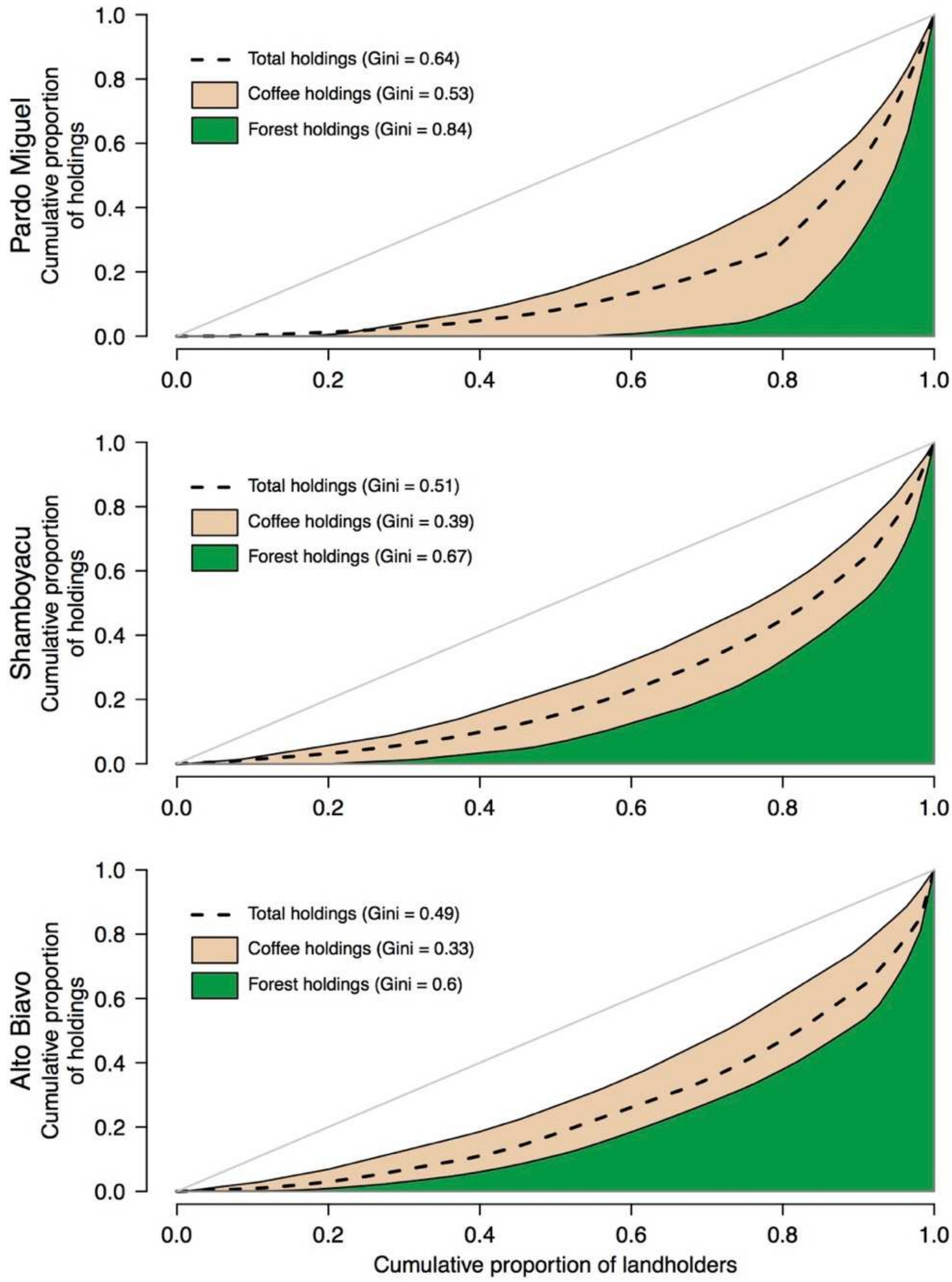

Figure 4-4: Lorenz curves (from which Gini indices are calculated) showing the distribution of different types of land among respondents in each district.
The curves shown in green represent the cumulative distribution of forest holdings; in beige, the cumulative distribution of coffee holdings; and the dotted line is the cumulative distribution of total land holdings.

4.5. Discussion

We find the mean size of landholdings declined through time in two of the three districts while metrics of inequality increased across all three districts. This increase in inequality–whether measured by Gini index or by the proportion of land held by the top quintile of landholders (Figure 4-3)–has largely resulted from new migrants arriving and acquiring smaller and smaller land parcels while early arrivals continue to maintain relatively large landholdings (Figure 4-1). The importance of arrival time to total landholdings is shown by the OLS model where the years since a household arrived in a community explained more of the variance in total landholdings than did household size and household working age proportion combined (Table 4-1).

This dynamic–whereby inequality increases as a result of newly-arriving migrants acquiring small holdings–is very different from the way inequality has been observed to increase in parts of the Amazon where cattle production predominates, for example in work by Ludewigs and colleagues (2009). The example described by Ludewigs and colleagues shows a developing "hollow frontier" as has been described elsewhere (Casetti and Gauthier 1977; Rudel et al. 2002; Busch and Vance 2011). On a "hollow" frontier, parcel sizes increase and inequality increases as large landholders acquire smaller holdings in order to consolidate properties into increasingly large ranches. This process is associated with a depopulation of the area as smallholders sell their land and migrate to other locations (hence the term "hollow"). What I observed in the present study on a coffee frontier in Peru is an entirely different dynamic. Although inequality in landholdings is indeed increasing, that increase is not associated with any reduction in population density and is generally associated with a decrease in overall landholding sizes.

This pattern of inequality with decreasing parcel sizes is likely the result of the larger labour demands of coffee plantations per unit area as compared to labour requirements per area of pasture. While pasture expansion can increase landholder income at a rate that outpaces the required increase in labour inputs, coffee production is often limited by labour availability during the harvest season. In Alto Biavo, 21.4% of producers reported having lost at least one quintal (55kg; $85 US at 2013 prices)–and in some cases more than ten times that much–because of insufficient labour availability during the harvest. This problem was more pronounced in Alto Biavo than in the other two study districts because its relative remoteness means that there is no ready availability of wage labourers. I believe that the difference in production systems is a large part of the reason that I see no evidence supporting "hollow frontier" dynamics in the study districts.

4.5.1. Higher inequality in forested land than in coffee plantations

The landholding inequality that exists among respondents is strongest in holdings of standing forest and least in coffee holdings and holdings of other crops (Table 4-2; Figure 4-4). Inequality of total landholdings was intermediate between inequality of forest and that of coffee. Overall Gini indices of total land holdings, therefore, overstate the inequality when it comes to households' actual income-generating capacity. In all cases, the Gini index of income from crops was close to the Gini index of total land holdings–within 0.04–while being consistently below the inequality in forest holdings: it ranged from 0.24 below the income in forest holdings in Pardo Miguel to 0.13 below in Shamboyacu to 0.10 below in Alto Biavo. I believe that this is at least partly due to the labour constraints described above that limit the extent of coffee plantation that households establish.

The difference between the level of inequality seen in forest and that seen in coffee suggests that whatever inequality exists in households in terms of their productive land and their incomes, there is much higher inequality in the depth of resources that households are able to draw upon either in the case of a shock–for example the recent outbreak of coffee rust (Chapter 5)–or when changes in family lifecycle require that land be sold for cash or that more land be brought into agricultural production. One implication of this pattern is that the impacts of land inequality may manifest themselves most strongly in inter-generational dynamics. Forestland in these frontier communities is often used not as a productive asset but rather as a store of value and as a safeguard for the future opportunity to bring new land into production, either by a household in its current composition or by descendants. It is in this store of future potential where there exists the largest gap between the land-rich and the land-poor. The land-rich and land-poor thus differ less in their present crop-derived incomes than they do in their future ability to pass on land to future generations.

The difference in forestland distribution likely represents an important impact of landholding inequality on the development of this upper Amazonian frontier area–in higher rates of out-migration of settlers' children. As an increasing percentage of households have small landholdings, more of their children will be likely to seek opportunities elsewhere beyond the land that they would be able to inherit. Out-migration on the frontier can either increase or decrease total rates of forest loss, depending on whether the destination is to urban areas or further into the frontier, respectively (Carr et al. 2006). In this case, it is not possible to conclusively state whether an increase in the rate of out-migration would have a net-positive or net-negative impact on forest loss; however, in my previous work I demonstrated that poorer households were somewhat more likely to plan on migrating to the frontier while wealthier households were more likely to plan on migrating to urban areas (Chapter 2). If this pattern remains consistent, an increase in rates of out-migration of land-poor families could have the overall effect of increasing net rates of forest loss.

4.5.2. Implications for effectiveness of community forest conservation initiatives

Increasing inequality, and particularly increasing inequality in forest land, may have negative implications for the effectiveness of community-based forest conservation efforts. Private- and community-managed conservation units are increasingly important in Amazonia in general and in Peru in particular. Peru has the largest area of privately-protected forestland of any of the eight countries in the Amazon basin (Shanee et al. 2015). In San Martin in particular, community groups have been shown to be both motivated and effective at implementing successful forest conservation regimes (Shanee, 2013). As Ostrom and others have argued, increasing inequality has the potential to reduce the effectiveness of community resource management in part by reducing the potential for actors to find shared priorities and for costs to be shared in a way that is perceived as fair (Ostrom 2001; Janssen and Ostrom 2001). Increasing inequality of landholdings may interfere with the potential for effective community forest conservation efforts in these frontier districts by reducing the likelihood that community members will find overlap in their priorities. My additional finding–that inequality is most pronounced in forest holdings–may exacerbate this issue still further. The concentration of forest ownership is even more pronounced than the concentration of landholding generally. To the extent that local conservation efforts involve setting aside some area of forest–for example to protect a water source–the increasing concentration of forest ownership means that the opportunity cost of that set-aside will fall on a shrinking number of individuals. For reasons of fairness, community efforts towards forest conservation in the study communities rarely call on the smallest landholders to avoid forest clearing because this would be an unfair burden on those individuals who have little land to begin with. When the number of small landholders with little forest land increases, most of the burden of behavior change for forest conservation falls on a small number of land-rich households. This increasingly unbalanced situation risks reducing the potential for community consensus on effective forest conservation actions.

4.6. Conclusion

We have shown trends of increasing inequality of landholdings on a developing coffee frontier in Peru's upper Amazon. In three different districts, trends in reported landholdings through time indicated increasing inequality as represented by the percentage of land held by the top quintile of landholders and by the Gini coefficient. This increase in inequality was generally caused by an influx of new households acquiring relatively small landholdings while early arrivals maintained their larger landholdings. The greatest inequality was concentrated in the holdings of standing forest; this suggests that the largest gap between the land rich and the land poor may be in their ability to pass their land on to future generations–this is likely to increase the rate of out-migration from these frontier areas in future. The increasing concentration of the remaining forestland is also likely to affect the potential for effective community-level forest conservation efforts. As more of the perceived cost of conservation falls on the shrinking proportion of individuals who possess most of the area's forest, the level of support for conservation efforts by the actors that most matter may decrease. This dynamic should be recognized by organizations promoting community-based conservation in these areas so that appropriate structures and incentives can be devised.

4.7. References

Baland, J-M. and Platteau, J-P. 1999. The ambiguous impact of inequality on local resource management. *World Development*, 27(5): 773-788.

Barbieri, A. F., Bilsborrow, R. E., and Pan, W. K. 2006. Farm household lifecycles and land use in the Ecuadorian Amazon. *Population and Environment*, *27*(1): 1–27.

Busch, C. B., and Vance, C. 2011. The diffusion of cattle ranching and deforestation: Prospects for a hollow frontier in Mexico's Yucatán. *Land Economics*, *87*(4): 682–698.

Carr, D. L. 2004. Proximate population factors and deforestation in tropical agricultural frontiers. *Population and Environment*, *25*(6): 585–612.

Carr, D. L., Suter, L., and Barbieri, A. F. 2006. Population dynamics and tropical deforestation: state of the debate and conceptual challenges. *Population and Environment*, *27*(1): 89–113.

Casetti, E., and Gauthier, H. L. 1977. A formalization and test of the "hollow frontier" hypothesis. *Economic Geography*, *53*(1): 70–78.

Caviglia-Harris, J. L., Sills, E. O., and Mullan, K. 2012. Migration and mobility on the Amazon frontier. *Population and Environment*, *34*(3): 338–369.

Coomes, O. T., Takasaki, Y., and Rhemtulla, J. M. 2016. Forests as landscapes of social inequality: Tropical forest cover tracks land inequality among shifting cultivators. *Under Review*, 1–25.

de Sherbinin, A., VanWey, L., McSweeney, K., Aggarwal, R., Barbieri, A. F., Henry, S., et al. 2008. Rural household demographics, livelihoods and the environment. *Global Environmental Change*, *18*(1): 38–53.

Hardin, G. (1968). The Tragedy of the Commons. *Science*, *162*(5364): 1243–1248.

Hirsch, R. M., Slack, J. R., and Smith, R. A. 1982. Techniques of trend analysis for monthly water-quality data. *Water Resources Research*, *18*(1): 107–121.

Janssen, M. A., and Ostrom, E. 2001. Critical factors that foster local self-governance of common-pool resources: The role of heterogeneity (pp. 21–23). Presented at the Inequality, Collective Action and Environmental Sustainabiliy, Citeseer.

Jones, D. W., Dale, V. H., Beauchamp, J. J., Pedlowski, M. A., and O'Neill, R. V. 1995. Farming in Rondônia. *Resource and Energy Economics*, *17*(2): 155–188.

Ludewigs, T., de Oliveira D'antona, A., Brondízio, E. S., and Hetrick, S. 2009. Agrarian structure and land-cover change along the lifespan of three colonization areas in the Brazilian Amazon. *World Development*, *37*(8): 1348–1359.

Mac Nally, R. 2000. Regression and model-building in conservation biology, biogeography and ecology: the distinction between–and reconciliation of–'predictive'and 'explanatory'models. *Biodiversity and Conservation*, *9*(5): 655–671.

Marquette, C. M. 2006. Settler welfare on tropical forest frontiers in Latin America. *Population and Environment*, *27*(5/6): 397–444.

Milanovic, B. 2005. Why does global inequality matter and what to do about it. In *Worlds Apart: Measuring Global and International Inequality* (pp. 149–162). World Bank. Washington D.C.

Murphy, L., Bilsborrow, R., and Pichón, F. 1997. Poverty and prosperity among migrant settlers in the Amazon rainforest frontier of Ecuador. *Journal of Development Studies*, *34*(2): 35–65.

Murtinho, F., Tague, C., de Bievre, B., Eakin, H., and Lopez-Carr, D. 2013. Water Scarcity in the Andes: A Comparison of Local Perceptions and Observed Climate, Land Use and Socioeconomic Changes. *Human Ecology*, *41*(5): 667–681.

Muschler, R. G. 2001. Shade improves coffee quality in a sub-optimal coffee-zone of Costa

Rica. *Agroforestry Systems*, *51*(2): 131–139.

Olson, M. 1965. The logic of collective action. Harvard University Press. Cambridge.

Ostrom, E. 1999. Revisiting the Commons: Local Lessons, Global Challenges. *Science*, *284*(5412): 278–282.

Ostrom, E. 2001. Reformulating the commons. In J. Burger, E. Ostrom, R. B. Norgaard, P. D, and B. D. Goldstein (Eds.), *Protecting the commons: a framework for resource management in the Americas* (pp. 17–41). Island Press. Washington D.C.

Perz, S. G. 2001. Household demographic factors as life cycle determinants of land use in the Amazon. *Population Research and Policy Review*, *20*(3): 159–186.

Rudel, T. K., and Horowitz, B. 1993. Tropical deforestation: Small farmers and land clearing in the Ecuadorian Amazon. Columbia University Press. New York.

Rudel, T. K., Bates, D., and Machinguiashi, R. 2002. A tropical forest transition? Agricultural change, out-migration, and secondary forests in the Ecuadorian Amazon. *Annals of the Association of American Geographers*, *92*(1): 87–102.

Schjellerup, I. 2000. La Morada. A case study on the impact of human pressure on the environment in the Ceja de Selva, Northeastern Peru. *Ambio*, *29*(7): 451–454.

Schroth, G., Laderach, P., Dempewolf, J., Philpott, S., Haggar, J., Eakin, H., et al. 2009. Towards a climate change adaptation strategy for coffee communities and ecosystems in the Sierra Madre de Chiapas, Mexico. *Mitigation and Adaptation Strategies for Global Change*, *14*(7): 605–625.

Shanee, N., 2013. Campesino justification for self-initiated conservation actions: a challenge to mainstream conservation. Journal of Political Ecology 20: 414-428.

Shanee, N., Shanee, S., and Horwich, R. H. 2015. Effectiveness of locally run conservation initiatives in north-east Peru. *Oryx*, *49*(2): 239–247.

Takasaki, Y., Barham, B. L., and Coomes, O. T. 2001. Amazonian peasants, rain forest use, and income generation: The role of wealth and geographical factors. *Society & Natural Resources*, *14*(4): 291–308.

Thiesenhusen, W. C. 1991. Implications of the rural land tenure system for the environmental debate: three scenarios. *Journal of Developing Areas*, *26*(1): 1–23.

Tole, L. 2004. A quantitative investigation of the population-land inequality-land clearance nexus. *Population and Environment*, *26*(2): 75–106.

Walker, R., Perz, S. G., Caldas, M., and Silva, L. G. T. 2002. Land use and land cover change in forest frontiers: the role of household life cycles. *International Regional Science Review*, *25*(2): 169–199.

World Bank (no date). DataBank. The World Bank: IBRD. Retrieved from http://databank.worldbank.org/data/home.aspx. Washington D.C.

Connecting statement: Land distribution to the impact of a coffee rust epidemic.

In the three preceding chapters, I have examined the development of the Peruvian frontier and how processes of migration and land acquisition evolve through time to affect the economic incentives faced by landholders and to structure patterns of landholding and land use. In Chapter five, I record the effects of a shock that arrived to two of the study districts–coffee rust, a fungal pathogen–in order to demonstrate how that shock begat a shift in agricultural strategies. Additionally, I show how the impact of coffee rust was itself mediated by the history of settlement in the area, particularly by the timing of settler arrival and by the patterns of coffee varietal choice that were partly determined by that timing of arrival. Whereas previous chapters have used data from three different study districts, Chapter five only includes data from two: Pardo Miguel and Alto Biavo. These were the two districts in which I completed fieldwork in 2013 (Shamboyacu fieldwork took place in 2012), and so it was only in these two districts that I witnessed the worst impacts of the coffee rust epidemic.

Chapter 5. Reduction of crop diversity during the Latin American coffee rust epidemic: a case study from the highland jungle of Peru.

5.1. Abstract

The Latin American coffee rust epidemic of 2012 and 2013 was devastating for many coffee growers. Its impact was uneven, however, and areas that for historical reasons had a higher prevalence of rust-resistant varieties were much less affected. I collected information on coffee yields and coffee plantings in seven communities in two districts in the region of San Martin, Peru. In the communities in one of these districts, 68.9% of the area of coffee plantations was composed of varieties known to be susceptible to coffee rust and respondents reported overall declines in yield from 2011 to 2013 of 76.9%. In communities in the other district, however, only 21.6% of coffee area was planted in susceptible varieties and yields during the epidemic declined by 30.4%–less than half than the decline seen in the first district. An OLS linear model indicated that an additional 10% of a grower's holdings in susceptible varieties was associated with a further 4.9% decline in yield in 2012-2013. In addition to large declines in yields and associated impacts on livelihoods that growers experienced, the epidemic may also have legacy effects on coffee-growing communities due to its effect on the diversity and composition of coffee varieties being grown. In the years of the rust epidemic, growers shifted to planting almost exclusively rust-resistant varieties. Because there are few such varieties available in the local areas, this has entailed a reduction in the overall diversity of varieties being planted. The coffee rust epidemic may thus have acted as a crop diversity

bottleneck in these areas. The reduction in diversity may reduce resilience of coffee growers to future changes in climate or to future pest or pathogen outbreaks.

5.2. Introduction

Coffee rust is a leaf disease caused by the fungus *Hemileia vastatrix*. Its first major recorded outbreaks were in Ceylon–now Sri Lanka–and southern India in 1869 (McCook, 2006). Rust outbreaks caused most growers in Ceylon to abandon coffee production entirely; the tea for which Ceylon later became famous was largely adopted as an alternative crop after rust caused the failure of the coffee industry (Cressey, 2013; McCook, 2006). Coffee rust spread throughout Indian Ocean and Pacific Island coffee producers and then eventually to West Africa. Its effect was frequently devastating, although it varied greatly in its impact among countries. In West Africa, infection rates varied from a low of 19% in Zaire (now DRC) to a high of 73% in Côte d'Ivoire (McCook, 2006). Farmers in Latin America were warned about potentially catastrophic impacts if coffee rust crossed the Atlantic (Vandermeer et al., 2014). Indeed, within twenty years of its first detection in the Americas, in Brazil in 1970, coffee rust had spread to every coffee-growing country in Latin America (Avelino and Rivas, 1999; McCook, 2006). However, despite some severe outbreaks–for example in Costa Rica (1989) and Nicaragua (1995)–coffee rust in the Americas, while widespread, was until recently limited to being a low-level threat (Avelino et al., 2015; Cressey, 2013; Vandermeer et al., 2014). Estimates in Central America in the 1980s suggested that rust was causing annual harvest losses of only 3% to 4% (McCook, 2006). This difference in intensity between the impact of coffee rust in Asia and West Africa versus the Americas was at least partly as a result of the highland climate of most growing areas in the Americas (Avelino et al., 2015; McCook, 2006)

The status of coffee rust as a low-level threat in the Americas has changed in recent years. Beginning in 2008-2011 in Colombia, rust epidemics have occurred with intensities greater than any previously observed in the Americas; these progressed in 2012 and 2013 to Central America, Mexico, Ecuador, and Peru (Avelino et al., 2015). Colombian coffee production declined by 31% relative to 2007 during the epidemic years, while production in Central American countries dropped by 16% in 2013 relative to the two years previous (Avelino et al., 2015). The reasons for the epidemic after years of low intensity infections are not entirely understood; however, Avelino and colleagues (2015) highlight two central factors. First, a decrease in coffee prices and therefore profitability in 2012 and 2013 likely led to lower-intensity crop management and lower rates of application of fertilizers and pesticides which would have left plants more vulnerable to rust. Second, meteorological factors during the epidemic years–particularly lower-than-average diurnal temperature ranges–favored rust propagation.

