

**Land investment and land access trends among smallholders near tropical forests:
Implications for conservation and development**

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Abstract

This dissertation is comprised of three distinct studies about land— particularly, land in high priority areas for biodiversity conservation that are experiencing rapid social change and economic development. I focus on understanding *who* is using the land, *how* they are using it, and how land users’ purposes and opportunities are affected by factors from within and beyond the land policy arena. I analyze household and parcel level data at multiple scales, drawing from a combination of land change science and econometrics approaches, as well as local perspectives from fieldwork. Chapter 1 examines the way land users responded to an environmental registration system meant to enhance monitoring and enforcement of forest policies in the Brazilian state of Pará. I show that land users’ desire to stake and strengthen land claims may have influenced the way they responded to the environmental registry. This reaffirms the importance of considering tenure dynamics in environmental policy, and shows how incentives from different land policies can interact. Chapters 2 and 3 are sited in Uganda and investigate household determinants of buying land. Chapter 2 is a longitudinal study based on field research occurring over two decades on the border of a national park. I demonstrate how the park edge is transitioning from a site where marginalized people could find room, to a site with rising land values that is attracting investment by wealthier landowners. Chapter 3 makes use of a national survey to examine whether households are investing non-farm income in purchasing rural land. I show that at low-levels, non-farm income may pull households away from buying rural land, while in large increments, it increases the chance of investing in land and it may enable some households to break in to agriculture. The fact that the amount received at once matters more than the total amount received annually suggests a potential role for savings institutions in mediating how much households choose to invest in land. Threads common to all chapters include heterogeneity and dynamism among land users under land competition, and the potential for interacting effects that influence the way social processes map onto the landscape.

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Introduction

The field of research devoted to Conservation and Development is motivated by ethical concerns for both human and nonhuman welfare and by practical knowledge that these elements are linked (Adams 2004; Adams & Hutton 2007). Whether working to preserve biodiversity or to alleviate poverty, understanding the ways that conservation initiatives and development initiatives reinforce or undermine each other is essential to avoid negative policy outcomes.

The processes of conservation and rural development are linked through land as the basis of production and support for non-human life and human livelihoods. Questions about the extent that the same land can support both, and the scale at which this should happen, make up the ongoing debate about land-sparing vs. land-sharing. In a land-sparing framework, land is separately allocated to either agricultural production or conservation with each area intended to be maximally effective towards its purpose. In a land-sharing framework, conservation and production occur on the same land; the aim is to maximize their joint possibilities by promoting mutually reinforcing processes that allow sustained productivity and diversity over the long run. One of the most familiar examples of land-sparing policy is the creation of protected areas- where a set of production-oriented activities are formally restricted in a designated place. In short, land is spared by setting restrictions on the supply available for production. Other approaches aim to reduce *demand* for land by increasing non-farm employment opportunities, or intensifying agriculture through better inputs and technologies. Both of these options assume that reducing smallholders' dependence on land for incomes should have positive implications for conservation, allowing decisions about land allocation between production and conservation to occur at a larger, more efficient scale (Lambin & Meyfroidt 2011). A contrasting policy perspective is that individual landholders will make better decisions for conservation if they can internalize more of the benefits of those decisions. The most obvious example of this land sharing type of policy is the creation of markets for ecosystem services to pay 'producers' of these services. Increasing land tenure security is another example in this second family of policies. Secure tenure should create conditions where

individual landholders make land use decisions that maximize long-term benefits, rather than a short-term ‘cut-and-run’ mentality. This land-sharing perspective holds that landholder profits and conservation are not mutually exclusive, even with smaller scale decision-making, as long as externalities are internalized and landholders are incentivized to consider long time horizons. Land-sparing implies addressing a problem of spatial scale – that production and conservation cannot be reconciled at too fine a resolution (Redford et al., 2003). Land-sharing implies addressing a problem of incentives and of temporal and social scale – that benefits of investment in compatible production and conservation practices accrue in the long run, to a dispersed network of people, not just to the owner of the land in the current period. As with most issues of scale, these categories are not on either side of a dichotomy; rather they resemble an array of different perspectives on where to look for problems and solutions (Sayre 2009).

Choosing among land-sparing and land-sharing oriented strategies for balancing conservation and development goals depends on understanding the different motivations, constraints, and trajectories of the people using land. This dissertation focuses on land in high priority areas for conservation that are experiencing rapid economic development. In three distinct studies in two countries, I explore *who* is using the land, *how* they are using it, and how land users’ purposes and opportunities are affected by factors from within and beyond the land policy arena. Themes common throughout these chapters are 1) rising *land competition* and an ongoing ‘scramble’ for land and land rights 2) *heterogeneity in wealth* and incomes among land users and the implications for the constraints and motivations governing land use, and 3) understanding land users as dynamic and adaptive actors whose decisions reflect the *confluences* of policy incentives, institutions, socio-economic trends, and land users’ own agendas. I next offer a brief context for each of these themes and then introduce the dissertation chapters.