Arabica coffee (*Coffea arabica*) is susceptible to coffee rust whereas robusta coffee *(C. canephora* var. robusta), although considered inferior in flavor, is highly resistant to coffee rust (McCook, 2006). In the 1940s in East Timor, wild crosses between the two species of coffee resulted in the "*Hibrido de Timor*" (HdT) which has most of the characteristics of *C. arabica*–including its cup quality–as well as the coffee rust resistance of *C. canephora* (van der Vossen, 2009). Back-crossing between HdT and non-hybrid varieties of *C. arabica* resulted in a range of new rust-resistant varieties that are said to have similar cup quality to pure *C. arabica*; two of the most common of these are Catimor and 'Colombia' (McCook, 2006; van der Vossen, 2009). In Peru, it is estimated that 76% of the coffee area is cultivated with non-hybrid varieties of *C. arabica*–primarily Caturra, Typica, and Bourbon–that are vulnerable to rust while the majority of the remaining 24% is cultivated in rust-resistant Catimor (JNC, 2013).

Coffee growers select which variety to plant based on their understanding of its production characteristics, product quality, yield, resistance to rust and to other pathogens, and suitability to local elevation and climate. Tradeoffs exist among these attributes. As highlighted above, there can be a tradeoff in variety selection between improved rust-resistance of hybrids and the perception of better product quality of pure *C. arabica* varieties (van der Vossen, 2009). Non-hybrid varieties, while susceptible to rust, can also produce larger fruit and higher yields which improve farmer revenues (Muschler, 2001). There are some tradeoffs between resistance to different types of pathogen. For example, the hybrid variety Catimor, while resistant to coffee rust, is more susceptible to another fungal infection–American leaf spot (Staver et al., 2001). This complex set of relationships is mediated by the differential response of pathogens and coffee varieties to temperatures and levels of humidity. These in turn are affected by the extent of tree cover at the local scale and by global changes in climate at the landscape scale. As tree cover is reduced at local scales, there may be a shift in burden from pathogens and pests that benefit from higher humidity (coffee rust; American leaf spot) to those that benefit from drier conditions (coffee leaf miner; mealybugs) (Staver et al., 2001). Figure 5-1 is a schematic of this set of relationships linking local conditions, pathogens, variety choice, and livelihood outcomes for growers.

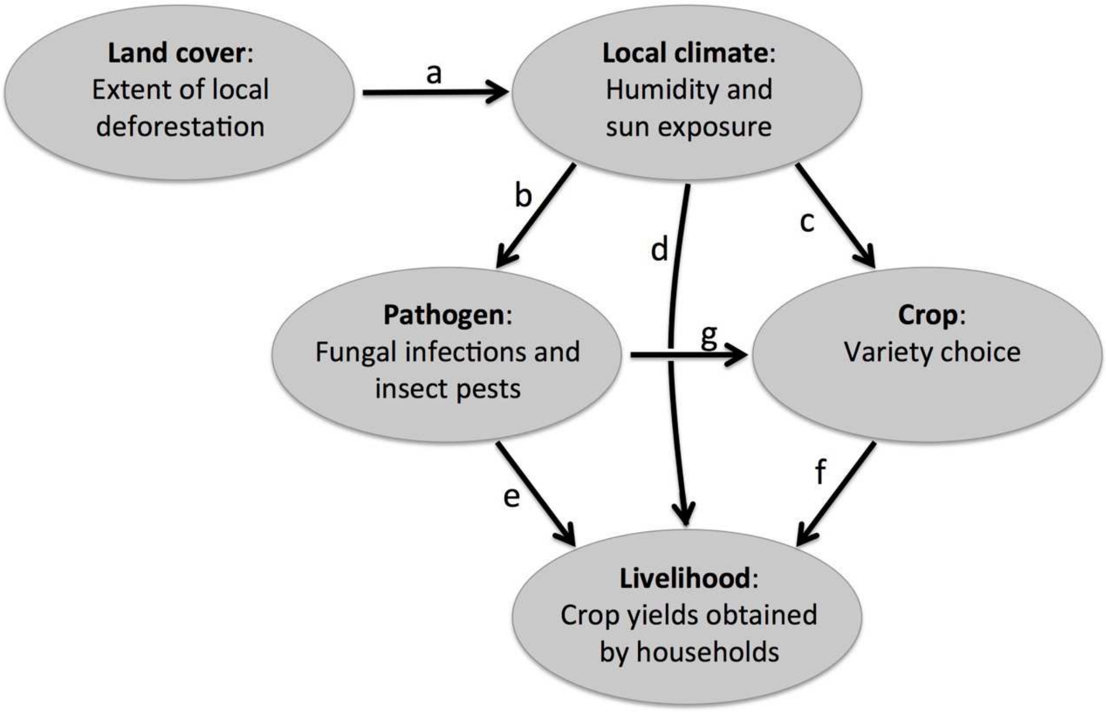

Figure 5-1: Conceptual diagram of the relationships among land cover, local climate, crop pathogens, crop type, and community livelihoods.
As forest clearing causes a decrease in shade and local humidity (a), those local-scale changes will affect the incidence of different crop pathogens (b) as well as performance of and preference for particular coffee varieties (c). Changes in local climate will have a direct impact on coffee yields (d) as well as indirect impacts on yields that are mediated by climate effects on crop pathogens incidence (e) and by the effect of climate on the selection of the coffee varieties that are being grown (f). Pathogens will similarly have an indirect effect on yields–in addition to the direct effect they have–by affecting the varieties that farmers choose to plant (g).

In this chapter, I examine how the coffee rust epidemic has affected production by smallholder coffee growers in the premontane rainforest of Peru (relationship 'e' in Figure 5-1). I also evaluate how the varieties chosen for planting by growers have changed in the past ten years, particularly in the two years of the coffee rust epidemic ('g' in Figure 5-1). Coffee is a long-lived crop–it takes three years to fully produce, and can stay productive for up to twenty years–which means that present planting decisions will have long-term implications for the diversity of coffee varieties planted in this landscape.

5.3. Study area

We conducted this study in two districts of the Region of San Martin, Peru. San Martin is in the premontane rainforest–the "*selva alta*"–of Peru and occupies a transition zone between the Andean *sierra* and the lowland Amazon (Figure 5-2). The Amazonian Regions of Ucayali and Loreto are to the east and north of San Martin while the Andean Regions of Huanuco, La Libertad, and Amazonas are to the south and west. The population of San Martin in 2013 was 806,452, of which 23.7% lived in one of the two largest cities, Tarapoto and Moyobamba (INEI, 2013). The region covers 51,253 km^2 and its elevation ranges from 200m asl to 4000m asl. San Martin is an area of significant deforestation; in the late-1980s, it had a higher rate of deforestation than any state in Brazil (Perz et al., 2005). My analysis of more recent data (Hansen et al., 2013) indicates that San Martin between 2000 and 2012 had a rate of deforestation that was higher than any other Peruvian region and all Brazilian states except two (Rondonia and Mato Grosso); and higher than any Bolivian departments, Colombian departments, Ecuadorian provinces, or Venezuelan states (Chapter 3; Table 3-5).

The economy of San Martin is dominated by agriculture. In 2007, 54.4% of employed individuals worked in the agricultural or forestry sectors (INEI, 2014), which was the third-highest proportion among Peru's 25 regions. Coffee is the second-most important crop in San Martin when measured in terms of economic return to producers. Of 57 crops on which the Ministry of Agriculture and Irrigation collected data in 2012, rice was responsible for 30.6% of gross agricultural revenue to producers while coffee was second at 24.1% (MINAGRI, 2013). However, whereas rice is grown mostly in the long-settled low elevation valleys in the central parts of the region, coffee is grown at higher elevations in areas that tend to be further removed from the main highways and cities of the region and are often more recently-settled. For this reason, coffee is the crop in San Martin that has the largest effect on the advance of the agricultural frontier and of deforestation.

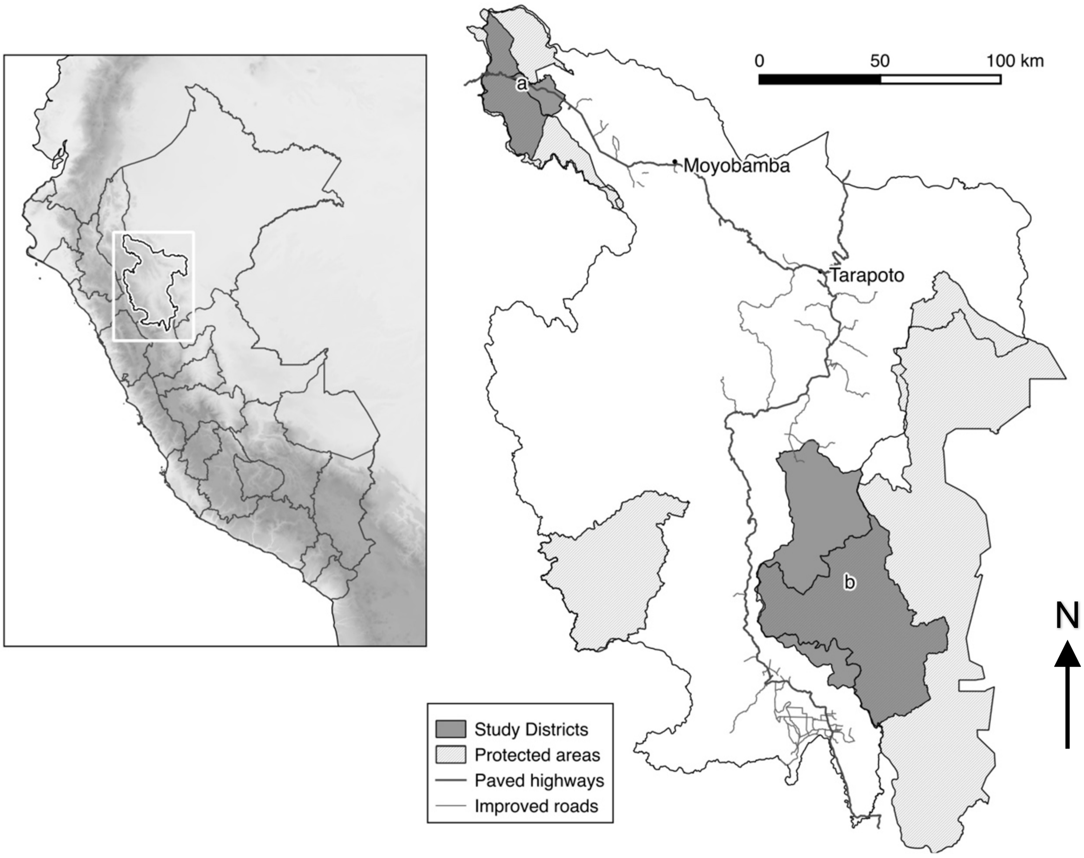

Figure 5-2: The Region of San Martin (right); San Martin indicated by rectangle in inset map of Peru (left). Marked study districts are (a) Pardo Miguel and (b) Alto Biavo.

Coffee rust had a major impact in Peru and in San Martin beginning in 2012 and through 2013. The Junta Nacional del Café (JNC) estimated in February 2013 that 32% of the national coffee production area had already been infected by coffee rust and that it was likely affecting 53,000 coffee growers (JNC, 2013). The JNC also described San Martin as the worst-hit region in the country and estimated that 40% of San Martin's 2012 coffee harvest had been lost. Data from the FAO indicate that Peruvian national production fell by 22.8% from 2011 to 2013 (FAO, n.d.). The impacts of the recent outbreak may unfortunately become more common in the coming decades as expected climate changes begin to be felt in this area. The temperature in San Martin is expected to increase by 3^{o} to 3.5^{o} by 2100 while average precipitation is expected to increase by 5%-10%, although the uncertainty of precipitation estimates is high. Both of these changes would tend towards increasing the risk of coffee rust which benefits from humid conditions and which is generally worst at lower elevations (McCook, 2006). There is already some evidence from Colombia that increasing average temperatures have raised the upper elevation limit of coffee rust (Avelino et al., 2015).

In this study, I evaluate data from seven study communities in two districts of San Martin: Pardo Miguel and Alto Biavo. Pardo Miguel is in the region's northwest and abuts the Alto Mayo Protected Forest. In 1974, highway workers who were completing the first road connection between San Martin and the coast became the first settlers in Pardo Miguel. The remote valley where the Alto Biavo study communities are located, however, was settled much more recently. The earliest settler in the study communities in Alto Biavo arrived in 1998 and the majority of individuals have come since the middle of the first decade of the 2000s. Whereas the median arrival year to the community for households in Pardo Miguel is 1998.5, in Alto Biavo it is 2006. Coffee plantations in Pardo Miguel are at higher average elevations than in Alto Biavo. The mean elevation of land held by respondents in Pardo Miguel is 1263masl with a range of 980 masl to 1660 masl. The mean elevation of plantations held by respondants in Alto Biavo is 912masl with a range of 770 masl to 1260 masl.

5.4. Methods

We collected information on coffee production in seven communities in the districts of Pardo Miguel and Alto Biavo. These districts were selected as part of a broader project on the social and economic dynamics of agricultural expansion in a high-migration frontier environment. The districts were selected to meet three criteria: that within the last decade they had been an area of active frontier expansion and deforestation, that they were the target of either NGO or government forest conservation programs, and that among them they represented a range of settlement histories. For the broader project, I worked in a third district in addition to the two described here–the District of Shamboyacu. However, my fieldwork in

Shamboyacu was completed in 2012 before the full extent of the coffee rust epidemic was understood. For that reason I have focused this analysis on the two districts that I surveyed in 2013.

We interviewed 116 coffee growers: 60 in three communities in Pardo Miguel and 56 in four communities of Alto Biavo. I created a map of all of the dwellings in each community and used systematic numbering with a random starting point and regular intervals to select households for interviews. This sampling method ensured even geographical sampling across the community so as to eliminate personal or social bias in my selection. In six of the seven communities, I interviewed either 20 heads of household or else 20% of the households in the community. In the one community where I fell short of this sampling goal for logistical reasons, I interviewed 17 heads of household representing 14% of the households in the community. In the interviews I recorded information on families' history of coffee plantings–total areas, year of planting, and variety composition–as well as their experience with coffee pests and pathogens. I asked heads of household for their total production in *quintales* (55kg sacs) of coffee for the three previous harvests: 2011, 2012, and 2013. Most landholders do not keep any written records of their harvests, and I found that trying to gather information on harvests from more than three years previous was often difficult. I converted the harvest amounts into yields per hectare. In order to examine the impact of coffee rust, I also expressed 2012 and 2013 yields as a percentage of 2011 yields. This allowed me to look at changes through time while controlling for differences in absolute yields among growers.

Coffee plants produce their first fruit in the second year after planting, but in that year they produce only a small quantity. It is in the third year that a coffee plant will produce its first full harvest. In order to estimate yields, I only included plants that were in their third year or older, i.e., that had begun producing coffee at the full capacity of an adult plant. For that reason, in order to have a time series of production data for 2011, 2012, and 2013, the coffee must have been planted in 2008 or earlier. This limited my sample size as many plantations were established more recently–especially in Alto Biavo where much of the population has arrived relatively recently. Out of 116 growers I interviewed, I was only able to reconstruct a timeline of yields between 2011 and 2013 for 56 growers. In order to include more households in the analysis, I also completed separate analyses on yield changes from 2012 to 2013 for those growers whose plantations began producing fully in 2012 (n = 21).

There were some cases where growers did not know the coffee varieties in their plantation or where the plantation contained too many different varieties to be able to estimate the area planted in each. In these cases, I have stated that the variety was unknown and I have removed these cases from an ordinary least-squares analysis that includes variety as one of the variables. These cases of unknown variety were in the minority: I was able to establish the coffee variety planted for 88.2% of the area of the plantations held by respondents.

There are two components of diversity in crop varieties: richness and evenness. Richness refers to the absolute number of varieties while evenness describes the relative extent by which multiple varieties are represented; the opposite of evenness would be dominance by one or a few varieties. Shannon's diversity index provides a joint measure for richness and evenness by describing the level of uncertainty regarding the identity of an individual picked at random. In descriptions of the diversity of coffee plantings, I present both richness–the average number of species included in each planting event–and the Shannon Index. I calculate the Shannon Index in two ways: first for the overall sample in each given year (representing the diversity of the overall system) as well as an average of the Shannon Index for individual planting events.

In my results, I establish that the varietal composition of plantations and the average age of coffee plants are two metrics on which the two districts differ significantly. In order to determine which, if either, of these has a larger effect on the extent of impact of coffee rust, I run an ordinary least-squares regression model where the independent variables are the percent of holdings in coffee rust-susceptible varieties, the mean age of coffee holdings, and a dummy variable for the district. The dependent variable in this analysis is the change in yield between 2012 and 2013. In this analysis, a Shapiro-Wilk test for the normality of errors determined that the error term was significantly non-normal. On inspection, I determined that most of this variation from normality was due to a single large outlier. I ran that model both with that outlier excluded and with it included and found that the results were qualitatively similar. I present the results in Table 5-1 with both models–with outlier included and excluded–but in the text below discuss the results from the version with all data included.

5.5. Results

Coffee growers in these study communities reported experience with one insect pest and three fungal diseases of coffee. The insect pest is the coffee berry borer (*Hypothenemus hampei*; "*broca*" locally), while the fungi are American leaf spot (*Mycena citricolor*; "*ojo de pollo*" in San Martin and "*ojo de gallo*" in most other places), thread blight (*Pellicularia koleroga*; "*arañero*") and coffee rust (*Hemileia vastatrix*; "*roya*"). Of these four, it is coffee rust that has had by far the greatest impact on coffee growers in San Martin in recent years. With the two other fungal infections–American leaf spot and thread blight–respondents described ongoing low-level impacts on yields. Those infections affected only limited sections of coffee plantations and, in most cases, the affected plants continued to produce fruit, albeit at a reduced volume. The worst impact reported by any of the respondents resulting from either American leaf spot or thread blight was an estimated 40% loss of yield in one year, due to American leaf spot. In all other cases, growers reported that these two infections reduced their overall harvests by 20% or less. The coffee borer has also been a problem for growers, but growers were often able to mitigate its impact through harvesting practices. None of the respondents reported yield losses resulting from *broca* that were higher than 10%.

5.5.1. Impact of coffee rust: 2011 to 2013

In contrast to the consistent but low-level impact that growers experienced with the insect pest and the two other fungal pathogens, coffee rust had a sudden and devastating impact in San Martin beginning in 2012. The impact of rust was far greater than any pest or pathogen that growers in the area had previously had experienced. Whereas the coffee borer and the other fungi had decreased yields, coffee rust caused harvests to be lost completely. In many cases, farmers had entirely cleared their coffee plantations in order to either plant new plantations with different varieties or else to convert their land to pasture. Of the 77 respondents who harvested coffee in 2013 and for at least one year prior to that on the same land, 59 saw a decrease in their yield between 2012 and 2013 (76.6%) and only 13 saw an increase (16.9%). For those growers who had been growing coffee on the same land for three or more years (n=56), their 2013 yields as a percentage of 2011 yields were only 23.1% and 69.6% (i.e., declines of 76.9% and 30.4%), respectively, in the districts of Pardo Miguel and Alto Biavo (Figure 5-3). In Pardo Miguel, 2012 yields were significantly lower than 2011 (Welch $t_{55.6} = 2.23$; $p = 0.030$) while 2013 yields were significantly lower than 2012 ($t_{44.4} = 4.28$; $p < 0.001$). In Alto Biavo, the intermediate steps were not significant, but 2013 yields were significantly below 2011 yields ($t_{40.0} = 2.64$; $p = 0.012$). Patterns in Pardo Miguel were similar for those growers who had only been producing coffee for two years ($n = 21$): their yields in 2013 were significantly lower ($t_{16.0} = 3.11$; $p = 0.007$) than 2012 yields. On average, growers in Pardo Miguel who began producing for the first time in 2012 only produced 51.7% as much in 2013 as they had the previous year. In Alto Biavo, growers who produced coffee for the first time in 2012 did not see a significant change in their production between 2012 and 2013.

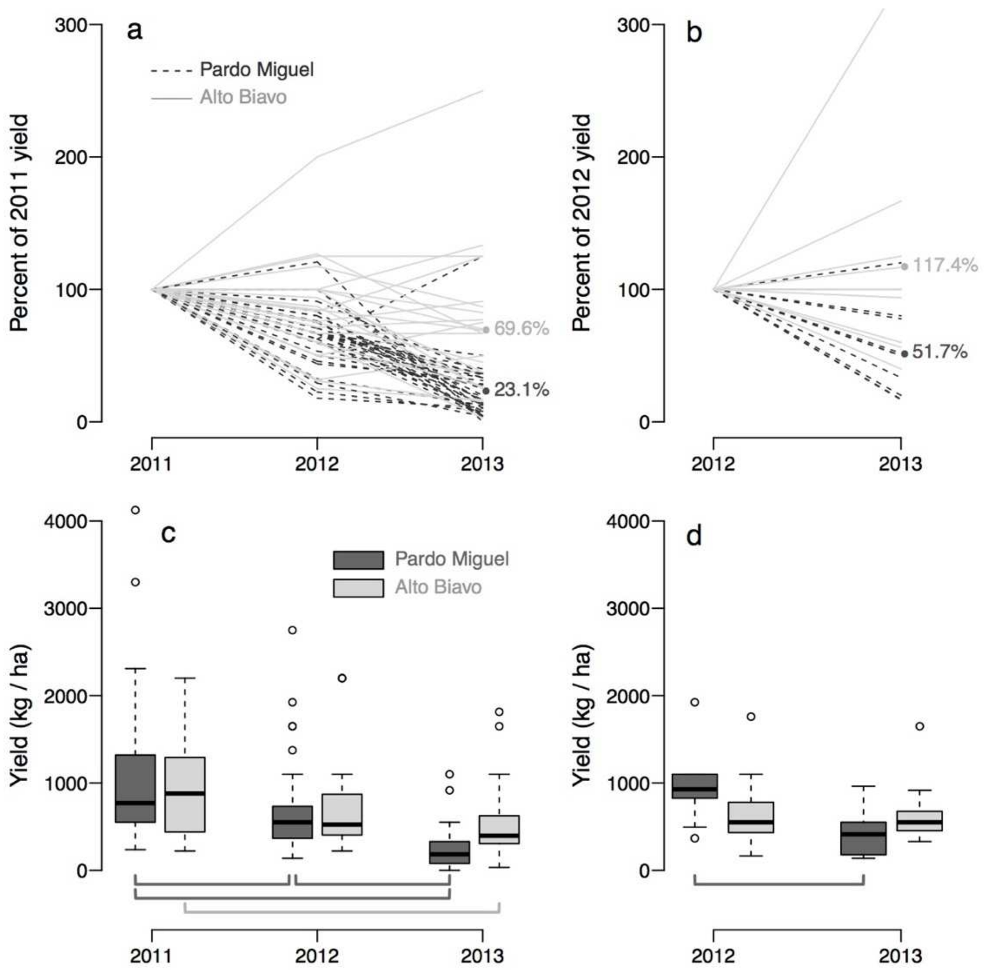

Figure 5-3: Yields from coffee in the two years immediately after coffee rust became broadly established in San Martin, 2011-2013.
Plots on top row (A and B) show yields of individual farmers expressed as a percentage of 2011 yields (A; n = 56) or as a percentage of 2012 yields for those farmers whose coffee was not yet producing in 2012 (B; n = 21). In Alto Biavo, 2013 yields were 23.1% of 2011 yields for those farmers who had coffee already producing in 2011, while 2013 yields were 51.7% of 2012 yields for farmers who had coffee that started producing in 2012. In Pardo Miguel, 2013 yields were 69.6% of 2011 yields for those who were producing in 2011 whereas 2013 yields were 117.4% for those whose coffee started producing only in 2012. Box plots on bottom row (C and D) show yields in kilogram per hectare that is split between district (darker grey and lighter grey for Pardo Miguel and Alto Biavo, respectively). Brackets below boxes represent intervals where there was a significant difference at 5% probability.

Changes in yield were more pronounced in Pardo Miguel than in Alto Biavo. Yields per hectare were not statistically different between the two districts in 2011 or in 2012, but by 2013 the average yield in Alto Biavo of 634 kilograms of dry green coffee per hectare was significantly higher ($t_{70.6} = 3.96$; $p < 0.001$) than the average of 299 kg/ha in Pardo Miguel. These values had declined from 2011 yields of 967 kg/ha in Alto Biavo and 1107 kg/ha in Pardo Miguel. The 2011-2013 average reduction in yield experienced by individuals in Alto Biavo of 30.4% was significantly less than the average 2011-2013 reduction in yield in Pardo Miguel of 76.9% ($t_{27.5} = 3.94$; $p < 0.001$). Declines during the one-year period from 2012 to 2013 were similarly more pronounced in Pardo Miguel (51.8% reduction) than they were in Alto Biavo (6.1% reduction; $t_{28.6} = 3.63$; $p < 0.001$).

5.5.2. Age distribution of plantings

Part of the explanation for the more pronounced declines in yields in Pardo Miguel relative to Alto Biavo is likely the different composition of coffee varieties grown between the two districts (Figure 5-4). The most common variety of coffee in Pardo Miguel was Caturra which covered 51.7% of the area of reported coffee plantations in 2013; the same variety only represents 9.4% of planted area in Alto Biavo. Catimor was the most widespread variety in Alto Biavo (65.7%) and was more than three times as abundant there as it was in Pardo Miguel (17.8%). Eight different varieties of *C. arabica* and hybrids were reported planted in the two districts, but 86.4% of the total area between the two districts was planted in just four varieties: Catimor, Caturra, Pache, and Typica (the latter is generally referred to in San Martin as "*Nacional*"). Excluding the area where farmers did not know the variety or else were unable to estimate the area planted in each variety (11.8% of plantation area), the proportion of area composed of the four most common varieties increases to 97.9%. The remaining four varieties each constitute less than 1% of the total area; these were Gran Colombia (0.7%), Catuai (0.5%), Costa Rica (0.4%) and Bourbon (0.3%).

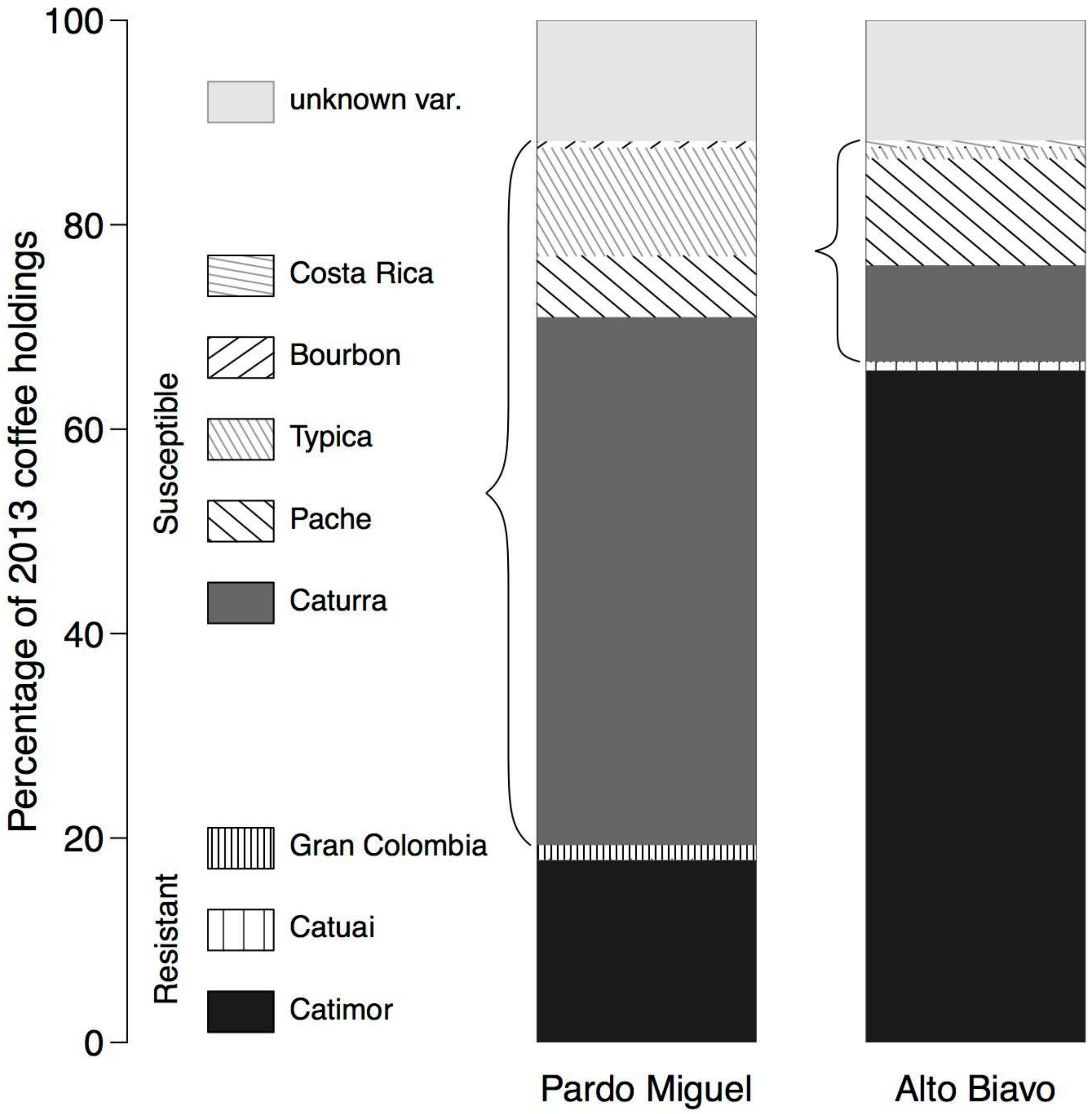

Figure 5-4: Planted area of each variety of coffee compared between districts of Pardo Miguel and Alto Biavo.
Data show respondents' 2013 coffee holdings. Curved brackets indicate the proportion of holdings composed of varieties that are known to be susceptible to coffee rust (*Hemileia vastatrix*). In Pardo Miguel, 68.9% of holdings by area were of known susceptible varieties, whereas in Alto Biavo the percentage of holdings that were susceptible was 21.6%. The most abundant variety in Pardo Miguel is Caturra with 51.7% of area planted (9.4% in Alto Biavo) while the most abundant in Alto Biavo is Catimor with 65.7% of the area planted (17.8% in Pardo Miguel).

Three of the varieties planted in the study communities–Catimor, Catuai, and Gran Colombia–are resistant to coffee rust while the other five varieties are susceptible to it. There is a marked difference between the two districts in the proportion of coffee area that is susceptible to coffee rust. In Pardo Miguel, 68.9% percent of planted area is of varieties that are known to be susceptible (78.1% if excluding plantations where variety is unknown). In contrast, in Alto Biavo, only 21.6% of planted area is of varieties known to be susceptible (24.5% if areas of unknown variety are excluded). Part of the reason for this difference is the different history of settlement in the two areas. Pardo Miguel has been settled for longer and its coffee plantations are generally older. The oldest standing coffee plants reported by respondents in Pardo Miguel were 25 years old whereas the oldest in Alto Biavo were only 15 years old. Nearly half (47.6%) of the 2013 area of respondents' plantations in Alto Biavo had been planted in 2010 or later. By contrast, only 29.7% of the area reported in Pardo Miguel was planted in 2010 or later. The area-weighted average age of plantations was 4.9 years in Alto Biavo but 8.3 years in Pardo Miguel (Figure 5-5); the weighted mean age of holdings by households in Alto Biavo was significantly lower than the age of household holdings in Pardo Miguel ($t_{66.0} = 4.18$; $p < 0.001$).

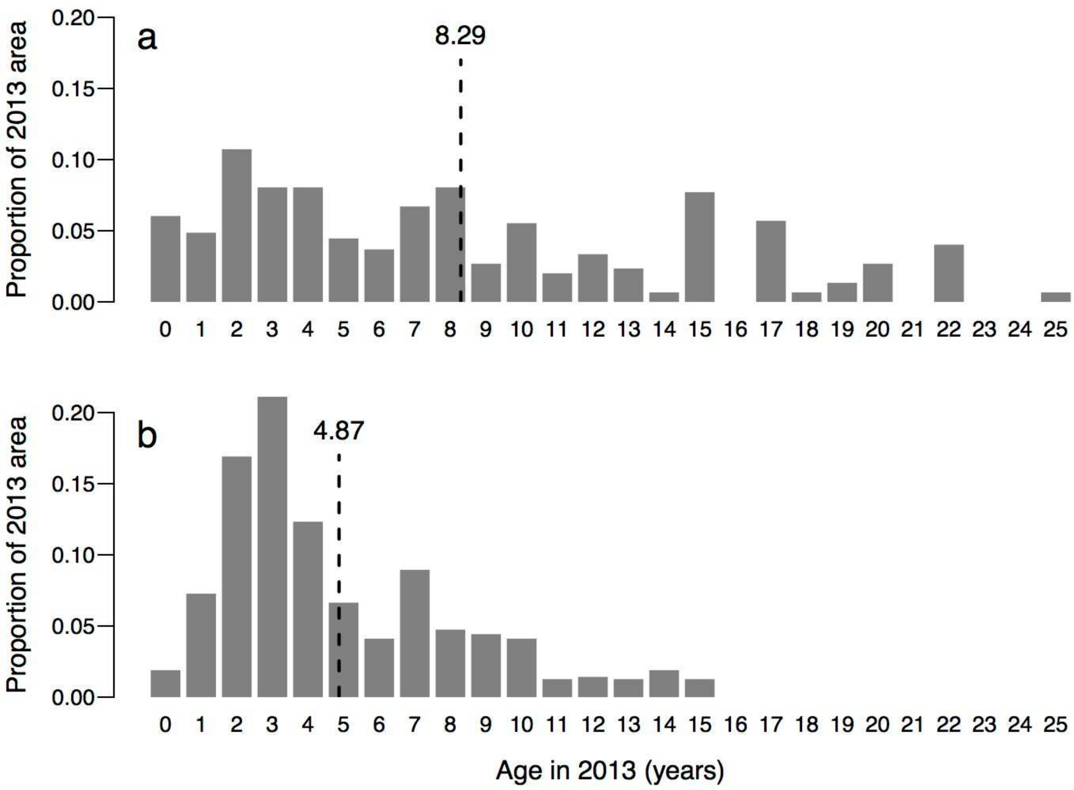

Figure 5-5: Age distribution in 2013 of coffee plantations in two districts as a proportion of total area.
The area-weighted mean age of plantations in Pardo Miguel (a) is 8.3 years whereas in Alto Biavo (b) it is 4.9 years.

Older coffee plantations are more likely to be composed of varieties susceptible to coffee rust because the first rust-resistant varieties to be introduced in San Martin only appeared in the mid- to late-1990s. Before that, planting was dominated by Caturra, Pache, and Typica. Catimor was the first rust-resistant variety in the area of Pardo Miguel: reports of the timing of its first arrival range from 1995 to 2000. Reports vary on who first brought Catimor to the area, but in all accounts Catimor was introduced by an outside organization: either a coffee-buying company, an agricultural bank, or a government agricultural extension agency (likely each of those groups did indeed introduce Catimor to certain growers). In addition to being the first, Catimor remains the most widely-planted rust-resistant variety by a wide margin: whereas it represents 17.8% and 65.7% of planted area in Pardo Miguel and Alto Biavo, respectively, the percentages for Catuai are 0.1% and 0.9% and for Gran Colombia are 1.4% and 0%. Gran Colombia is a particularly recent introduction. It is a variety developed in Colombia that descends from a hybrid of Timor coffee and Caturra, and was first introduced to farmers in Pardo Miguel by the international environmental NGO Conservation International (CI) as part of a program to convince farmers to sign forest conservation agreements. Growers in Alto Biavo had not yet encountered Gran Colombia in 2013 and the first plantings in Pardo Miguel only took place in 2012. As of 2013, the only growers in Pardo Miguel who had access to the variety were those who had signed agreements with CI: seeds of the variety were not yet available in any local market and CI had to import them from the neighboring region of Cajamarca. This will likely change in coming years as the first plants mature and produce seeds to be shared with or sold to other community members.

Since the outbreak of coffee rust, plantings of the five rust-susceptible varieties–Caturra, Pache, Typica, Bourbon, and Costa Rica–have all but stopped (Figure 5-6a). Having represented 80.5% of plantings in 2003, these five varieties represented only 11.0% of the area planted in 2012 and 0% of the area in 2013. Catimor has since become the dominant variety; it represented 86.2% of new plantings in 2012 and 81.1% in 2013. As a result of this shift towards dominance of Catimor, the diversity of coffee varieties being planted in each plantation decreased through time from an area-weighted average of 2.4 coffee varieties planted per planting event in 2003 to an average of 1.3 varieties per planting in 2013 (Figure 5-6b). Shannon's diversity index showed a negative correlation (Pearson's) with year from 2003 to 2013 both at the level of individual plantings ($r = -0.84$; $p = 0.001$) and when aggregated across the whole sample ($r = -0.83$; $p = 0.002$). In 2003, the average Shannon's index of individual plantings was 0.70 while in 2013 it was 0.19. Values were higher when aggregated across the whole sample but there was a similar decline from 1.29 to 0.48.

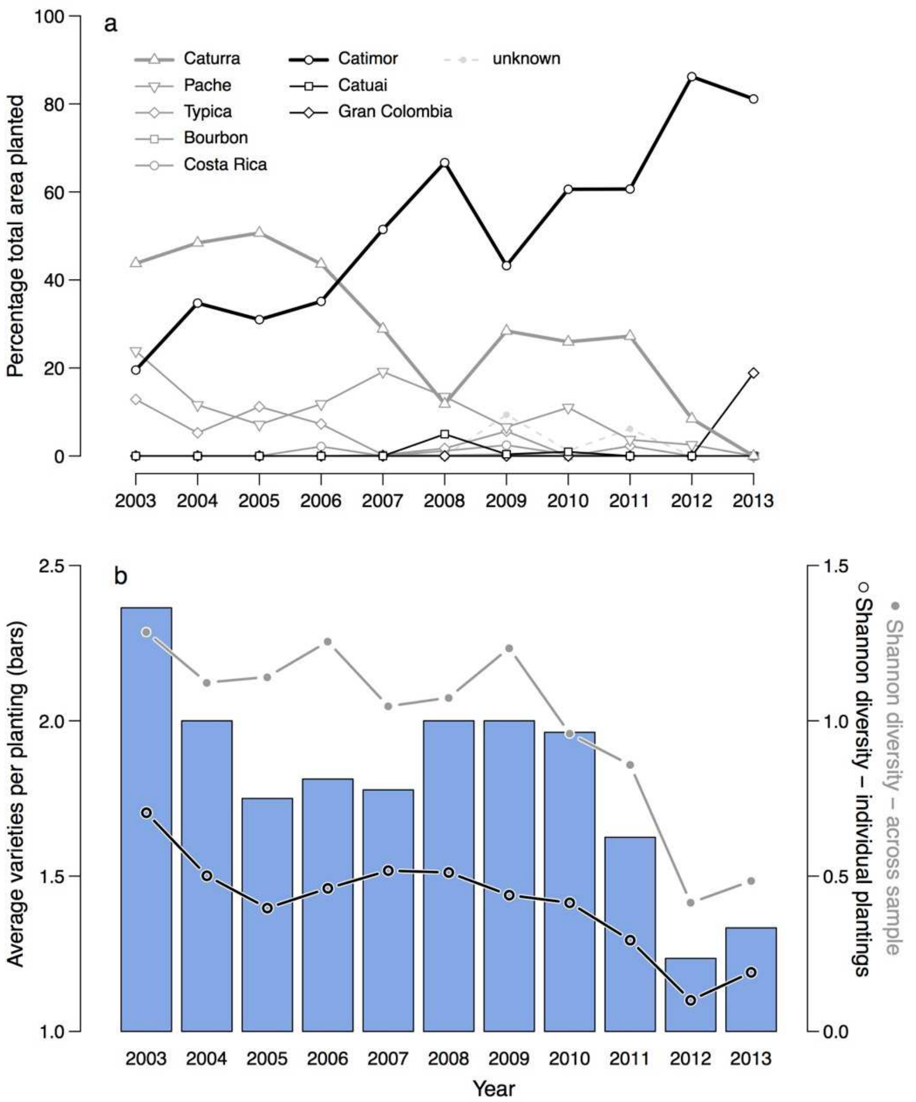

Figure 5-6: Change through time from 2003 to 2013 in (a) the composition of coffee varieties and (b) the area-weighted average of number of varieties being planted in each planting event.
The area planted in the rust-susceptible variety Caturra declined from 43.8% of the total area planted in 2003 to 0% in 2013. At the same time, Catimor increased from 19.5% of total area planted to 81.1%. In 2003, individuals planted an average of 2.4 different varieties of coffee each time they planted; in 2013, this number was 1.3. This decline was significant at a 1% probability level (Pearson's correlation between year and average varieties = -0.76; $p = 0.007$). The Shannon diversity index for plantings across the whole sample fell significantly ($r = -0.83$; $p = 0.002$) from 1.29 in 2003 to 0.48 in 2013 while an average of the same index for individual planting events fell significantly ($r = -0.84$; $p = 0.001$) from 0.70 to 0.19 between 2003 and 2013.

As mentioned above, the declines in yield between 2011 and 2013 were more pronounced in Pardo Miguel than in Alto Biavo. The composition of plantations in the two districts was different in two ways: first, plantations in Pardo Miguel tended to be older, and second, they had a higher proportion of rust-susceptible varieties (the latter partly as a result of the former). An ordinary least-squares model indicates that the percent of holdings in susceptible varieties was a significant predictor of the percentage decline in yield between 2012 and 2013 ($\beta = -0.494$; $p = 0.028$). The coefficient indicates that a grower having an additional 10% of holdings in susceptible varieties would be associated with an additional reduction in 2013 equivalent to 4.9% of the grower's 2012 yield. By contrast, the average age of a grower's plantation was not a significant predictor of the change in yield between 2012 and 2013 (Table 5-1). The adjusted R-square value of this model suggests that variables representing the percent of holdings in susceptible varieties, the mean age of holdings, and the district, together explained 29.8% of the variance in the yield change between 2013 and 2012.

Table 5-1: OLS models estimating the yield change between 2012 and 2013; dependent variable is the change in yield between 2012 and 2013 expressed as a percentage of 2012 yield. Second column shows same analysis with largest outlier excluded; the error term of the model violates assumption of normality with all data included, but conforms to normal distribution with one outlier removed. Results are qualitatively similar between the two models.