Land competition and land rights

How does competition for land and the struggle for land rights affect conservation and development outcomes? Although there is general consensus that clear and strengthened land rights is a

positive condition for land users, changes in security of land tenure can act for or against forests (Robinson et al., 2014). More secure tenure increases the probability of reaping the benefits of investment, which increases people's propensity to invest in land, which can increase or reduce deforestation depending on what investments are made and how they affect the values of alternative land uses (Angelsen & Kaimowitz 1999). The causal relationship can also go the other direction; deforestation can increase tenure security if it plays a role in establishing property rights or claims to land. In a context where land rights are informal and contested, it is much easier to invoke usufruct rights to land after demonstrating some kind of investment (e.g. land clearing for crops or pasture) than when the land remains in natural vegetation. This can result in land use that is not efficient or even profitable if landholders are speculating on the future value of property claims (Campbell 2014). In this context, competition to secure rights to land affects land use decisions and can exacerbate deforestation, In Chapter 1, I will show that clarifying land tenure could also reduce deforestation in a policy context where land rights are awarded contingent on good environmental behavior.

The impacts of increasing land competition on land cover is a long-standing question involving Malthusian and Boserupian arguments about whether higher inputs of labor and technology will compensate for higher draw on resources. There are many aspects to this debate, but I focus on the impact of land competition on land use and forest cover primarily through the way it is mediated by land markets. Some scholars suggest that land markets evolve as a natural response to land competition from increasing population density and increased cash-cropping (Chimhowu & Woodhouse 2006; but see Platteau 1996). In several African countries, land markets are being promoted as a non-violent mechanism for achieving an optimal land distribution under increasing competition (Holden et al., 2010), though there are serious concerns about whether land markets will help alleviate poverty through market efficiency or result in loss of land access for the poor (Colin & Woodhouse 2010), especially in places with overlapping or transitioning systems of customary or informal tenure (Benjaminsen & Lund 2002; Peters 2004). The effect of land markets on forest cover and land use remains an open question. The rise

of land markets could be associated with land cover change if land sales bring in new land users with different assets and constraints (Chapter 2), or if the land market facilitates investment of non-farm income in rural land (both Chapters 2 and 3).

Wealth, heterogeneity, and land use

What role does differentiated wealth play in land use change? The distribution of land and wealth is extremely uneven in many parts of the tropics. For example, in Brazil, there is an on-going debate about the extent to which deforestation is driven by less capitalized smallholders or more capitalized large-scale ranchers and soy farmers (e.g. Godar et al., 2014). Questions about the role of wealthier vs. poorer actors in driving changes in the land are relevant in East Africa and elsewhere as well (e.g. Jayne et al., 2014; Angelsen & Wunder 2003). We know that households with different assets can access different land use options (e.g. Takasaki et al., 2001; Zwane 2007). We also know that pressure on forests can differ with wealth, where in negative cases, poorer people may cause forest degradation through resource extraction while wealthier people may convert forest entirely to other land uses (e.g. Baranga et al., 2009; Angelsen & Kaimowitz 1999). In most places, there is a heterogeneous mix of people along a spectrum of wealth, which means that both wealth-driven and poverty-driven land change processes can occur, along with land change processes resulting from conflicts and displacement between these groups (e.g. Aldrich et al., 2012). Much of the attention to the role of different actors in land use change is motivated by the desire to avoid punishing the ‘wrong’ people and to make policies more effective by targeting those driving deforestation. In Chapter 1, I invert this framing and instead use heterogeneity in the deforestation responses of people with different landholding sizes to tease apart which policy elements are having the biggest effect. In Chapter 2, I return to the more classic approach and examine whether land use changes around a protected forest are associated with wealthier or poorer landholders, or processes of competition between them. In Chapter 3, I explore whether non-farm income is driving increasing land and wealth inequality in rural Uganda by examining whether nonfarm income is invested in accumulating farm land.

Dynamics and interactions in the study of land use change

The research community recognizes the importance of moving from general explanations of land use change (like population pressure and poverty) to studies more attentive to the interaction of economic and institutional factors (Lambin et al., 2001). Attention to temporal heterogeneity in populations using land is also important for studies of land change, especially as macro-scale climate and socio-economic factors continue to alter the playing field (Guyer et al., 1997; Sassen et al., 2013). We know that land users change over time as a result of household lifecycles, frontier expansion, state interventions and land reform, gender relations, gentrification, and “land grabs” by larger actors. Studies have reported land cover change as a result of changes in large-scale actors- i.e. state programs and expanding enterprise (Rudel 2007), and as a result of aggregated changes in small-scale actors, for example, as households age (e.g. Perz 2001) or as gender-relations shift within households (Turner, 1999). Actor mobility adds a spatio-temporal element as migration and urban-rural linkages leave their own land change signals (Rudel et al., 2005; Padoch 2008; Aide et al., 2013). This growing body of research signals that it is critical to track temporal trends and that it may be more important to study confluences of drivers than attempt to isolate pure effects from any one driver. In Chapter 1, I show how the *interaction* of land titling and forest monitoring policies led to reductions in deforestation in a place where securing and strengthening land tenure is a predominant local agenda. In Chapter 2, I examined land cover and land user change over a 20 year period under the confluence of increasing population, economic growth, and increasing land and commodity prices. In Chapter 3, I explore the way that limited options for saving money may *interact* with nonfarm income to affect trajectories of smallholder investment in rural land.