	All data	Largest outlier excluded
(Intercept)	-22.088 (19.664)	-29.331 (14.180) *
Percent in susceptible varieties	-0.494 (0.219) *	-0.395* (0.016)
Mean age of holdings	-0.049 (1.545)	-0.088 (1.112)
District: Alto Biavo (dummy)	30.555 (0.050)	27.241* (11.005)
Adjusted R^2	0.298	0.374
F-statistic	$9.488_{3,57}$ ***	$12.740_{3,56}$ ***
Shapiro-Wilk W (test of normality of error term)	0.823 ***	0.986
Sample size	*n* = 61	*n* = 60

Significance levels of p-values as follows: *** < 0.001 < ** < 0.01 < * < 0.05.

5.6. Discussion

Coffee yields vary greatly depending on production systems and the level of investment in fertilization and pest control. High-yielding commercial systems can produce annually between 1500 and 3000 kilograms of dry green coffee beans per hectare (Avelino et al., 2006; Soto-Pinto et al., 2002; Staver et al., 2001; Vaast et al., 2005; van der Vossen, 2009). Lower-investment smallholder systems have shown yields between 100 and 650 kg/ha (Eakin et al., 2011; Staver et al., 2001; van der Vossen, 2009). Growers in Pardo Miguel and Alto Biavo reported production in 2011 that was intermediate between these extremes with average yields of 1107 kg/ha and 967 kg/ha, respectively (Figure 5-3). These values dropped dramatically during the epidemic of coffee rust to 299 kg/ha and 634 kg/ha. In Pardo Miguel, growers saw average declines in yield of 76.9% between 2011 and 2013, whereas the average decline in Alto Biavo was 30.4%. This compares with an average drop nationally in Colombia during epidemic years of 31% and a decline in Central American production of 16% during the worst year of the epidemic (Avelino et al., 2015). Total national production in Peru during the same period–2011 to 2013–declined by 22.8% (FAO, n.d.). The declines in yield seen in these two Peruvian districts were therefore worse–and in the case of Pardo Miguel considerably so–than the average declines seen at national levels in other parts of Latin America during this outbreak.

The effect of coffee rust was considerably more pronounced in the communities in one of the study districts, Pardo Miguel, than in those in the other district, Alto Biavo. This was almost certainly a result of the different varietal compositions between the two districts (Figure 5-4): in Pardo Miguel, only 19.3% of the plantation area (21.9% if areas of uncertain variety are excluded) is composed of varieties that are descended from the *Hibrido de Timor* and are therefore highly resistant to coffee rust. In Alto Biavo, 66.6% is planted in varieties known to be resistant (75.5% if uncertain areas are excluded). These differences are at least partly a result of the longer history of settlement in Pardo Miguel: the earliest-settled study community in Pardo Miguel were first settled in 1974 whereas the first arrival to any of the study communities in Alto Biavo arrived in 1998 (Chapter 2). As a result, the average age of plantations in the landscape was lower in Alto Biavo (4.9 years) than in Pardo Miguel (8.3 years). Because rust-resistant varieties–Catimor, Catuai, and Gran Colombia–were introduced later to the area than were rust-susceptible ones, the difference in age structure between the two districts has had a legacy effect on the variety composition. Although plantations in Alto Biavo are at lower elevations than those in Pardo Miguel–which would generally put them at higher risk for coffee rust (Avelino et al., 2015; McCook, 2006)–because of their more recent planting and the resulting higher proportion of resistant varieties, plantations in Alto Biavo have fared better during the recent epidemic.

Coffee growers consider many different factors when selecting which variety of *C. arabica* to plant; among these are yield, product quality, suitability to local growing conditions, and resistance to fungal and insect pathogens. In San Martin between 2011 and 2013, this complex set of considerations was largely reduced to a single one: whether or not a variety is resistant to coffee rust. Although the most commonly planted rust-resistant variety, Catimor, is perceived by local farmers as having lower overall production than non-hybrid varieties, the dominance of Catimor in recent plantings suggests that farmers' primary consideration in recent years has been rust resistance rather than the potential for higher yields once the epidemic passes. This is consistent with studies showing farmers generally being risk-averse and willing to forgo higher potential yields and extra income in order to obtain longer-term stability of yields (Asrat et al., 2010; Castro et al., 2012; Ogurtsov et al., 2008).

In addition to possible effects on long-term yields, a shift towards a landscape dominated by Catimor may have effects on the use of shade trees in coffee cultivation. In Latin America, there is a trend towards reducing shade cover in coffee plantations and moving towards high-yield sun coffee; this has raised concerns about the effect on biodiversity (Perfecto et al., 2005). Catimor is reported to be more susceptible to American leaf spot ('*ojo de pollo*') which is much more prevalent in shaded sections of plantations that have higher levels of humidity (Staver et al., 2001). Where Catimor is the primary variety being planted, American leaf spot is likely to become a more important determinant of yields; that shift may create an additional incentive for growers to reduce shade by removing trees from their coffee plantations and from adjacent lands. However, there is a potentially countervailing effect: shade is known to improve the quality and size of coffee beans, and in Catimor this shade benefit is even more pronounced than it is in Caturra (Muschler, 2001). The overall effect of this shift in varieties on the prevalence of shade trees in this landscape is difficult to predict, and will have to be monitored in coming years.

Diversity in crop varieties can serve an important role as an insurance system against future changes in growing conditions such as those posed by a changing climate (Jarvis et al., 2008). In northeastern Peru–where San Martin is located on the eastern slope of the Andes–it is projected that the climate will become warmer and have higher precipitation in coming decades (Met Office, 2011). These changes may begin to shift burdens of pests and pathogens; in many of Latin America's highland growing regions, pests and pathogens may extend their range to higher elevations than those at which they had previously been present (Gay et al., 2006; Schroth et al., 2009). During the recent rust epidemic, there was some evidence of rust presence at higher elevations than is typical (Avelino et al., 2015). As climate changes occur, the insurance value that crop diversity provides may be particularly important. Even if one or a few crop varieties are dominant, maintaining diversity by keeping additional varieties in the system at low densities can still make an important contribution to the potential for adaptation (Jarvis et al., 2008). My results show coffee growers increasingly planting a single variety for every planting event–the average number of varieties in a planting event in 2003 was 2.4 while in 2013 it was only 1.3 (Figure 5-6). Varietal diversity, as measured by Shannon's index, declined from 2003 to 2013 both when averaged at the level of individual plantings (where it has declined from 0.70 to 0.19) and when the entire sample is considered as a whole (from 1.29 to 0.48). If these patterns of planting continue, it is likely that future years will see much higher levels of dominance of a smaller number of varieties in these coffee-growing landscapes.

Coffee is one of the world's best-researched crops and there is little risk of losing any of the varieties in question at a global level. However, in San Martin–as is common in places where production is dominated by smallholders–many growers only have access to those varieties that are already in production in the local area (Asrat et al., 2010; Edmeades et al., 2008). When varieties are lost from a given area, although it remains possible for their seeds to be brought back from other locations, this process is slow and growers with few financial resources are limited in their ability to engage in it. In 2013, those growers in Pardo Miguel who either had contracts with an NGO or else had financial resources to travel had access to the variety Gran Colombia, but most growers did not. While this may change in coming years as the early adopters have mature seed-producing plants, it illustrates how bringing a new variety into an area–even one that has existed for decades in neighboring regions–can be a slow process. When an event like the coffee rust epidemic causes varieties to stop being planted, they risk being lost from the local area. It has been shown in previous studies that because farmers tend to evaluate planting decisions at an individual level, they are likely to plant levels of diversity that are below what would be optimal for the broader community (Smale et al., 2001). This may be the case in the study areas in San Martin where individual decisions to focus on the variety Catimor (and on Gran Colombia for the group of farmers that has access to it) leads to a landscape with reduced diversity overall. Although these may be rational planting decisions at the level of individual growers, because of the considerable time and resources required to re-introduce a variety to a given area, a local loss of diversity in coffee varieties will potentially slow a community's adaptation to future changes.

5.7. Conclusion

In this chapter, I have reported the extent of the damage that the 2008-2013 coffee rust epidemic had on two coffee growing districts in Region of San Martin in Peru. I observed yield losses that were worse than any of the nationally-averaged losses that have been reported, including the losses reported for Peru itself. These losses were markedly different between the two study areas–a difference that I believe can be attributed to a difference in the composition of coffee varieties in the two districts which in turn can be attributed to their different histories of settlement. In one of the two districts, a much higher prevalence of rust-resistant varieties mitigated much of the damage from the epidemic. During the epidemic, rust-resistant varieties–of which only three are available in the area–came to dominate planting almost entirely. If these planting patterns continue in the coming years, they are likely to reduce the overall level of crop diversity in these coffee growing landscapes. Reducing diversity may slow the ability to adapt to future changes in these environments that may occur as a result of climate change or of future shifts in pest and pathogen burdens.

5.8. References

Asrat, S., Yesuf, M., Carlsson, F., and Wale, E. 2010. Farmers' preferences for crop variety traits: Lessons for on-farm conservation and technology adoption. *Ecological Economics*, *69*(12): 2394–2401.

Avelino, J., and Rivas, G. 1999. La roya anaranjada del cafeto. In B. Bertrand and B. Rapidel (Eds.), *Desafios de la caficultura en Centroamerica* (pp. 194–241). IICA. San José.

Avelino, J., Cristancho, M., Georgiou, S., Imbach, P., Aguilar, L., Bornemann, G., et al. 2015. The coffee rust crises in Colombia and Central America (2008–2013): impacts, plausible causes and proposed solutions. *Food Security*, *7*(2): 303–321.

Avelino, J., Zelaya, H., Merlo, A., Pineda, A., Ordoñez, M., and Savary, S. 2006. The intensity of a coffee rust epidemic is dependent on production situations. *Ecological Modelling*, *197*(3-4): 431–447.

Castro, L. M., Calvas, B., Hildebrandt, P., and Knoke, T. 2012. Avoiding the loss of shade coffee plantations: how to derive conservation payments for risk-averse land-users. *Agroforestry Systems*, *87*(2): 331–347.

Cressey, D. 2013. Coffee rust regains foothold. *Nature*, *493*(7434): 587–587.

Eakin, H., Benessaiah, K., Barrera, J. F., Cruz-Bello, G. M., and Morales, H. 2011. Livelihoods and landscapes at the threshold of change: disaster and resilience in a Chiapas coffee community. *Regional Environmental Change*, *12*(3): 475–488.

Edmeades, S., Phaneuf, D. J., Smale, M., and Renkow, M. 2008. Modelling the Crop Variety Demand of Semi-Subsistence Households: Bananas in Uganda. *Journal of Agricultural Economics*, *59*(2): 329–349.

FAO. (n.d.). FAOSTAT. Food and Agriculture Organisation (FAO). Retrieved from http://faostat3.fao.org/home/E. Rome.

Gay, C., Estrada, F., Conde, C., Eakin, H., and Villers, L. 2006. Potential Impacts of Climate Change on Agriculture: A Case of Study of Coffee Production in Veracruz, Mexico. *Climatic Change*, *79*(3-4): 259–288.

Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., et al. 2013. High-resolution global maps of 21st-century forest cover change. *Science*, *342*(6160): 850–853.

INEI. 2013. *Estado de la población Peruana 2013* (pp. 1–40). Instituto Nacional de Estadística e Informática. Lima.

INEI. 2014. Redatam (database). Instituto Nacional de Estadística e Informática. Retrieved December 1, 2014, from http://censos.inei.gob.pe/Censos2007/redatam

Jarvis, D. I., Brown, A. H. D., Cuong, P. H., Collado-Panduro, L., Latournerie-Moreno, L., Gyawali, S., et al. 2008. A global perspective of the richness and evenness of traditional crop-variety diversity maintained by farming communities. *Proceedings of the National Academy of Sciences*, *105*(14): 5326–5331.

JNC. (2013, February 27). Más del 30% del área cafetalera peruana ha sido afectada por plaga de Roya. Lima, Peru: Junta Nacional del Café. Retrieved from http://juntadelcafe.org.pe/node/105

McCook, S. 2006. Global rust belt: Hemileia vastatrix and the ecological integration of world coffee production since 1850. *Journal of Global History*, *1*(02): 177.

Met Office. 2011. Climate: Observations, projections and impacts. Peru, 1–123.

MINAGRI. 2013. *Producción Agrícola 2012* (pp. 1–265). Ministro de Agricultura y Riego; República del Perú. Retrieved from http://siea.minagri.gob.pe/

Muschler, R. G. 2001. Shade improves coffee quality in a sub-optimal coffee-zone of Costa Rica. *Agroforestry Systems*, *51*(2): 131–139.

Ogurtsov, V. A., Van Asseldonk, M. P. A. M., and Huirne, R. B. M. 2008. modelling catastrophic risk perce. *NJAS - Wageningen Journal of Life Sciences*, *56*(1-2): 39–58.

Perfecto, I., Vandermeer, J., Mas, A., and Pinto, L. S. 2005. Biodiversity, yield, and shade coffee certification. *Ecological Economics*, *54*(4): 435–446.

Perz, S. G., Aramburú, C., and Bremner, J. L. 2005. Population, Land Use and Deforestation in the Pan Amazon Basin: a Comparison of Brazil, Bolivia, Colombia, Ecuador, Perú and Venezuela. *Environment, Development and Sustainability*, *7*(1): 23–49.

Schroth, G., Laderach, P., Dempewolf, J., Philpott, S., Haggar, J., Eakin, H., et al. 2009. Towards a climate change adaptation strategy for coffee communities and ecosystems in the Sierra Madre de Chiapas, Mexico. *Mitigation and Adaptation Strategies for Global Change*, *14*(7): 605–625.

Smale, M., Bellon, M. R., and Gómez, J. A. A. 2001. Maize diversity, variety attributes, and farmers' choices in southeastern Guanajuato, Mexico. *Economic Development and Cultural Change*, *50*(1): 201–225.

Soto-Pinto, L., Perfecto, I., and Caballero-Nieto, J. 2002. Shade over coffee: its effects on berry borer, leaf rust and spontaneous herbs in Chiapas, Mexico. *Agroforestry Systems*, *55*(1): 37–45.

Staver, C., Guharay, F., Monterroso, D., and Muschler, R. G. 2001. Designing pest-suppressive multistrata perennial crop systems: shade-grown coffee in Central America. *Agroforestry Systems*, *53*(2): 151–170.

Vaast, P., Bertrand, B., Perriot, J.-J., Guyot, B., and Génard, M. 2005. Fruit thinning and shade improve bean characteristics and beverage quality of coffee (Coffea arabica L.) under optimal conditions. *Journal of the Science of Food and Agriculture*, *86*(2): 197–204.

van der Vossen, H. A. M. 2009. The cup quality of disease-resistant cultivars of arabica coffee (Coffea arabica). *Experimental Agriculture*, *45*(03): 323.

Vandermeer, J., Jackson, D., and Perfecto, I. 2014. Qualitative Dynamics of the Coffee Rust Epidemic: Educating Intuition with Theoretical Ecology. *BioScience*, *64*(3): 210–218.

Chapter 6. Conclusion and policy recommendations

6.1. Original contribution

In this dissertation, I examined the dynamics of three rapidly-evolving frontier areas in the upper Amazon of San Martin, Peru. Data collected from 194 household interviews allowed me to demonstrate patterns of change in migration, in land markets, and in land distribution that are largely consistent among districts. I discuss the implications for forest conservation policies and programs stemming from each of the patterns described. This work provides insight into an under-studied geographical area: the upper Amazon on the east flank of the Andes. The great majority of work on Latin American frontiers takes place in Brazil, meaning that theory surrounding frontier dynamics is often built on an empirical base that is weighted heavily towards Brazil. This dissertation has brought to light some particular characteristics of a frontier dominated by a crop–coffee–that is more labour-intensive than those that dominate Brazilian frontiers. Additionally, I created and analyzed what I believe is the first dataset of land sales in a frontier area of the Amazon. Previous work with land prices in frontier areas has focused on landholder-stated values rather than on land transactions (Merry et al. 2008; Sills and Caviglia-Harris 2008). Studies that collected data on actual land transactions are limited to areas at much later stages of development where regular record-keeping was already in place (Zegarra 1999; Chomitz et al. 2005). This analysis of transactions on the frontier provides important insight into the economic incentives surrounding both forest clearing and land speculation. Lastly, this dissertation provides a unique analysis of the response of frontier landholders to a sudden shock–in this case, the coffee rust epidemic that arrived in the area between two field seasons. This shock serves as an example of how frontier development can be unpredictable, but also illustrates how an understanding of past patterns of migration and settlement can help explicate the choices made by frontier landholders.

6.2. Key findings

In Chapter 2 of this dissertation, I examined patterns of migration to the frontier and analyzed the ways in which migration history can affect land acquisition and land use. That analysis revealed the importance of household economic status in the place of origin in determining patterns on the frontier. One of the strongest predictors of how much land a household acquired within two years of arriving on the frontier was whether or not they had sold land in their place of origin before arriving. Among migrants, there was a clear early-mover effect. Those migrants who arrived closest to the year of initial settlement of a given district tended over time to clear much more forest than those who arrived later. This pattern was generally associated with the early arrivals having been able to acquire larger and more heavily-forested parcels of land. Regarding future migration intentions, between 39% and 51% of households in the study considered moving away from their current place of residence. Interestingly, the most common desired location was a town or a city rather than to an area of the frontier where more land was available. Households that expressed interest in moving to an urban area tended to be wealthier both in land and in income than those who were interested in moving further into the frontier. This finding likely reflects the expense of settling and establishing in urban areas relative to areas further afield. This dynamic may affect the likelihood of a forest transition in this area if rising incomes allow a larger number of people to migrate away from rural areas and into urban ones.

From the 194 household interviews, I gathered information on 326 land acquisition events (purchases, inheritances, claims, or allocations), of which 261 were land purchases. This retrospective dataset allowed me to create a hedonic model of land prices that estimated the rate of change of land prices through time in these three frontier areas. Similar to past work on determinants of land price in the Amazon, I found that land prices were higher with lower forest cover, shorter travel times to market, and on frontiers that were more developed and had more social services. This price model also allowed me to estimate the opportunity cost of sparing forest as revealed by the predicted difference in sale price that would result from forest clearing. I found that this opportunity cost was in fact increasing through time. For example, in Shamboyacu, clearing an additional hectare of forest would have increased the price of an average land sale by $226 in 2003–but in 2013, that value was $1821. Over the ten-year period from 2003 to 2013, I found that the average opportunity cost of sparing forest at the time of a land sale rose by between $86 and $159 per hectare, per year–a rate of increase of 11% to 26% annually.

Hollow frontier dynamics have often been observed as frontiers evolve. Land consolidation by large-scale landowners pushes small landholders to leave an area either for a city or to travel further into the frontier (Rudel et al. 2002), resulting in a depopulation of the area behind the advancing frontier and generally a reduction in productivity. I found evidence, presented in Chapter 4, that the opposite process is happening in coffee-growing regions of San Martin; rather than consolidating, average parcel size in communities is decreasing as new migrants arrive and acquire progressively smaller parcels. It is possible that in a coffee-dominated landscape, the economic forces are different than they are in areas where cattle-grazing or soy are dominant. By the nature of the harvesting process, coffee is much more labour intensive than beef production or industrialized soy farming, meaning that although land-holding inequality persists and sometimes increases, the process of depopulation that is associated with the hollow frontier may be less likely to occur.

In Chapter 5, I documented the patterns of change in coffee varietal plantings that occured before and during an outbreak of coffee rust in San Martin. Farmers in this area have a choice of several varieties to plant, some of which are resistant to rust and some of which are not. Rust-resistant varieties were introduced later to San Martin, meaning that farmers in the longer-established district of Pardo Miguel had planted less of them and thus tended to be impacted much harder by the epidemic than were farmers in the more recently-settled district of Alto Biavo. When the rust epidemic arrived, planting of rust-susceptible varieties of coffee all but stopped in study communities, a reasonable choice for farmers to make. However, because there are relatively few rust-resistant varieties–and a single variety that dominates most planting–the effect of this choice will be to greatly reduce future crop diversity in these communities. Because most farmers plant collected seeds rather than purchased ones, this local reduction in crop diversity may have long-run implications for adaptability of the coffee system in the area and its ability to respond to future changes and shocks.

6.3. Policy implications

6.3.1. Drivers of deforestation remote from the frontier

A central message of this dissertation is that the processes driving land cover change on the frontier are often remote from the frontier itself. In an area such as the Peruvian upper Amazon, in-migration dominates patterns of land acquisition and land cover change. As a result, it is essential to understand the economic and social drivers of the migration process. Some of those drivers relate to the availability of land and the quality of land in the Andes and on the coast of Peru. While this needs to be recognized, there is relatively little direct action that policy makers can take to change those realities. Where there may be useful points of intervention, however, is in the social process of migration. As demonstrated in Chapter 2, social networks play a very important role in determining where individuals decide to migrate. The role of social networks in migration sometimes results from family ties and sometimes from the actions of individuals who claim large tracts of land with the specific purpose of returning to the *sierra* and promoting those tracts for sale. It is in those interactions taking place in the *sierra* where interventions may be useful. In some cases, migrants have settled inside areas that had previously been zoned for conservation or sustainable use–in the Alto Mayo Protected Forest in particular. Campaigns of education in the *sierra* regarding where land is legal to settle and where it is illegal could be very useful. Individuals promoting sale of land within the protected forest–called "land traffickers" by local NGOs–undoubtedly understood what they were doing, but by the time they had sold the land to hundreds of unsuspecting migrants there was little recourse either for those migrants (who could not afford to abandon land they had spent their savings on) or for the government service that administers the protected area (that could not risk conflict with so many individuals). Such situations could be reduced through more active engagement and information-sharing in the areas of the *sierra* where the largest numbers of migrants originate.

6.3.2. Community-based forest conservation may be more effective than PES

As demonstrated in Chapter 3, the potential returns to forest clearing in these frontier areas are relatively high. In financial terms, they are certainly far higher than the value of the in-kind payments that are made by Conservation International (CI) in the Alto Mayo, the one project in my study area that was engaging in some form of payments-for-conservation. Landholders did sign contracts with CI and may have reduced their rates of forest clearing during the time they were project participants. However, it is clear that project participants were strategic about when to join the project and when to leave it; they generally joined when they had already cleared the amount of forest they wanted to clear, and they left if they decided they wanted to clear more. It is unlikely that the payments and the contracts themselves resulted in significant reductions in forest clearing. Efforts that seemed more effective, however, were those that depended on wider community buy-in and that were tied to a concrete collective benefit to community members–for example, conserving forest around the headwaters of a community water source in order to maintain the quantity and quality of the water source. Pressure from other community members can be much more effective for reducing the rate of forest clearing than would a contract enforced by project staff who may visit the community once a month. By tying forests to an irreplaceable value such as the community water supply, the motivation may also be much stronger than any incentive created by payments. Fertilizer and tools from in-kind payments can be easily substituted for with the increased income from the additional coffee plantation that would result from cleared forest.

6.3.3. Forest conservation planning needs to be more anticipatory

The results of each chapter of this dissertation illustrate a different aspect of frontier change in the study communities. In each case, time-frames for change were relatively short– for example, in most communities, informal land claims only co-exist with land sales for two years at most. A community that in 1998 was accessible only by foot and had no government services, by 2013 had road access, a health post, a primary school, and a secondary school. Given the sometimes slow process of policy proposal, design, and implementation, it is easy to see how activities conceived of under one set of social and economic conditions can be significantly less effective in a radically different community. The change in potential for conservation activities that results from changing local contexts is particularly important in the early stages of frontier development when returns to land speculation are highest and when changes happen the fastest. Planning efforts should attempt to predict future trends and likely areas of frontier expansion and as much as possible plan in ways that anticipate future processes.

6.4. Future research directions

In the rapidly-changing frontier areas of the Peruvian upper Amazon, it is very difficult to design effective policy options. As I argue throughout this dissertation, it is necessary for a planning process to anticipate change as well as possible. Previous chapters have provided some insight that may be useful in predicting patterns of change in these frontier areas; however, there is much useful research that could further our understanding. Below, I highlight three topics of research that I believe would build on the work presented in this dissertation.

6.4.1. Spatially-explicit models of land price changes

Hedonic models can be useful to establish the determinants of land price as has previously been shown in Amazonia (Merry et al. 2008; Sills and Caviglia-Harris 2008) and as demonstrated in Chapter 2. Given appropriate data on land cover, elevation, soil quality, travel distances, and other factors, it would be possible to develop spatially-explicit models of land price. However, the return on investment to land speculation does not depend on land prices themselves, but rather on the rate of increase of prices. A useful avenue for future research would be to develop a spatially-explicit model of land price increase. A model of this type could be structurally similar to a hedonic price model, but would predict the change in land prices. Being able to predict rates of land price increase–effectively doing exactly what land speculators themselves are trying to do intuitively–could be a powerful tool for predicting future hotspots of forest clearing.

6.4.2. Willingness to pay for forest sparing

In Chapter 3, I used models of land price to estimate the opportunity cost to landholders of sparing forest and the rate at which that opportunity cost was changing through time. This work was based on the assumption that the increase in potential sale price that a landholder can gain by clearing forest is an indicator of the cost to that landholder of leaving the forest standing instead. In future work, it would be useful to explicitly measure landholder willingness to accept compensation for sparing forest through a technique such as discrete choice experimentation, a technique that uses defined sets of hypothetical choices in order to reveal respondent preferences (Carson et al. 1994; Hoyos 2010). In the context of environmental decision making, this has often been used to evaluate values that individuals attribute to environmental services (ES) either in terms of willingness to pay (WTP) for the good as an ES user (Carlsson et al. 2003; Brey et al. 2007) or in terms of willingness to accept (WTA) payment for the good as an ES provider (Torres et al. 2013; Barr and Mourato 2014; Lizin et al. 2015).

6.4.3. Monitoring change through time on a frontier

In order to describe dynamic processes on the frontier, this dissertation has employed two techniques to estimate changes through time: retrospective data and a space-for-time substitution. Retrospective data on land sales, land holdings, and migration timing allowed me to estimate past trajectories of land prices, land distribution, and arrival trajectories, respectively. However, retrospective data has limitations. The most important of these limitations is the survival effect–I am only able to collect data from individuals who have remained on the frontier, not those households who left before fieldwork began. To cross-check this retrospective data, I used a space-for-time substitution among my three study districts. Because Pardo Miguel was settled earlier than Shamboyacu which was settled earlier than Alto Biavo, I would expect that if trends through time are generalizable, then I would observe a consistent pattern among the districts, with Pardo Miguel at a more advanced stage of a given pattern and Alto Biavo at a more delayed stage. This approach is a valuable cross-check, but also is limited in that it does not sufficiently account for particularities of each district. I do believe that these two approaches–taken in tandem with appropriate cross-checks–allow robust inferences about changes through time in frontier areas. However, confirmation of the dynamics that I describe in this dissertation could best be achieved by follow-up work and long-term monitoring. Re-visiting these field sites in five or ten years would allow more rigorous testing of the dynamic patterns that I have described in this dissertation.

Processes of change on a frontier–economic, social, institutional–are complex. They are made particularly difficult to unravel by the chronic lack of data in what are usually remote areas. However, the very factors that make them complex–the speed of change, the presence of actors with widely different motivations, the lack of institutional organization–are often the very same factors that make frontiers crucially important for forest conservation efforts. In this dissertation, I have attempted to analyze several of the processes of change in frontier areas of San Martin. It is my hope that this work can usefully inform those policies and programs that seek to reduce rates of deforestation in order to make them more effective at ensuring sustainable livelihoods and sustainable land use.

6.5. References

Barr, R. F., and Mourato, S. 2014. Investigating fishers' preferences for the design of marine Payments for Environmental Services schemes. *Ecological Economics*, *108*(C): 91–103.

Brey, R., Riera, P., and Mogas, J. 2007. Estimation of forest values using choice modeling: An application to Spanish forests. *Ecological Economics*, *64*(2): 305–312.

Carlsson, F., Frykblom, P., and Liljenstolpe, C. 2003. Valuing wetland attributes: an application of choice experiments. *Ecological Economics*, *47*(1): 95–103.

Carson, R. T., Louviere, J. J., Anderson, D. A., Arabie, P., Bunch, D. S., Hensher, D. A., et al. 1994. Experimental analysis of choice. *Marketing Letters*, *5*(4): 351–367.

Chomitz, K. M., Alger, K., Thomas, T. S., Orlando, H., and Vila Nova, P. 2005. Opportunity costs of conservation in a biodiversity hotspot: the case of southern Bahia. *Environment and Development Economics*, *10*, 293–312.

Hoyos, D. 2010. The state of the art of environmental valuation with discrete choice experiments. *Ecological Economics*, *69*(8): 1595–1603.

Lizin, S., Van Passel, S., and Schreurs, E. 2015. Farmers’ perceived cost of land use restrictions: A simulated purchasing decision using discrete choice experiments. *Land Use Policy*, *46*, 115–124.

Merry, F. D., Amacher, G., and Lima, E. 2008. Land Values in Frontier Settlements of the Brazilian Amazon. *World Development*, *36*(11): 2390–2401.

Rudel, T. K., Bates, D., and Machinguiashi, R. 2002. A tropical forest transition? Agricultural change, out-migration, and secondary forests in the Ecuadorian Amazon. *Annals of the Association of American Geographers*, *92*(1): 87–102.

Sills, E. O., and Caviglia-Harris, J. L. 2008. Evolution of the Amazonian frontier: Land values in Rondônia, Brazil. *Land Use Policy*, *26*(1): 55–67.

Torres, A. B., MacMillan, D. C., Skutsch, M., and Lovett, J. C. 2013. Payments for ecosystem services and rural development: Landowners' preferences and potential participation in western Mexico. *Ecosystem Services*, *6*(C): 72–81.

Zegarra, E. 1999. *El mercado de tierras rurales en el Perú. Volumen I: Análisis institucional* (pp. 1–114). Santiago, Chile: United Nations.

Bibliography

Agrawal, A. 2001. Common property institutions and sustainable governance of resources. *World Development*, *29*(10): 1649–1672.

Akaike, H. 1974. A new look at the statistical model identification. *Automatic Control, IEEE Transactions on*, *19*(6): 716–723.

Allen, J. C., and Barnes, D. F. 1985. The causes of deforestation in developing countries. *Annals of the Association of American Geographers*, *75*(2): 163–184.

Alston, L. J., Libecap, G. D., and Mueller, B. 1999. Titles, conflict, and land use: The development of property rights and land reform on the Brazilian Amazon frontier. University of Michigan Press. Ann Arbor.

Alvarado, J. 1994. Transacciones de tierras y crédito en la pequeña agricultura comercial. *Debate Agrario*, *20*, 107–126. Retrieved from http://www.cepes.org.pe/debate/num-ante.htm

Alvarado, J. 1995. Los derechos de propiedad de la tierra: Una aproximación desde la economía. *Debate Agrario*, *23*, 1–12. Retrieved from http://www.cepes.org.pe/debate/num-ante.htm

Alvarez, N. L., and Naughton-Treves, L. 2003. linking national agrarian policy to deforestation in the Peruvian Amazon: a case study of Tambopata, 1986–1997. *AMBIO: a Journal of the Human Environment*, *32*(4): 269–274.

Angelsen, A. 1995. Shifting cultivation and "deforestation": a study from Indonesia. *World Development*, *23*(10): 1713–1729.

Angelsen, A. 2010. Policies for reduced deforestation and their impact on agricultural production. *Proceedings of the National Academy of Sciences*, *107*(46): 19639–19644.

Angelsen, A., and Kaimowitz, D. 1999. Rethinking the causes of deforestation: Lessons from economic models. *World Bank Research Observer*, *14*(1): 73–98.

Angelsen, A., Brockhaus, M., Kanninen, M., Sills, E. O., Sunderlin, W. D., and Wertz-Kanounnikoff, S. (Eds.). 2009. Realising REDD+: national strategy and policy options (pp. 1–390). CIFOR. Bogor, Indonesia.

Arima, E. Y. 2016. A spatial probit econometric model of land change: the case of infrastructure development in Western Amazonia, Peru. *PLoS ONE*, *11*(3): e0152058–22.

Asner, G. P., Knapp, D. E., Martin, R. E., Tupayachi, R., Anderson, C. B., Mascaro, J., et al. 2014. Targeted carbon conservation at national scales with high-resolution monitoring. *Proceedings of the National Academy of Sciences*, *111*(47): E5016–22.

Asrat, S., Yesuf, M., Carlsson, F., and Wale, E. 2010. Farmers' preferences for crop variety traits: Lessons for on-farm conservation and technology adoption. *Ecological Economics*, *69*(12): 2394–2401.

Assies, W. 2008. Land tenure and tenure regimes in Mexico: an overview. *Journal of Agrarian Change*, *8*(1): 33–63.

Avelino, J., and Rivas, G. 1999. La roya anaranjada del cafeto. In B. Bertrand and B. Rapidel (Eds.) *Desafios de la caficultura en Centroamerica* (pp. 194–241). San José: IICA.

Avelino, J., Cristancho, M., Georgiou, S., Imbach, P., Aguilar, L., Bornemann, G., et al. 2015. The coffee rust crises in Colombia and Central America (2008–2013): impacts, plausible causes and proposed solutions. *Food Security*, *7*(2): 303–321.

Avelino, J., Zelaya, H., Merlo, A., Pineda, A., Ordoñez, M., and Savary, S. 2006. The intensity of a coffee rust epidemic is dependent on production situations. *Ecological Modelling*, *197*(3-4): 431–447.

Ballantyne, B., Bristow, M., Davison, B., Harrington, S., and Khan, K. 2000. How Can Land Tenure and Cadastral Reform Succeed? An Inter-Regional Comparison of Rural Reforms. *Canadian Journal of Development Studies/Revue Canadienne D'études Du Développement*, *21*(3): 693–723.

Barbier, E. B., and Burgess, J. C. 2001. Tropical deforestation, tenure insecurity, and unsustainability (Vol. 47, pp. 497–509). Presented at the Forest Science.

Barbieri, A. F., Bilsborrow, R. E., and Pan, W. K. 2006. Farm Household Lifecycles and Land Use in the Ecuadorian Amazon. *Population and Environment*, *27*(1): 1–27.

Barona, E., Ramankutty, N., Hyman, G., and Coomes, O. T. 2010. The role of pasture and soybean in deforestation of the Brazilian Amazon. *Environmental Research Letters*, *5*(2): 024002.

Barr, R. F., and Mourato, S. 2014. Investigating fishers' preferences for the design of marine Payments for Environmental Services schemes. *Ecological Economics*, *108*(C): 91–103.

Bax, V., Francesconi, W., Quintero, M., 2016. Spatial modeling of deforestation processes in the Central Peruvian Amazon 29, 79–88.

Bastian, C. T., McLeod, D. M., Germino, M. J., Reiners, W. A., and Blasko, B. J. 2002. Environmental amenities and agricultural land values: A hedonic model using geographic information systems data. *Ecological Economics*, *40*(3): 337–349.

Bates, D., and Rudel, T. K. 2004. Climbing the "'Agricultural Ladder'": Social Mobility and Motivations for Migration in an Ecuadorian Colonist Community, 1–17.

Bebbington, A. J., and Bury, J. T. 2009. Institutional challenges for mining and sustainability in Peru. *Proceedings of the National Academy of Sciences*, *106*(41): 17296–17301.

Berry, S. 1997. Tomatoes, land and hearsay: property and history in Asante in the time of structural adjustment. *World Development*, *25*(8): 1225–1241.

Bilsborrow, R. E. 1987. Population pressures and agricultural development in developing countries: A conceptual framework and recent evidence. *World Development*, *15*(2): 183–203.

Borrego, A., and Skutsch, M. 2014. Estimating the opportunity costs of activities that cause degradation in tropical dry forest: Implications for REDD. *Ecological Economics*, *101*(C): 1–9.

Bowman, M. S., Soares-Filho, B. S., Merry, F. D., Nepstad, D. C., Rodrigues, H., and Almeida, O. T. 2012. Persistence of cattle ranching in the Brazilian Amazon: A spatial analysis of the rationale for beef production. *Land Use Policy*, *29*(3): 558–568.

Börner, J., and Wunder, S. 2008. Paying for avoided deforestation in the Brazilian Amazon: from cost assessment to scheme design. *International Forestry Review*, *10*(3): 496–511.

Börner, J., Wunder, S., Wertz-Kanounnikoff, S., Tito, M. R., Pereira, L., and Nascimento, N. 2010. Direct conservation payments in the Brazilian Amazon: Scope and equity implications. *Ecological Economics*, *69*(6): 1272–1282.

Brack Egg, A. 1997. Pobreza y manejo adecuado de los recursos en la Amazonia Peruana. *Revista Andina*, *15*, 15–40.

Bradley, A. 2012. Does community forestry provide a suitable platform for REDD?: A case study from Oddar Meanchey, Cambodia. In L. Naughton-Treves and C. Day (Eds.): *Lessons about land tenure, forest governance and REDD+: Case studies from Africa, Asia and Latin America* (pp. 61–72). USAID.

Bradley, A. V., and Millington, A. C. 2008. Coca and colonists: Quantifying and explaining forest clearance under coca and anti-narcotics policy regimes. *Conservation Ecology*, *13*(1).

Brey, R., Riera, P., and Mogas, J. 2007. Estimation of forest values using choice modeling: An application to Spanish forests. *Ecological Economics*, *64*(2): 305–312.

Brooks, T. M., Mittermeier, R. A., da Fonseca, G., Gerlach, J., Hoffmann, M., Lamoreux, J. F., et al. 2006. Global biodiversity conservation priorities. *Science*, *313*(5783): 58–61.

Brottem, L., and Unruh, J. D. 2009. Territorial tensions: rainforest conservation, postconflict recovery, and land tenure in Liberia. *Annals of the Association of American Geographers*, *99*(5): 995–1002.

Brown, D.S., Brown, J.C., Brown, C., 2016. Land occupations and deforestation in the Brazilian Amazon. Land Use Policy 54, 331–338.

Buizer, M., Humphreys, D., and de Jong, W. 2014. Climate change and deforestation: The evolution of an intersecting policy domain. *Environmental Science and Policy*, *35*, 1–11.

Burnham, K. P. 2004. Multimodel Inference: Understanding AIC and BIC in Model Selection. *Sociological Methods and Research*, *33*(2): 261–304.

Busch, C. B., and Vance, C. 2011. The diffusion of cattle ranching and deforestation: Prospects for a hollow frontier in Mexico's Yucatán. *Land Economics*, *87*(4): 682–698.

Carlsson, F., Frykblom, P., and Liljenstolpe, C. 2003. Valuing wetland attributes: an application of choice experiments. *Ecological Economics*, *47*(1): 95–103.

Carr, D. L. 2004. Proximate population factors and deforestation in tropical agricultural frontiers. *Population and Environment*, *25*(6): 585–612.

Carr, D. L. 2009. Population and deforestation: Why rural migration matters. *Progress in Human Geography*, *33*(3): 355–378.

Carr, D. L., Suter, L., and Barbieri, A. F. 2006. Population dynamics and tropical deforestation: State of the debate and conceptual challenges. *Population and Environment*, *27*(1): 89–113.

Carrero, G. C., and Fearnside, P. M. 2011. Forest clearing dynamics and the expansion of landholdings in Apuí, a deforestation hotspot on Brazil's Transamazon Highway. *Ecology and Society*, *16*(2).

Carson, R. T., Louviere, J. J., Anderson, D. A., Arabie, P., Bunch, D. S., Hensher, D. A., et al. 1994. Experimental analysis of choice. *Marketing Letters*, *5*(4): 351–367.

Casetti, E., and Gauthier, H. L. 1977. A Formalization and Test of the "Hollow Frontier" Hypothesis. *Economic Geography*, *53*(1): 70–78.

Cassels, S., Curran, S. R., and Kramer, R. 2005. Do migrants degrade coastal environments? Migration, natural resource extraction and poverty in north Sulawesi, Indonesia. *Human Ecology*, *33*(3): 329–363.

Castro, A., Gómez, E., Durand, E., Allende, M., Pedroni, L., and Hofstede, R. *Readiness preparation proposal (R-PP): Peru (final English translation)* (pp. 1–145). Ministry of Environment, Peru.

Castro, L. M., Calvas, B., Hildebrandt, P., and Knoke, T. 2012. Avoiding the loss of shade coffee plantations: how to derive conservation payments for risk-averse land-users. *Agroforestry Systems*, *87*(2): 331–347.

Caviglia-Harris, J. L., Sills, E. O., and Mullan, K. 2012. Migration and mobility on the Amazon frontier. *Population and Environment*, *34*(3): 338–369.

Celentano, D., Sills, E. O., Sales, M., and Veríssimo, A. 2012. Welfare outcomes and the advance of the deforestation frontier in the Brazilian Amazon. *World Development*, *40*(4): 850–864.

Chen, X., Lupi, F., He, G., and Liu, J. 2009. Linking social norms to efficient conservation investment in payments for ecosystem services (Vol. 106, pp. 11812–11817). Presented at the Proceedings of the National Academy of Sciences of the United States of America.

Chhatre, A., and Agrawal, A. 2009. Trade-offs and synergies between carbon storage and livelihood benefits from forest commons. *Proceedings of the National Academy of Sciences*, *106*(42): 17667–17670.

Chomitz, K. M., Alger, K., Thomas, T. S., Orlando, H., and Vila Nova, P. 2005. Opportunity costs of conservation in a biodiversity hotspot: the case of southern Bahia. *Environment and Development Economics*, *10*, 293–312.

Conservation International. 2011. *Iniciativa de conservation del bosque de protection Alto Mayo* (pp. 1–43). Conservation International.

Coomes, O. T., Takasaki, Y., and Rhemtulla, J. M. 2016. Forests as landscapes of social inequality: Tropical forest cover tracks land inequality among shifting cultivators. *Under Review*, 1–25.

Cotula, L., and Mayers, J. 2009. Tenure in REDD: Start-point or afterthought? (pp. 1–67). International Institute for Environment and Development (IIED).

Cressey, D. 2013. Coffee rust regains foothold. *Nature*, *493*(7434): 587–587.

Day, C., and Naughton-Treves, L. 2012. Lessons from early efforts to secure land tenure within forest carbon management projects. In L. Naughton-Treves and C. Day (Eds.), *Lessons about land tenure, forest governance and REDD+: Case studies from Africa, Asia and Latin America* (pp. 1–10). USAID.

de Sherbinin, A., VanWey, L., McSweeney, K., Aggarwal, R., Barbieri, A. F., Henry, S., et al. 2008. Rural household demographics, livelihoods and the environment. *Global Environmental Change*, *18*(1): 38–53.

de Soto, H. 2000. The mystery of capital: why capitalism triumphs in the West and fails everywhere else (First edition). New York: Basic Books.

Deininger, K. W., Castagnini, R., and González, M. A. 2004. Comparing land reform and land markets in Colombia. World Bank Publications.

Deininger, K., and Feder, G. 2009. Land registration, governance, and development: Evidence and implications for policy. *World Bank Research Observer*, *24*(2): 233–266.

Deininger, K., Zegarra, E., and Lavadenz, I. 2003. Determinants and impacts of rural land market activity: Evidence from Nicaragua. *World Development*, *31*(8): 1385–1404.

Delacote, P., Palmer, C., Bakkegaard, R. K., and Thorsen, B. J. 2014. Unveiling information on opportunity costs in REDD: Who obtains the surplus when policy objectives differ? *Resource and Energy Economics*, *36*(2): 508–527.

Dubé, J., and Legros, D. 2014. Spatial econometrics using microdata (First). Hoboken, NJ: John Wiley & Sons.

D'Antona, Á. O., VanWey, L. K., and Hayashi, C. M. 2006. Property size and land cover change in the Brazilian Amazon. *Population and Environment*, *27*(5-6): 373–396.

Eakin, H., Benessaiah, K., Barrera, J. F., Cruz-Bello, G. M., and Morales, H. 2011. Livelihoods and landscapes at the threshold of change: disaster and resilience in a Chiapas coffee community. *Regional Environmental Change*, *12*(3): 475–488.

Edmeades, S., Phaneuf, D. J., Smale, M., and Renkow, M. 2008. Modelling the crop variety demand of semi-subsistence households: Bananas in Uganda. *Journal of Agricultural Economics*, *59*(2): 329–349.

Ehrlich, P. R., and Holdren, J. P. 1971. Impact of population growth. *Science*, *171*(3977): 1212–1217.

Engel, S., Pagiola, S., and Wunder, S. 2008. Designing payments for environmental services in theory and practice: An overview of the issues. *Ecological Economics*, *65*(4): 663–674.

Erler, D., Frank, S., Hein, J.-I., Hotz, H., Santa Cruz Melgarejo, A.-M., and Zelli, F. 2011. *Inclusión social en el proceso REDD en el Peru: Una perspectiva de gobernanza en múltiples niveles* (No. Nota Técnica # 2) (pp. 1–16). DIE: Deutsches Institut fur Entwicklungspolitik. Lima.

Evans, T., Arpels, M., and Clements, T. 2012. Pilot REDD Activities in Cambodia are Expected to Improve Access to Forest Resource Use Rights and Land Tenure for Local Communities. In L. Naughton-Treves and C. Day (Eds.): *Lessons about land tenure, forest governance and REDD+: Case studies from Africa, Asia and Latin America* (pp. 73–82). USAID.

FAO. (2014, April 6). FAOLEX: Legislative database of FAO legal office. Food and Agriculture Organisation (FAO). Retrieved from http://faolex.fao.org/. Rome.

FAO. (n.d.). FAOSTAT: Food and Agriculture Organisation (FAO). Retrieved from http://faostat3.fao.org/home/E. Rome.

Farley, K. A., Ojeda-Revah, L., Atkinson, E. E., and Eaton-González, B. R. 2012. Changes in land use, land tenure, and landscape fragmentation in the Tijuana River Watershed following reform of the ejido sector. *Land Use Policy*, *29*(1): 187–197.

Fearnside, P. M. (1998). Missing a moving target? Colonist technology development on the Amazon frontier; Michael Richards (Review). *Environmental Conservation*, *25*(03): 279–289.

Fearnside, P. M. 2001. Land-tenure issues as factors in environmental destruction in Brazilian Amazonia: the Case of Southern Pará. *World Development*, *29*(8): 1361–1372.

Fearnside, P. M. 2002. Can pasture intensification discourage deforestation in the Amazon and Pantanal regions of Brazil. In C. H. Wood and R. Porro (Eds.), *Deforestation and land use in the Amazon* (pp. 299–314). Gainesville, FL: University Press of Florida.

Fearnside, P. M. 2005. Deforestation in Brazilian Amazonia: History, rates, and consequences. *Conservation Biology*, *19*(3): 680–688.

Fearnside, P. M. 2008. The roles and movements of actors in the deforestation of Brazilian Amazonia. *Ecology and Society*, *13*(1).

Feder, G., and Nishio, A. 1999. The benefits of land registration and titling: economic and social perspectives. *Land Use Policy*, *15*(1): 25–43.

Fernández-Maldonado, A. M., and Bredenoord, J. 2010. Progressive housing approaches in the current Peruvian policies. *Habitat International*, *34*(3): 342–350.

Ferraro, P. J., and Kiss, A. 2002. Direct payments to conserve biodiversity. *Science*, *298*(5599): 1718–1719.

Fisher, B., Edwards, D. P., Giam, X., and Wilcove, D. S. (2011a). The high costs of conserving Southeast Asia's lowland rainforests. *Frontiers in Ecology and the Environment*, *9*(6): 329–334.

Fisher, B., Lewis, S. L., Burgess, N. D., and Malimbwi, R. E. (2011b). Implementation and opportunity costs of reducing deforestation and forest degradation in Tanzania. *Nature Climate Change*, 161–224.

Fort, R. 2008. The homogenization effect of land titling on investment incentives: evidence from Peru. *NJAS - Wageningen Journal of Life Sciences*, *55*(4): 325–343.

Fujisaka, S., Bell, W., Thomas, N., Hurtado, L., and Crawford, E. 1996. Slash-and-burn agriculture, conversion to pasture, and deforestation in two Brazilian Amazon colonies. *Agriculture, Ecosystems & Environment*, *59*(1-2): 115–130.

GADM (Ed.). 2012. GADM database of Global Administrative Areas (2nd ed.). Retrieved December 23, 2014, from

Gay, C., Estrada, F., Conde, C., Eakin, H., and Villers, L. 2006. Potential impacts of climate change on agriculture: A case of study of coffee production in Veracruz, Mexico. *Climatic Change*, *79*(3-4): 259–288.

Geist, H.J., Lambin, E.F., 2001. What drives tropical deforestation? A meta-analysis of proximate and underlying causes of deforestation based on subnational case study evidence. LUCC Report Series No. 4. Louvain-la-Neuve. 1–136.

Gertler, P., and Glewwe, P. 1990. The willingness to pay for education in developing countries. Evidence from rural Peru. *Journal of Public Economics*, *42*(3): 251–275.

Gibson, L., Lee, T. M., Koh, L. P., Brook, B. W., Gardner, T. A., Barlow, J., et al. 2011. Primary forests are irreplaceable for sustaining tropical biodiversity. *Nature*, *478*(7369): 378–381.

Gobierno Regional de San Martín. *Las potencialidades y limitaciones del departamento de San Martín: Zonificación ecológica y económica como base para el ordenamiento territorial*. (Instituto de Investigaciones de la Amazonía Peruana, Ed.) (pp. 1–213). Lima: Gobierno Regional de San Martín.

GORESAM. 2009. *Las potencialidades y limitaciones del departamento de San Martín: Zonificación ecológica y económica como base para el ordenamiento territorial* (pp. 1–209). Gobierno Regional de San Martín (GORESAM). Retrieved from http://www.cnpp-otca.gob.pe/index.php?q=node/334

Gould, K. A. 2006. Land regularization on agricultural frontiers: The case of Northwestern Petén, Guatemala. *Land Use Policy*, *23*(4): 395–407.

Gould, K. A., Carter, D. R., and Shrestha, R. K. 2006. Extra-legal land market dynamics on a Guatemalan agricultural frontier: Implications for neoliberal land policies. *Land Use Policy*, *23*(4): 408–420.

Gray, C. L. 2009. Environment, land, and rural out-migration in the southern Ecuadorian Andes. *World Development*, *37*(2): 457–468.

Grieg-Gran, M. 2006. *The cost of avoiding deforestation* (pp. 1–20). International Institute for Environment and Development (IIED).

Grieg-Gran, M. 2008. *The Cost of Avoiding Deforestation: Update of the Report prepared for the Stern Review of the Economics of Climate Change* (pp. 1–26). London: International Institute for Environment and Development (IIED).

Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., et al. 2013. High-resolution global maps of 21st-century forest cover change. *Science*, *342*(6160): 850–853.

Hardin, G. (1968). The Tragedy of the Commons. *Science*, *162*(5364): 1243–1248.

Hayes, T. M. 2007. Does tenure matter? A comparative analysis of agricultural expansion in the Mosquitia Forest Corridor. *Human Ecology*, *35*(6): 733–747.

Hecht, S. B. 2005. Soybeans, development and conservation on the Amazon frontier. *Development and Change*, *36*(2): 375–404.

Henningsen, A. (2013, August 20). Package "censReg." R Project for Statistical Computing.

Hirsch, R. M., Slack, J. R., and Smith, R. A. 1982. Techniques of trend analysis for monthly water-quality data. *Water Resources Research*, *18*(1): 107–121.

Hope, R. A., Porras, I. T., and Miranda, M. 2005. *Can payments for environmental services contribute to poverty reduction? A livelihoods analysis from Arenal, Costa Rica*. *Centre for Land Use and Water Resources Research.* Newcastle Upon Tyne, UK.

Hoyos, D. 2010. The state of the art of environmental valuation with discrete choice experiments. *Ecological Economics*, *69*(8): 1595–1603.

Ichikawa, M., Ricse, A., Ugarte, J., and Kobayashi, S. 2014. Migration patterns and land use by immigrants under a changing frontier society in the Peruvian Amazon. *Tropics*, *23*(2): 73–82.

ICO (Ed.). 2015. Exporting countries: total production. Retrieved March 20, 2015, from

Imbernon, J. 1999. A comparison of the driving forces behind deforestation in the Peruvian and the Brazilian Amazon. *Ambio*, *28*(6): 509–513.

IMF. 2012. World Economic Outlook. International Monetary Fund. Retrieved from http://www.imf.org/external/pubs/ft/weo/2012/01/weodata/weoselgr.aspx. Washington D.C.

IMF. (no date). IMF Primary Commodity Prices. Retrieved November 12, 2014, from http://www.imf.org/external/np/res/commod/index.aspx. Washington D.C.

INEI. 2013. *Estado de la población Peruana 2013* (pp. 1–40). Instituto Nacional de Estadística e Informática. Lima.

INEI (Ed.). 2014. Redatam (database). Instituto Nacional de Estadística e Informática. Retrieved December 1, 2014, from http://censos.inei.gob.pe/Censos2007/redatam. Lima.

INRENA. 2006. *Plan maestro de Cordillera Azul (2003-2008)* (pp. 1–303). Instituto Nacional de Recursos Naturales (INRENA). Retrieved from http://sinia.minam.gob.pe/index.php?idElementoInformacion=267&idformula=&idTipoElemento=. Lima.

INRENA. 2008. *BP Alto Mayo: Plan Maestro 2008 - 2013* (pp. 1–273). Lima: Instituto Nacional de Recursos Naturales (INRENA). Lima.

Janssen, M. A., and Ostrom, E. 2001. Critical factors that foster local self-governance of common-pool resources: The role of heterogeneity (pp. 21–23). Presented at the Inequality, Collective Action and Environmental Sustainabiliy, Chiang Mai.

Jarvis, D. I., Brown, A. H. D., Cuong, P. H., Collado-Panduro, L., Latournerie-Moreno, L., Gyawali, S., et al. 2008. A global perspective of the richness and evenness of traditional crop-variety diversity maintained by farming communities. *Proceedings of the National Academy of Sciences*, *105*(14): 5326–5331.

JNC. (2013, February 27). Más del 30% del área cafetalera peruana ha sido afectada por plaga de Roya. Lima, Peru: Junta Nacional del Café. Retrieved from http://juntadelcafe.org.pe/node/105

Jones, D. W., Dale, V. H., Beauchamp, J. J., Pedlowski, M. A., and O'Neill, R. V. 1995. Farming in Rondônia. *Resource and Energy Economics*, *17*(2): 155–188.

Kaimowitz, D., and Angelsen, A. (1998). *Economic models of tropical deforestation: a review* (pp. 1–153). Bogor, Indonesia: CIFOR.

Keane, A., Jones, J. P. G., Edwards-Jones, G., and Milner-Gulland, E. J. 2008. The sleeping policeman: understanding issues of enforcement and compliance in conservation. *Animal Conservation*, *11*(2): 75–82.

Kent, R. B. 1993. Geographical dimensions of the Shining Path insurgency in Peru. *Geographical Review*, *83*(4): 441–454.

Killeen, T. J., Guerra, A., Calzada, M., Correa, L., Calderon, V., Soria, L., et al. 2008. Total Historical Land-Use Change in Eastern Bolivia: Who, Where, When, and How Much? *Ecology and Society*, *13*(1).

Kindermann, G., Obersteiner, M., Sohngen, B., Sathaye, J., Andrasko, K., Rametsteiner, E., et al. 2008. Global cost estimates of reducing carbon emissions through avoided deforestation. *Proceedings of the National Academy of Sciences*, *105*(30): 10302–10307.

Kirby, K. R., Laurance, W. F., Albernaz, A. K., Schroth, G., Fearnside, P. M., Bergen, S., et al. 2006. The future of deforestation in the Brazilian Amazon. *Futures*, *38*(4): 432–453.

Knoke, T., Steinbeis, O.-E., Bösch, M., Román-Cuesta, R. M., and Burkhardt, T. 2011. Cost-effective compensation to avoid carbon emissions from forest loss: An approach to consider price–quantity effects and risk-aversion. *Ecological Economics*, *70*(6): 1139–1153.

Knoke, T., Weber, M., Barkmann, J., Pohle, P., Calvas, B., Medina, C., et al. 2009. Effectiveness and distributional impacts of payments for reduced carbon emissions from deforestation. *Erdkunde*, *63*(4): 365–384.

Lambin, E. F., Turner, B. L., Geist, H. J., Agbola, S. B., Angelsen, A., Bruce, J. W., et al. 2001. The causes of land-use and land-cover change: moving beyond the myths. *Global Environmental Change-Human and Policy Dimensions*, *11*(4): 261–269.

Larson, J. M., Smith, S. M., Abler, D. G., and Trivelli, C. 2003. An economic analysis of land titling in Peru. *Quarterly Journal of International Agriculture*, *42*(1): 79–97.

Laurian, L., Bilsborrow, R. E., and Murphy, L. L. (1998). Migration decisions among settler families in the Ecuadorian Amazon: the second generation. *Research in Rural Sociology and Development*, *7*, 169–195.

Lemel, H. 1988. Land titling: conceptual, empirical and policy issues. *Land Use Policy*, 1–18.

Lin, L., Sills, E. O., and Cheshire, H. 2014. Targeting areas for Reducing Emissions from Deforestation and forest Degradation (REDD+) projects in Tanzania. *Global Environmental Change*, *24*, 277–286.

Lizin, S., Van Passel, S., and Schreurs, E. 2015. Farmers' perceived cost of land use restrictions: A simulated purchasing decision using discrete choice experiments. *Land Use Policy*, *46*, 115–124.

Llanos, R. E., and Feather, C. 2011. *The reality of REDD+ in Peru: Between theory and practice* (pp. 1–64). AIDESEP and FPP.

Lopez-Carr, D., and Burgdorfer, J. 2013. Deforestation Drivers: Population, Migration, and Tropical Land Use. *Environment: Science and Policy for Sustainable Development*, *55*(1): 3–11.

Ludewigs, T., de Oliveira D'antona, A., Brondízio, E. S., and Hetrick, S. 2009. Agrarian Structure and Land-cover Change Along the Lifespan of Three Colonization Areas in the Brazilian Amazon. *World Development*, *37*(8): 1348–1359.

Mac Nally, R. 2000. Regression and model-building in conservation biology, biogeography and ecology: the distinction between–and reconciliation of–'predictive'and 'explanatory'models. *Biodiversity and Conservation*, *9*(5): 655–671.

Margulis, S. 2004. Causes of Deforestation of the Brazilian Amazon (pp. 1–107). World Bank.

Marquette, C. M. 2006. Settler welfare on tropical forest frontiers in Latin America. *Population and Environment*, *27*(5/6): 397–444.

McCook, S. 2006. Global rust belt: Hemileia vastatrix and the ecological integration of world coffee production since 1850. *Journal of Global History*, *1*(02): 177.

Merry, F. D., Amacher, G., and Lima, E. 2008. Land Values in Frontier Settlements of the Brazilian Amazon. *World Development*, *36*(11): 2390–2401.

Mertens, B., Poccard-Chapuis, R., Piketty, M. G., Lacques, A. E., and Venturieri, A. 2002. Crossing spatial analyses and livestock economics to understand deforestation processes in the Brazilian Amazon: the case of São Félix do Xingú in South Pará. *Agricultural Economics*, *27*(3): 269–294.

Met Office. 2011. Climate: Observations, projections and impacts. Peru, 1–123.

Michalski, F., Metzger, J. P., and Peres, C. A. 2010. Rural property size drives patterns of upland and riparian forest retention in a tropical deforestation frontier. *Global Environmental Change*, *20*(4): 705–712.

Milanovic, B. 2005. Why does global inequality matter and what to do about it. In *World apart* (pp. 149–162).

MINAGRI. 2013. *Producción Agrícola 2012* (pp. 1–265). Ministro de Agricultura y Riego; República del Perú. Retrieved from http://siea.minagri.gob.pe/

MINAGRI. 2014. *Producción Pecuaria e Industrial Avícola* (pp. 1–168). Ministerio de Agricultura y Riego. Retrieved from http://siea.minag.gob.pe/siea/?q=produccion-pecuaria-e-industria-avicola

Morton, D. C., DeFries, R. S., Shimabukuro, Y. E., Anderson, L. O., Arai, E., del Bon Espirito-Santo, F., et al. 2006. Cropland expansion changes deforestation dynamics in the southern Brazilian Amazon. *Proceedings of the National Academy of Sciences*, *103*(39): 14637–14641.

Moulton, B. R. 1990. An illustration of a pitfall in estimating the effects of aggregate variables on micro units. *The Review of Economics and Statistics*, *72*(2): 334–338.

Mulley, B. G., and Unruh, J. D. 2004. The role of off-farm employment in tropical forest conservation: labor, migration, and smallholder attitudes toward land in western Uganda. *Journal of Environmental Management*, *71*(3): 193–205.

Murphy, L. L. 2001. Colonist farm income, off-farm work, cattle, and differentiation in Ecuador's northern Amazon. *Human Organization*, *60*(1): 67–79.

Murphy, L., Bilsborrow, R., and Pichón, F. 1997. Poverty and prosperity among migrant settlers in the Amazon rainforest frontier of Ecuador. *Journal of Development Studies*, *34*(2): 35–65.

Murtinho, F., Tague, C., de Bievre, B., Eakin, H., and Lopez-Carr, D. 2013. Water scarcity in the andes: a comparison of local perceptions and observed climate, land use and socioeconomic changes. *Human Ecology*, *41*(5): 667–681.

Muschler, R. G. 2001. Shade improves coffee quality in a sub-optimal coffee-zone of Costa Rica. *Agroforestry Systems*, *51*(2): 131–139.

Müller, R., Müller, D., Schierhorn, F., Gerold, G., and Pacheco, P. 2011. Proximate causes of deforestation in the Bolivian lowlands: an analysis of spatial dynamics. *Regional Environmental Change*, *12*(3): 445–459.

Naidoo, R., and Adamowicz, W. L. 2006. Modeling opportunity costs of conservation in transitional landscapes. *Conservation Biology : the Journal of the Society for Conservation Biology*, *20*(2): 490–500.

Naidoo, R., and Ricketts, T. H. 2006. mapping the economic costs and benefits of conservation. *Plos Biology*, *4*(11): e360.

NASA, JAXA. (2009, June 3). ASTER Global DEM. Retrieved from https://lpdaac.usgs.gov/products/aster_products_table/astgtm

Naughton-Treves, L. 2004. Deforestation and carbon emissions at tropical frontiers: a case study from the Peruvian Amazon. *World Development*, *32*(1): 173–190.

Naughton-Treves, L., and Day, C. 2012. Lessons about land tenure, forest governance and REDD+: Case studies from Africa, Asia and Latin America. (L. Naughton-Treves and C. Day, Eds.) (pp. 1–120). USAID. Retrieved from http://www.rmportal.net/landtenureforestsworkshop

Nepstad, D. C., Schwartzman, S., Bamberger, B., Santilli, M., Ray, D., Schlesinger, P., et al. 2006. Inhibition of Amazon deforestation and fire by parks and indigenous lands. *Conservation Biology*, *20*(1): 65–73.

Ogurtsov, V. A., Van Asseldonk, M. P. A. M., and Huirne, R. B. M. 2008. Modelling catastrophic risk perce. *NJAS - Wageningen Journal of Life Sciences*, *56*(1-2): 39–58.

Oliveira, P. J. C., Asner, G. P., Knapp, D. E., Almeyda, A., Galvan-Gildemeister, R., Keene, S., et al. 2007. Land-use allocation protects the Peruvian Amazon. *Science*, *317*(5842): 1233–1236.

Olson, M. 1965. The logic of collective action. Harvard University Press. Cambridge.

Ostrom, E. 1999. Revisiting the commons: local lessons, global challenges. *Science*, *284*(5412): 278–282.

Ostrom, E. 2001. Reformulating the commons. In J. Burger, E. Ostrom, R. B. Norgaard, P. D, and B. D. Goldstein (Eds.), *Protecting the commons: a framework for resource management in the Americas* (pp. 17–41). Washington D.C.: Island Press.

Pacheco, P. 2012. Actor and frontier types in the Brazilian Amazon: Assessing interactions and outcomes associated with frontier expansion. *Geoforum*, *43*(4): 864–874.

Pacheco, P., Barry, D., Cronkleton, P., and Larson, A. M. 2012. The recognition of forest rights in latin america: Progress and shortcomings of forest tenure reforms, *25*(6): 556–571.

Pagiola, S., and Bosquet, B. 2009. *Estimating the costs of REDD at the country level* (pp. 1–23). Forest Carbon Partnership Facility (FCPF), World Bank.

Paneque-Gálvez, J., Mas, J.-F., Guèze, M., Luz, A. C., Macía, M. J., Orta-Martínez, M., et al. 2013. Land tenure and forest cover change. The case of southwestern Beni, Bolivian Amazon, 1986-2009. *Applied Geography*, *43*(C): 113–126.

Parry, L., Day, B., Amaral, S., and Peres, C. A. (2010a). Drivers of rural exodus from Amazonian headwaters. *Population and Environment*, *32*(2-3): 137–176.

Parry, L., Peres, C. A., Day, B., and Amaral, S. (2010b). Rural-urban migration brings conservation threats and opportunities to Amazonian watersheds. *Conservation Letters*, *3*(4): 251–259.

Pattanayak, S. K., Wunder, S., and Ferraro, P. J. 2010. Show me the money: Do payments supply environmental services in developing countries? *Review of Environmental Economics and Policy*, *4*(2): 254–274.

Perfecto, I., Vandermeer, J., Mas, A., and Pinto, L. S. 2005. Biodiversity, yield, and shade coffee certification. *Ecological Economics*, *54*(4): 435–446.

Perz, S. G. 2001. Household demographic factors as life cycle determinants of land use in the Amazon. *Population Research and Policy Review*, *20*(3): 159–186.

Perz, S. G., and Walker, R. T. 2002. Household life cycles and secondary forest cover among small farm colonists in the Amazon. *World Development*, *30*(6): 1009–1027.

Perz, S. G., Aramburú, C., and Bremner, J. L. 2005. Population, land use and deforestation in the pan Amazon basin: A comparison of Brazil, Bolivia, Colombia, Ecuador, Perú and Venezuela. *Environment, Development and Sustainability*, *7*(1): 23–49.

Pfaff, A., Sills, E. O., Amacher, G. S., Coren, M. J., Lawlor, K., and Streck, C. 2010. *Policy impacts on deforestation: Lessons learned from past experiences to inform new initiatives* (pp. 1–54). Nicholas Institute, Duke University. Durham.

Pichón, F. J. 1997. Colonist land-allocation decisions, land use, and deforestation in the Ecuadorian Amazon frontier. *Economic Development and Cultural Change*, *45*(4): 730–744.

Piu, H. C., and Menton, M. 2014. *The context of REDD+ in Peru: Drivers, agents and institutions* (No. Occasional Paper 106) (pp. 1–84). Center for International Forestry Research (CIFOR). Bogor, Indonesia.

Plumb, S. T., Nielsen, E. A., and Kim, Y.-S. 2012. Challenges of opportunity cost analysis in planning REDD+: a Honduran case study of social and cultural values associated with indigenous forest uses. *Forests*, *3*(4): 244–264.

Poffenberger, M. 2009. Cambodia's forests and climate change: Mitigating drivers of deforestation. *Natural Resources Forum*, *33*, 285–296.

Potapov, P. V., Dempewolf, J., Talero, Y., Hansen, M. C., Stehman, S. V., Vargas, C., et al. 2014. National satellite-based humid tropical forest change assessment in Peru in support of REDD+ implementation. *Environmental Research Letters*, *9*(12): 1–13.

Potvin, C., Coomes, O. T., and Grimard, F. 2007. Will RED Work Where It Should? *Science*, July 10.

Pritchard, M. F. 2013. Land, power and peace: Tenure formalization, agricultural reform, and livelihood insecurity in rural Rwanda. *Land Use Policy*, *30*(1): 186–196.

ProCeja. 2011. *ProCeja: Plan Operativa Anual 2012* (pp. 1–55). Gobierno Regional de San Martín (GORESAM).

Redo, D. 2011. The role of the individual producer in driving land change: the case of Santa Cruz, Bolivia, 1986–2006. *GeoJournal*, *78*(1): 69–84.

Rindfuss, R. R., Entwisle, B., Walsh, S. J., Mena, C. F., Erlien, C. M., and Gray, C. L. 2007. Frontier land use change: Synthesis, challenges, and next steps. *Annals of the Association of American Geographers*, *97*(4): 739–754.

Rodrigues, A. S. L., Ewers, R. M., Parry, L., Souza, C. J., Veríssimo, A., and Balmford, A. 2009. Boom-and-bust development patterns across the Amazon deforestation frontier. *Science*, *324*(5933): 1435–1437.

Roebeling, P. C., and Hendrix, E. M. T. 2010. Land speculation and interest rate subsidies as a cause of deforestation: The role of cattle ranching in Costa Rica. *Land Use Policy*, *27*(2): 489–496.

Rudel, T. K. 1995. When do property rights matter? Open access, informal social controls, and deforestation in the Ecuadorian Amazon. *Human Organization*, 1–8.

Rudel, T. K., and Horowitz, B. 1993. Tropical deforestation: Small farmers and land clearing in the Ecuadorian Amazon. New York: Columbia University Press.

Rudel, T. K., Bates, D., and Machinguiashi, R. 2002. A tropical forest transition? Agricultural change, out-migration, and secondary forests in the Ecuadorian Amazon. *Annals of the Association of American Geographers*, *92*(1): 87–102.

Saatchi, S. S., Harris, N. L., Brown, S., Lefsky, M., Mitchard, E. T. A., Salas, W., et al. 2011. Benchmark map of forest carbon stocks in tropical regions across three continents. *Proceedings of the National Academy of Sciences*, *108*(24): 9899–9904.

Salisbury, D. S., and Fagan, C. 2011. Coca and conservation: cultivation, eradication, and trafficking in the Amazon borderlands. *GeoJournal*: 10.1007/s10708-011-9430-x

Sanchez-Cuervo, A. M., and Aide, T. M. 2013. Consequences of the armed conflict, forced human displacement, and land abandonment on forest cover change in Colombia: A multi-scaled analysis. *Ecosystems*, *16*(6): 1052–1070.

Schelhas, J., and Sánchez-Azofeifa, G. A. 2006. Post-frontier forest change adjacent to Braulio Carrillo National Park, Costa Rica. *Human Ecology*, *34*(3): 407–431.

Schjellerup, I. 2000. La Morada. A case study on the impact of human pressure on the environment in the Ceja de Selva, Northeastern Peru. *Ambio*, *29*(7): 451–454.

Schloegel, C. 2012. An Analysis of Structural Impediments to Landowner Participation in Ecuador's Socio Bosque Program. In L. Naughton-Treves and C. Day (Eds.), *Lessons about land tenure, forest governance and REDD+: Case studies from Africa, Asia and Latin America* (pp. 93–100). USAID.

Schmink, M., and Wood, C. H. 1992. Contested frontiers in Amazonia. New York: Columbia University Press.

Schroth, G., Laderach, P., Dempewolf, J., Philpott, S., Haggar, J., Eakin, H., et al. 2009. Towards a climate change adaptation strategy for coffee communities and ecosystems in the Sierra Madre de Chiapas, Mexico. *Mitigation and Adaptation Strategies for Global Change*, *14*(7): 605–625.

Schwartzman, S. 2000. Rethinking tropical forest conservation: Perils in parks, 1–7.

Shanee, N., 2013. Campesino justification for self-initiated conservation actions: a challenge to mainstream conservation. Journal of Political Ecology 20: 414-428.

Shanee, N., Shanee, S., and Horwich, R. H. 2015. Effectiveness of locally run conservation initiatives in north-east Peru. *Oryx*, *49*(2): 239–247.

Shively, G., and Fisher, M. 2004. Smallholder labor and deforestation: a systems approach. *American Journal of Agricultural Economics*, *86*, 1361–1366.

Sierra, R. 1999. Traditional resource-use systems and tropical deforestation in a multi-ethnic region in North-West Ecuador, 1–10.

Sills, E. O., and Caviglia-Harris, J. L. 2008. Evolution of the Amazonian frontier: Land values in Rondônia, Brazil. *Land Use Policy*, *26*(1): 55–67.

Smale, M., Bellon, M. R., and Gómez, J. A. A. 2001. Maize diversity, variety attributes, and farmers' choices in southeastern Guanajuato, Mexico. *Economic Development and Cultural Change*, *50*(1): 201–225.

Snyder, S. A., Kilgore, M. A., Hudson, R., and Donnay, J. 2008. Influence of purchaser perceptions and intentions on price for forest land parcels: A hedonic pricing approach. *Journal of Forest Economics*, *14*(1): 47–72.

Soler, L. de S., and Verburg, P. H. 2010. Combining remote sensing and household level data for regional scale analysis of land cover change in the Brazilian Amazon. *Regional Environmental Change*, *10*(4): 371–386.

Soto-Pinto, L., Perfecto, I., and Caballero-Nieto, J. 2002. Shade over coffee: its effects on berry borer, leaf rust and spontaneous herbs in Chiapas, Mexico. *Agroforestry Systems*, *55*(1): 37–45.

Southgate, D. 1990. The causes of land degradation along "spontaneously" expanding agricultural frontiers in the Third World. *Land Economics*, *66*(1): 93–101.

Staver, C., Guharay, F., Monterroso, D., and Muschler, R. G. 2001. Designing pest-suppressive multistrata perennial crop systems: shade-grown coffee in Central America. *Agroforestry Systems*, *53*(2): 151–170.

Stern, N. 2007. Stern review on the economics of climate change. London UK: UK Cabinet Office - HM Treasury.

St-Laurent, G.P., Gélinas, N., Potvin, C., 2013. REDD+ and the agriculture frontier: Understanding colonists' utilization of the land. Land Use Policy 31, 516–525.

Strassburg, B., Turner, R.K., Fisher, B., Schaeffer, R., Lovett, A., 2009. Reducing emissions from deforestation—The "combined incentives" mechanism and empirical simulations. Global Environmental Change 19, 265–278.

Sun, C. (2014, November 28). Package "erer." R Project for Statistical Computing.

Sunderlin, W. D. 2011. The global forest tenure transition: Background, substance, and prospects. In T. Sikor and J. Stahl (Eds.), *Forests and people: Property, governance, and human rights* (pp. 19–32). Earthscan.

Sunderlin, W. D., Angelsen, A., Belcher, B., Burgers, P., Nasi, R., Santoso, L., and Wunder, S. 2005. Livelihoods, forests, and conservation in developing countries: An Overview, *33*(9): 1383–1402.

Swallow, B. M., Kallesoe, M. F., Iftikhar, U. A., van Noordwijk, M., Bracer, C., Scherr, S. J., et al. 2009. Compensation and rewards for environmental services in the developing world: framing pan-tropical analysis and comparison. *Ecology and Society*, *14*(2).

Swallow, B. M., Meinzen-Dick, R. S., and van Noordwijk, M. 2005. Localizing demand and supply of environmental services. International Food Policy Research Institute (IFPRI).

Swenson, J. J., Young, B. E., Beck, S., Comer, P., Cordova, J. H., Dyson, J., et al. 2012. Plant and animal endemism in the eastern Andean slope: challenges to conservation. *Bmc Ecology*, *12*.

Takasaki, Y., Barham, B. L., and Coomes, O. T. 2001. Amazonian peasants, rain forest use, and income generation: The role of wealth and geographical factors. *Society & Natural Resources*, *14*(4): 291–308.

Thiesenhusen, W. C. 1991. Implications of the rural land tenure system for the environmental debate: three scenarios. *Journal of Developing Areas*, *26*(1): 1–23.

Thünen, Von, J. H. (1966). Der Isolierte Staat (The Isolated State; 1826). (C. M. Wartenberg, Trans.). New York: Pergamon Press.

Tole, L. 2004. A quantitative investigation of the population-land inequality-land clearance nexus. *Population and Environment*, *26*(2): 75–106.

Torres, A. B., MacMillan, D. C., Skutsch, M., and Lovett, J. C. 2013. Payments for ecosystem services and rural development: Landowners' preferences and potential participation in western Mexico. *Ecosystem Services*, *6*(C): 72–81.

UNCED. *The Rio declaration on environment and development* (pp. 1–19). United Nations Conference on Environment and Development.

UNODC ICMP. 2007. Coca cultivation in the Andean region: A survey of Bolivia, Colombia, Ecuador and Peru. UNODC.

Unruh, J. D. 2003. Land tenure and legal pluralism in the peace process. *Peace & Change*, *28*(3): 352–377.

Unruh, J. D., Cligget, L., and Hay, R. 2005. Migrant land rights reception and "clearing to claim" in sub-Saharan Africa: A deforestation example from southern Zambia. *Natural Resources Forum*, *29*(3): 190–198.

Vaast, P., Bertrand, B., Perriot, J.-J., Guyot, B., and Génard, M. 2005. Fruit thinning and shade improve bean characteristics and beverage quality of coffee (Coffea arabica L.) under optimal conditions. *Journal of the Science of Food and Agriculture*, *86*(2): 197–204.

van der Vossen, H. A. M. 2009. The cup quality of disease-resistant cultivars of arabica coffee (Coffea arabica). *Experimental Agriculture*, *45*(03): 323.

van der Werf, G. R., Morton, D. C., DeFries, R. S., Olivier, J. G. J., Kasibhatla, P. S., Jackson, R. B., et al. 2009. CO2 emissions from forest loss. *Nature Geoscience*, *2*(11): 737–738.

Vandergeest, P., and Peluso, N. L. 1995. Territorialization and state power in Thailand. *Theory and Society*, *24*(3): 385–426.

Vandermeer, J., Jackson, D., and Perfecto, I. 2014. Qualitative Dynamics of the Coffee Rust Epidemic: Educating Intuition with Theoretical Ecology. *BioScience*, *64*(3): 210–218.

Varughese, G., and Ostrom, E. 2001. The contested role of heterogeneity in collective action: Some evidence from community forestry in Nepal. *World Development*, *29*(5): 747–765.

Verburg, P. H., Overmars, K. P., and Witte, N. 2004. Accessibility and Land-Use Patterns at the Forest Fringe in the Northeastern Part of the Philippines. *The Geographical Journal*, *170*(3): 238–255.

Verburg, R., Filho, S. R., Lindoso, D., Debortoli, N., Litre, G., and Bursztyn, M. 2014. The impact of commodity price and conservation policy scenarios on deforestation and agricultural land use in a frontier area within the Amazon. *Land Use Policy*, *37*, 14–26.

Veronesi, M., Reutemann, T., Zabel, A., and Engel, S. 2015. Designing REDD + schemes when forest users are not forest landowners: Evidence from a survey-based experiment in Kenya. *Ecological Economics*, *116*(C): 46–57.

Vhugen, D., and Miner, J. 2012. Carbon Rights in Mozambique: Harmonizing Land and Forest Laws to Conform with REDD. In L. Naughton-Treves and C. Day (Eds.), *Lessons about land tenure, forest governance and REDD+: Case studies from Africa, Asia and Latin America* (pp. 23–32). USAID.

Vosti, S. A., Witcover, J., and Carpentier, C. L. 2002. *Agricultural Intensification by Smallholders in the Western Brazilian Amazon: From Deforestation to Sustainable Land Use* (pp. 1–147). International Food Policy Research Institute (IFPRI). Retrieved from http://www.ifpri.org/sites/default/files/publications/rr130.pdf

Walker, R. 2003. Mapping process to pattern in the landscape change of the Amazonian frontier. *Annals of the Association of American Geographers*.

Walker, R., Perz, S. G., Caldas, M., and Silva, L. G. T. 2002. Land use and land cover change in forest frontiers: the role of household life cycles. *International Regional Science Review*, *25*(2): 169–199.

Weinhold, D., Reis, E.J., Vale, P.M., 2015. Boom-bust patterns in the Brazilian Amazon. Global Environmental Change 35, 391–399.

Weisse, M.J., Naughton-Treves, L.C., 2016. Conservation Beyond Park Boundaries: The Impact of Buffer Zones on Deforestation and Mining Concessions in the Peruvian Amazon. Environmental Management 1–15.

Wiebe, K. D., and Meinzen-Dick, R. 1998. Property rights as policy tools for sustainable development. *Land Use Policy*, *15*(3): 203–215.

Wollenberg, E., Merino, L., Agrawal, A., and Ostrom, E. 2007. Fourteen years of monitoring community-managed forests: learning from IFRI's experience. *International Forestry Review*, *9*(2): 670–684.

Wooldridge, J. M. 2006. Introductory econometrics: a modern approach (Third Edition). Mason, OH: Thomson South-Western.

World Bank. (n.d.). World DataBank. The World Bank: IBRD. Retrieved from http://databank.worldbank.org/data/home.aspx

Wright, S. J., and Muller-Landau, H. C. 2006. The Future of Tropical Forest Species. *Biotropica*, *38*(3): 287–301.

Wunder, S. 2001. Poverty Alleviation and Tropical Forests--What Scope for Synergies? *World Development*, *29*(11): 1817–1833.

Wunder, S. 2005. Payments for environmental services: some nuts and bolts. *CIFOR Occasional Paper*, *42*(1). CIFOR. Bogor, Indonesia.

Wunder, S. 2006. Are direct payments for environmental services spelling doom for sustainable forest management in the tropics? *Ecology and Society*, *11*(2).

Wunder, S. 2007. The Efficiency of Payments for Environmental Services in Tropical Conservation. *Conservation Biology : the Journal of the Society for Conservation Biology*, *21*(1): 48–58.

Wunder, S., The, B. D., and Ibarra, E. 2005. Payment is good, control is better: Why payments for forest environmental services in Vietnam have so far remained incipient. CIFOR. Bogor, Indonesia.

Wünscher, T., Engel, S., and Wunder, S. 2008. Spatial targeting of payments for environmental services: A tool for boosting conservation benefits. *Ecological Economics*, *65*(4): 822–833.

Xu, F., Mittelhammer, R. C., and Barkley, P. W. 1993. Measuring the contributions of site characteristics to the value of agricultural land. *Land Economics*, *69*(4): 356–369.

Young, K. R. 1996. Threats to biological diversity caused by coca/cocaine deforestation in Peru. *Environmental Conservation*, *23*(01): 7–15.

Zanella, M. A., Schleyer, C., and Speelman, S. 2014. Why do farmers join Payments for Ecosystem Services (PES) schemes? An Assessment of PES water scheme participation in Brazil. *Ecological Economics*, *105*(C): 166–176.

Zegarra, E. (1999a). *El mercado de tierras rurales en el Perú. Volumen I: Análisis institucional* (pp. 1–114). Santiago, Chile: United Nations.

Zegarra, E. (1999b). *El mercado de tierras rurales en el Perú. Volumen II: Análisis económico* (pp. 1–63). Santiago, Chile: United Nations.

Zimmerer, K. S. 2011. “Conservation booms” with agricultural growth?: Sustainability and shifting environmental governance in Latin America, 1985-2008 (Mexico, Costa Rica, Brazil, Peru, Bolivia). *Latin American Research Review*, *46*, 82–114.

Appendix 1: Ethics approval

Initial approval (2012):

McGill

Research Ethics Board Office
James Administration Bldg, room 429
845 Sherbrooke St West
Montreal, QC H3A 0G4

Tel: (514) 398-6831
Fax: (514) 398-4644
Ethics website:www.mcgill.ca/research/researchers/compliance/human/

Research Ethics Board I
Certificate of Ethical Acceptability of Research Involving Humans

REB File #: 16-0612

Project Title: Forest conservation on a dynamic frontier: Interaction between migration, land markets, and reducing emissions from deforestation and degradation (REDD+) programs in San Martin, Peru.

Principal Investigator: Tim Holland **Department:** Geography

Student Status: Ph.D. Student **Supervisor:** Prof. O. Coomes

Co-Investigators/Other Researchers: Catherine Potvin

This project was reviewed by delegated review.

Rex Bryn

Rex Brynen, Ph.D.
Delegated Reviewer, REB I

Approval Period: __31 July 2012___ **to** ____30 July 2013_____

This project was reviewed and approved in accordance with the requirements of the McGill University Policy on the Ethical Conduct of Research Involving Human Subjects and with the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans.

---

* All research involving human participants requires review on an annual basis. A Request for Renewal form should be submitted 2-3 weeks before the above expiry date.
* When a project has been completed or terminated a Study Closure form must be submitted.
* Should any modification or other unanticipated development occur before the next required review, the REB must be informed and any modification can't be initiated until approval is received.

Renewal of approval (2013):

ETHICS REVIEW
RENEWAL REQUEST/STUDY CLOSURE FORM

Continuing review of research involving humans requires, at a minimum, the submission of an annual status report to the REB. This form must be completed to request renewal of ethics approval. If a renewal is not received before the expiry date, the project is considered no longer approved and no further research activity may be conducted. When a project has been completed, this form can also be used to officially close the study. To avoid expired approvals and, in the case of funded projects, the freezing of funds, this form should be returned 2-3 weeks before the current approval expires.

REB File #: 16-0612
Project Title: Forest conservation on a dynamic frontier: Interaction between migration, land markets, and reducing emissions from deforestation and degradation (REDD+) programs in San Martin, Peru.
Principal Investigator/Department: Tim Holland / Geography
Email: tim.holland@mail.mcgill.ca
Faculty Supervisor (if student is the PI): Oliver Coomes

1. Were there any significant changes made to this research project that have any ethical implications? ✓ No
If yes, and these have not already been reported to the REB, describe these changes and append any relevant documents that have been revised.

2. Are there any ethical concerns that arose during the course of this research? ✓ No. If yes, please describe.

3. Have any participants experienced any unanticipated issues or adverse events in connection with this research project? ✓ No
If yes, please describe.

4. Is this a funded study? ✓ No
List the agency name and project title and the Principal Investigator of the award if not yourself. This information is necessary to ensure compliance with agency requirements and that there is no interruption in funds.

_X_ Check here if this is a **request for renewal** of ethics approval.

___ Check here if the **study is to be closed** and continuing ethics approval is no longer required. A study can be closed when all data collection has been completed and there will be no further contact with participants.

Principal Investigator Signature: ______ Date: July 18/2013

Faculty Supervisor Signature: O. Coomes Date: 29/07/13
(if PI is a student)

For Administrative Use REB: X REB-I ___ REB-II ___ REB-III

___ The closing report of this terminated project has been reviewed

X The continuing review for this project has been reviewed and approved

X Delegated Review ___ Full Review

Signature of REB Chair or designate: ______ Date: Aug. 1, 2013

Approval Period: Aug. 1, 2013 to July 31, 2014

Submit to Lynda McNeil(lynda.mcneil@mcgill.ca), Research Ethics Officer, James Administration Building, 845 Sherbrooke Street West suite 429, Mtl., QC H3A0G4; fax: 398-4644 tel: 398-6831. Electronic submissions with scanned signatures are accepted but must come from the PI's McGill email.

(version 12/12)

I regret the quality of this renewal document; it was completed electronically while I was in Peru and the only copy I have is this (poor quality) scan.

Appendix 2: Survey form for household interviews

Encuesta de Hogar

Fecha: ________________ Hora: ________________ Día de la semana: _______________

Comunidad: ________________ Código del hogar: __________________ Número en el mapa __________

Lea la carta de presentación y la declaración de consentimiento. Asegúrese de que los participantes esten conscientes de que son libres de rechazar la entrevista. Si los participantes dan su consentimiento, continue con las preguntas.

A Datos demográficos

A.1 ¿Quién vive en esta casa?

Relación con el jefe de familia de familia	M / F	Edad	Otro hijos: (M/F) / (Edad)	
Jefe de familia				

A.2 ¿Usted tiene hijos que ya salieron de la casa? ¿Cuantos? _______________ ¿Donde estan? ____________________

A.3 ¿Usted o cualquier otra persona en el hogar tienen un cargo en la comunidad? (Ejemplo: agente, pres. de ronda, otros).

Si ☐ No ☐ Detalles: ____

A.4 ¿Hay algún otro familiar de la casa que tenga un cargo dentro la comunidad? ¿Qué relación es y cuál es el cargo?

Si ☐ No ☐ Detalles: ____

A.5 ¿Es usted miembro de una iglesia? Si es así, ¿cuál?

☐ No es miembro ☐ Adventista ☐ Evangelica ☐ Católica ☐ Otro (¿cuál? __________)

B Historia de migración

B.1 ¿ Hace cuanto timpo llego el primer mienbro de la familia a esta comunidad o zona?

Año _______________ *(y / o)* número de años __________

B.2 ¿Dónde vivían ustedes antes de venir aquí?

Describa la ubicación: ____

B.3 ¿Otros miembros de la familia vinieron aquí al mismo tiempo? Si ☐ No ☐

B.4 Si otros miembros del hogar llegaron después, ¿cuándo llegaron? ¿Por qué vinieron después?

____

B.5 ¿Usted y su esposa/o son natural de qué departemento (région)? ¿De que parte?

Jefe de familia: Cajamarca ☐ Piura ☐ Amazonas ☐ San Martin ☐ Otro région ☐: ______________

Provincia: _____________ Distrito: ______________

Esposa/o (¿igual? Si ☐ No ☐) Cajamarca ☐ Piura ☐ Amazonas ☐ San Martin ☐ Otro ☐: ______

Provincia: _____________ Distrito: ______________

B.6 ¿Ha venido aquí directamente de su distrito natural? Si ☐ No ☐

B.7 Si no, por favor, haga una lista de los lugares donde ha vivido desde su propria casa, y los años en que vivió allí o en otros luagres.

Departmento (Région)	Provincia	Distrito	Communidad	Número de años.	Período (por ejemplo, 1990-95).

B.8 ¿Por qué dejó su région natural? *(Para el entrevistador: el entrevistado debe usar sus propias palabras - no hacer sugerencias).*

____

____

____

B.9 (Si su vivienda anterior estaba en un région diferente de su region natural), ¿Por qué dejó la vivienda familiar anterior?

____

____

____

B.10 ¿Por qué razón se trasladó en esta zona (distrito de _________) y esta comunidad específicamente?

____

____

____

B.11 ¿Usted tenía su proprio terreno donde vivía anteriormente? Si ☐ No ☐

B.12 Si es asi, ¿ha vendido su terreno antes de venir aqui? Si ☐ No ☐

B.13 Si es asi, ¿Cuantas hectareas ers y por cuanto lo vendió? Año: _______ ha: _____; Soles _____; Tipo de tierra ____

B.14 ¿Ahora, tiene usted terrenos o una casa en otros lugarses? Sí ☐ No ☐

Detalles: ____

____

B.15 Antes de trasladarse en este distrito, ¿alguien le dió o prestó dinero para poder trasladarse o de establecerse? Si ☐ No ☐

¿Quién? / ¿De dónde era? / ¿qué relación? __________________________________

____

- ¿Fue dinero prestado ☐ o regalado ☐ ?

B.16 ¿Recibó ayuda de otra manera para trasladarse o establecerse?

____

____

B.17 ¿Ha trabajado comó peón por otro dueno en el tiempo que vivía aqui? Si ☐ No ☐

¿Cuando y por cuanto tiempo? ____

C El cambio climático

C.1 ¿Ha vivido en este distrito más que 10 años o menos de 10 años?

Más de 10 años ☐ Entre 2 y 10 años ☐ Menos que 2 años ☐

Si usted ha vivido aquí por menos que 2 años, por favor vaya al proximo sección.

C.2 En los útimos 10 años (o desde el momento que vinó a vivir aqui), ¿ha cambiado la cantidad de lluvia?

No, en absoluto ☐ Se ha cambiado un poco ☐ Se ha cambiado un montón ☐

C.3 Si usted piensa que la lluvia ha cambiado (véase el recuadro 2 ª o 3 ª encima), ¿cómo ha cambiado la cantidad de lluvia? (Marque uno de cada fila).

Se ha incrementado ☐ Se ha disminuido ☐ Ni disminuye ni aumenta ☐
El tiempo de las lluvias ha cambiado ☐ El tiempo no ha cambiado ☐

C.4 Si el tiempo de la lluvia ha cambiado, ¿cómo ha cambiado? ______________________________

C.5 En los útimos 10 años (o desde el momento que vinó a vivir aqui), ha cambiado la temperatura?

No, en absoluto ☐ Se ha cambiado un poco ☐ Se ha cambiado un montón ☐

C.6 Si usted piensa que ha cambiado la temperatura en promedio, se ha hecho más cálido o más frío?

Más cálido ☐ Mas frío ☐

C.7 Si usted piensa que el clima en esta zona ha cambiado en los útimos 10 años (o desde el momento que vinó a vivir aqui), ¿crees que hay una (o más) razón(es) para el cambio? Si es así, ¿qué razón(es)?

____

C.8 En los útimos 10 años (o desde el momento que vinó a vivir aqui), ¿ha cambiado el nivel de la rio/riachuelo mas cerca de su casa?

No, en absoluto ☐ Se ha cambiado un poco ☐ Se ha cambiado un montón ☐

C.9 Si usted piensa que el nivel de la rio/riachuelo (véase el recuadro 2 ª o 3 ª encima), ¿cómo ha cambiado?.

Mas alto ☐ Mas bajo ☐ Ni mas alto ni mas bajo pero mas variable ☐
Ni mas alto ni mas bajo pero mas constante ☐

C.10 Si usted piensa que el nivel de agua en este communidad ha cambiado, ¿crees que hay una (o más) razón(es) para el cambio? Si es así, ¿qué razón(es)?

____

D Tenencia de la tierra y uso de la tierra

D.1 ¿Cuánto de su tierra está cubierto de los tipos de cubiertos siguientes? (Haga eso por cada parcela de tierra)

	Parcela 1	Parcela 2	Parcela 3
Tiempo para llegar desde casa (caminando)			
Ubicación			
Area total	ha	ha	ha
Café (area total)	ha	ha	ha
#ha | edad / año sembrado	ha |	ha |	ha |
#ha | edad / año sembrado	ha |	ha |	ha |
#ha | edad / año sembrado	ha |	ha |	ha |
Otros cultivos permanentes (por ejemplo: cacao, árboles frutales). ¿Cuales? ___________________	ha | ? _________	ha | ? _________	ha | ? _________
Cultivos annuales (por ejemplo: arroz, yuca, frijoles, plátano). ¿Cuales? __________________________	ha | ? _________	ha | ? _________	ha | ? _________
Pasto	ha |	ha |	ha |
Purma	ha |	ha |	ha |
Bosque primario	ha |	ha |	ha |
Otros (¿Que? ________)	ha | ? _________	ha | ? _________	ha | ? _________

D.2 Indica cuales tipos de terreno no era hecho directamente de bosque:

____

D.3 Si usted tiene pasto, ¿ha convertido finca para sembrar su pasto? Si ☐ No ☐ ¿Cuantos hectareas? ______

D.4 ¿Usted ha usado abonno ☐ foliar ☐ fungicida ☐ o insecticida ☐ en su finca? (Ningun ☐)

Detalles:

____

D.5 ¿Tiene usted tierras que ha agarrados? Si ☐ No ☐

- Si es así, ¿le puede proporcionar más detalles? (¿Cuándo?, ¿cuantos hectareas?, ¿monte / purma / otro?).

____

D.6 Para cada parcela de tierra que tiene actualmente, ¿cuándo lo consequiste y cómo lo conseguió?

#	Año consiguió	Área total	Área bosque cuando conseg.	Área cafe cuando conseg.	Área purma cuando conseg.	Área pasto cuando conseg.	Área otro cuando consiguió (¿Que tipo? ______)	¿Habia una casa en la parcela?	¿Por cuanto compó? (S/.)
1		ha	ha	ha	ha	ha	ha ______		
2		ha	ha	ha	ha	ha	ha ______		
3		ha	ha	ha	ha	ha	ha ______		
4		ha	ha	ha	ha	ha	ha ______		

	Compró de quien?	Relación	¿Cómo se encuentró con el vendedor?	Donde fue el vendedor?
1		☐ Un amigo ☐ Un familiar ☐ No le conocía antes		
2		☐ Un amigo ☐ Un familiar ☐ No le conocía antes		
3		☐ Un amigo ☐ Un familiar ☐ No le conocía antes		

3		☐ Un amigo ☐ Un familiar ☐ No le conocía antes		

D.7 ¿Sabe usted quien era el primero posesionario de este tierra? Era alguien de San Martín, o de otro région?

Cajamarca ☐ Piura ☐ Amazonas ☐ San Martín ☐ Otro ☐ (Detalles: ______________________).

D.8 ¿Sabe usted en que año fue agarrada su terreno por la primera vez? Sí ☐ No ☐ (Año: ______________)

D.9 ¿ Sabe usted cuantos dueños tubo su terreno? Sí ☐ No ☐ (¿Cuantos? _____________)

____

D.10 ¿Su terreno cuenta actualmente con un titulo de propiedad? ¿O documentos de compra-venta? ¿O otro documento de propriedad? *(Utilice el mismo número de parcelas como en C.1).*

Titulo: Sí ☐ No ☐

Documento de compra-venta: Sí ☐ No ☐

¿El documento de compra-venta fue firmado por un autoridad?

Juez de la paz ☐ Notario ☐ Otro ___________ ☐ No esta firmado por un autoridad ☐

Otro documento de possession: Sí ☐ No ☐ Detailles: ____________________________

D.11 ¿Alguna vez ha recibido la visita de funcionarios del gobierno o personal de las ONG sobre la titulación formal de su tierra? Sí ☐ No ☐

- Si es así, le puede proporcionar más detalles? (Cuándo, quién, el resultado, vinculado a CIMA / ProCeja).

____

D.12 ¿Ha tumbado bosque primario desde que llegó aqui? Sí ☐ No ☐

D.13 Si ha tumbado bosque primario, qué cantidad de superficie (hectareas) ha tumbado? ¿Fue bosque primario o secondario?¿Qué año lo hizo? ¿Cuánta hectareas por año?

D.14 En algun tiempo ¿ha vendido madera? Sí ☐ No ☐ . Si es asi, ¿cuando ha vendido? y ¿cuanto dinero ha ganado por la venta de madera cada año? ____

D10: año	D10: superficie tumbado	año	superficie tumbado	año	superficie tumbado
1		6		11	
2		7		12	
3		8		13	

D.15 ¿Puede describir los productos que se han producido en los últimos 12 meses?

Producto	Producción total en los últimos 12 meses	Unidad para la producción	Cantidad vendió en el último año	Precio (S/.) por unidad (promedio)	Precio (S/.) mas alto y precio mas bajo en las últimas 12 meses (solo para café)
Café	2011: 2012: 2013:	quintal (56kg)			2011. Alto: Bajo: 2012. Alto: Bajo: 2013. Alto: Bajo:
Cacao					Cuanto de café puede producir en un muy buen año? Quintales: ________
Arroz					
Cultivos annuales (_____)					
Vacas (ahora, ¿Cuantos tiene? __________)		1 animal			
Gallos, gallinas, patos, pavos		1 animal			
Otros (¿Que? ________)					

D.16 ¿Donde vende sus productos? ____

D.17 ¿Cuanto demora desde su casa hasta el mercado?

Tiempo: ______________ Moda de transporte: __________________________

D.18 ¿Cuanto cuesta para transportar sus productos? (por ejemplo - cuanto para un quintal de café). ¿Cual es la diferencia en precio por un quintal de café entre __________ (ubicación de mercado) y aqui?

Cuanto cuesta para transportar un quintal: S./_______ Precio quintal mercado: S./______ Precio aquí: S./______

D.19 ¿Usted o alguien en su casa tiene otras fuentes de ingreso diferentes del ingreso por la venta de productos agricolas en las últimos 12 meses? Por ejemplo: ingresos por alquiler de la tierra, por venta de madera, por ventas de otros productos cosechados, por ventas de animales cazados, por sueldo de trabajo)? Sí ☐ No ☐

Actividad: ________________ Gane en los últimos 12 meses: _________________
Actividad: ________________ Gane en los últimos 12 meses: _________________

D.20 ¿Usted tiene peones para ayuderse con la cosecha? Sí ☐ No ☐

¿Cuanto / por cuanto tiempo? ____

D.21 ¿Que pourcentaje de la cosecha ha cosechado peones y que pourcentaje usted / su familia? _________________

D.22 ¿Cuantos hectareas puede cosechar una persona sola? ________________________________

D.23 ¿Usted ha perdido algo de su cosecha por falta de trabajadores? Sí ☐ No ☐ ¿Cuanto? __________

E Perspectiva de la tenencia de la tierra en la zona

E.1 ¿Hay problemas o conflitos frecuentes por los terrenos en este lugar entre miembros de la communidad?

Muy común ☐ Común ☐ No es muy común ☐ Nunca sucede ☐

E.2 Si hubiese disputas entre miembros de la communidad, ¿cuáles son los motivos más frecuentes? ¿Puede describir que pasaba?

____

E.3 Hay problemas o conflictos frecuentes por los terrenos en este lugar entre miembros de la communidad y personas de afuera?

Muy común ☐ Común ☐ No es muy común ☐ Nunca sucede ☐

E.4 Existe disputas con personas de afuera, ¿cuáles son los motivos más frecuentes? ¿Puede describir que pasaba?

____

____

E.5 ¿Antes de venir aqui, había escuchado usted algo sobre programas para otorgar titulos en este lugar?

Si ☐ No ☐

E.6 Si la respuesta es sí, ¿que tan importante fue esos programas para motivo para usted de se trasladar?

Muy importante ☐ Mas o menos importante ☐ No muy importante ☐ No es importante ☐
Por favor, responda y explique ____

E.7 ¿Tener el título formal sobre la tierra afecta el precio cuando la tierra se vende? Sí ☐ No ☐

E.8 ¿Puede describir cómo el título de la tierra podría afectar el precio de la tierra en esta zona? ¿Sabe cuanto cuesta un hectarea en este communidad en los siguientes casos? ¿Como han cambiado los precios en el tiempo que vivía aqui?

	Sin título, pero con documento de compra-venta	Con título	Precios cuando estaban mas alto (Año: ________)	Precios cuando llegó (Año: __________)
1 hectarea de café (2 años de edad)	S/.	S/.	S/.	S/.
1 hectarea de bosque primario	S/.	S/.	S/.	S/.
1 hectarea de pasto	S/.	S/.	S/.	S/.

F El mercado terreno

F.1 ¿Alguna vez ha pensado en vender su tierra en todo o en parte?

Si ☐ No ☐ . Si la respuesta es 'si', pensaba de vender en todo o en parte? __________________

F.2 Si la respuesta es 'si', ¿por qué quería vender?

____

____

F.3 ¿Que va a hacer si sigue la roya de café?

____

F.4 Si ha pensado en vender su terreno, ¿Por cuando quisiera venderlo?

☐ Tan pronto que posible
☐ Me gustaría vender en las proximas 2 años
☐ 2 - 5 años desde ahora
☐ Mas que 5 años desde ahora

F.5 Si vendiera, ¿a donde iria? ¿que haría?

____

____

F.6 Si usted vende su tierra en este momento, ¿por cuanto dinero cree usted que lo vendería?

____

F.7 ¿Esta precio esta incluyendo su casa? Si ☐ No ☐

F.8 ¿Cuanto sería el precio por su tierra sin casa? ________________________________

F.9 ¿Cuanto tiempo demora para encontrar a un comprador? (a el precio dicho en el pregunta anterior) _____________

☐ 15 dias o menos ☐ 1 mes o menos ☐ 3 meses o menos ☐ 6 meses o menos ☐ 1 año o menos ☐ mas de 1 año

F.10 ¿Ya ha recibido un offerta de compra por su terreno? Sí ☐ No ☐

Si la respuesta es si, ¿Cuando, y por cuanto? Año: ________ Offerta: S/.__________ ¿Por cuantos hectareas? ________

F.11 ¿Alguna vez ha vendido terrenos en esta zona? Sí ☐ No ☐

	Año vendó	Área total	¿Cuanto demora caminando?	Área bosque cuando vendó	Área cafe cuando vendó	Área purma cuando vendó	Área pasto cuando vendó	Área otro cuando vendó	¿Por cuanto vendó? (S/.)
1		ha		ha	ha	ha	ha	ha ________	
2		ha		ha	ha	ha	ha	ha ________	
3		ha		ha	ha	ha	ha	ha ________	
4		ha		ha	ha	ha	ha	ha ________	

F.12 ¿A quien lo ha vendido? ¿Alguien de afuera, o de la comunidad?

1. _____________________ 2. _____________________ 3. _____________________ 4. _____________________

G Los programas de conservación

G.1 Supongamos que usted tuviera un vecino que tenía 5 hectareas de café y 5 hectareas de bosque primario (10 hectareas total), y este vecino tumba 1 hectarea de bosque primario para sembrar otra hectarea de café, como se sentiera usted?

No me molestería ☐ Me molestería un poco ☐ Me molestería mucho ☐

G.2 ¿Por qué sentiría asi? ____

____

G.3 ¿Si este vecino vendiera su bosque a una nueva familia que lo tumba para hacer sus chacras, como se sintiera usted?

No sentiría nada ☐ Feliz de ver la communidad creciendo ☐ Me molestería un poco ☐ Me molestería mucho ☐

G.4 ¿Por qué sentiría asi? ____

____

G.5 ¿Cree usted que es importante de conservar los bosques en este distrito?

Muy imp. ☐ Mas o menos imp. ☐ No muy imp. ☐ No es imp. ☐

G.6 ¿Por qué cree usted que es importante conservar los bosques en este distrito o comunidad?

1. ________________________________
2. ________________________________
3. ________________________________

G.7 Si nuevas familias vienen en la communidad, compran tierras, y tumban bosques para hacer sus chacras, como se sintiera, mas alegre de ver que la communidad va creciendo, o mas triste de ver mas bosque tumbado?

Mas alegre ☐ Igual ☐ Mas triste ☐

Por favor, explique: ____

____

G.8 ¿Ha escuchado algo de una asociación que trabaja con productores de café sobre proteción de bosques? Si ☐ No ☐

G.9 ¿Que ha escuchado? ____

____

G.10 ¿Ha participado en algun manera con este asociación? Si ☐ No ☐

G.11 ¿Como? ____

G.12 ¿Ha firmado un acuerdo de conservación? Si ☐ No ☐

¿Si es asi, en que manera le afecta a usted? ________________________________

____

G.13 ¿Como se siente de este asociación? ¿Tiene un opinion que es positiva ☐ negativa ☐ ambivalente ☐?

Por favor, explique: ____

____

G.14 ¿El Bosque de Proteción Alto Mayo afecta su vida de alguna manera? En promedio, ¿piense que el impacto de esta area en su vida es positiva ☐ negativa ☐ ambos ☐ o insignificante ☐?

Por favor, explique: ____

____

G.15 Ahora, ¿como piensa acerca del BPAM?

Positivo ☐ Indiferente ☐ Negativo ☐

Por favor, explique:

____

G.16 ¿Hay una área de conservación communitario en este communidad o a lado de su frontera? Si ☐ No ☐

Si hay, ¿el área tiene cuantos hectareas? ______________

G.17 Si hay una area de conservación communitario, y si usted estuve viviendo aqui cuando la area fue estabelecido, ¿era a favor o contra de la estabelecimiento? A favor ☐ Contra ☐ Todavia vivía en la communidad ☐

Por favor, explique: ____

____

G.18 Si hay una area de conservación, ¿La area de conservación afecta su vida de alguna manera? En promedio, ¿piense que el impacto de esta area en su vida es positiva ☐ negativa ☐ ambos ☐ o insignificante ☐?

Por favor, explique:

____

____

G.19 Si no hay area de conservación en esta communidad, ¿le gustaría si una sea establecido?

No en todo ☐ Ambivalente ☐ Me gustaría ☐

G.20 Si hay area de conservación en esta communidad, ¿le gustaría si se sea ampliar o diminuar?

Diminuar ☐ Bien como esta ☐ Ampliar ☐

Por favor, explique:

____

____

Gracias por su tiempo!