Two geographic contexts

This dissertation includes three studies examining land dynamics, the factors that influence them, and their implications for conservation and development in two tropical regions: the Brazilian state of Pará in the Amazon biome, and the nation of Uganda, with a fieldwork component based around a

national park near the Albertine Rift. Both of these regions are important for biodiversity, both draw international concern for high rates of deforestation, but in most other ways are very different. I explore private land dynamics in both regions, but this is not a comparative study. Rather, by paying attention to the different factors driving land dynamics in these two realms, I keep an eye toward understanding general relationships between landholders, markets, and forests, and the particular factors that condition them.

In Uganda, little closed-canopy forest remains outside of protected areas. Land use is relatively consolidated, and population density is as high as 300 people per square-kilometer (Hartter 2010). Parks are the main conservation approach. In contrast, the Brazilian state of Pará still contains vast tracts of forest, but its eastern edge is part of the Amazon's famous Arc of Deforestation. Land use dynamics there are more characteristic of a classic frontier, and many regions of Pará are quite remote from governing centers. Average size of agricultural properties in Pará is just over 100 ha, while in western Uganda the average parcel size is less than 1 ha. Conservation approaches in Pará include protected areas but also an array of strategies to promote forest protection on private land. Despite the relative plentitude of land, the dynamic of a closing frontier and large investments in commodity agriculture have led to a sense of a land rush in Pará (Oliveira 2013). In sum, land competition is occurring in both Pará, Brazil and western Uganda, though the drivers, actors, and implications for forests are distinct in each region.

Overview of chapters

In Chapter 1, I examine how land users responded to an environmental registration system meant to enhance monitoring and enforcement of forest policies in the Brazilian state of Pará. I pay particular attention to the fact that the system is based on self-declared registrations, which, in a place where land records are famously chaotic, allows users to make their properties visible in ways that are most beneficial to them. I use a fixed effects model with panel data on deforestation and registration dates to investigate whether registrants decrease deforestation on registered properties after entering them into the

state system. I also looked at the size-distribution of properties registered, and measured the effect of registering on deforestation in different property size classes. Based on a finding of stacked size distributions under land policy thresholds and deforestation reductions only for a narrow size class with a positive confluence of policy incentives, I argue that land users' agendas around strategically staking and strengthening land claims influenced the way they enrolled in and responded to the environmental registry. Essentially, I suggest that in the small group of properties where deforestation reductions occur, reductions are tied to claimants being on their best environmental behavior because they suspect it may help them receive land titles in the future. Furthermore, there is evidence that at least some claimants are registering strategically sized portions of their property in order to have an optimally sized property for an easier titling process. Both of these effects are present, despite the fact that the registration system was originally designed to be independent of titling issues. This reaffirms the importance of tenure dynamics in environmental policy, and shows how incentives from different land policies can interact.

In Chapter 2, I track changes in land ownership and land use on the edge of a protected area in Uganda. This is a longitudinal study based on field research occurring over two decades in the same communities. I demonstrate how the park edge is transitioning— from a site where marginalized people find room, to a site with rising land values that is attracting investment by wealthier landowners. During the past two decades, the number of households using the same land area has doubled. By constructing family and land histories back-tracking to a 1993 study, I distinguish between households using land at the park edge as a result of legacy and inheritance, households that have purchased land near the park since 1993, and households renting but not owning land. With household survey data, I show that those buying land near the park now are wealthier than legacy households, while those renting are poorer. I use transect data to show that the area under food crops has remained constant, but natural forest, fallow, and brewing bananas near the park edge have given way to plantation trees (like eucalyptus) and perennial commercial crops like tea and coffee. These crops are less palatable for park wildlife and offer good returns for those with enough land and income to afford them. With information on respondents' land

transactions, I demonstrate that land values are rising around the park, and particularly since 2010. Inheritance practices, land markets, eucalyptus prices, and non-farm employment opportunities are interacting factors driving land use change. Taken together, these lines of evidence suggest a changing landscape around the park edge, from a destination for the land- and cash-poor in the 1970s, to a place with increasing opportunities for those with more land and income.

In Chapter 3, I explore land investment across Uganda. There is debate about whether non-farm employment takes pressure off land, and also whether land markets in Africa favor redistribution or land concentration by the wealthy few. Whether non-farm employment leads to land-sparing is dependent in part on how often income from non-farm sources is reinvested in farm activities, and the extent that investment in land is conditioned by local savings institutions. Chapter 3 is framed by these larger questions and focuses on understanding the effect of non-farm income on rural land purchases in Uganda. Specifically, I ask whether non-farm income increases the likelihood that households purchase rural land, and whether this depends on the total amount of non-farm income received annually and the amount received at once. I use publicly available data from the Living Standards Measurement Study conducted by the World Bank and the Ugandan Bureau of Statistics in 2005 and 2010. Analysis thus far shows that at low-levels, non-farm income may pull households away from buying rural land, while in large increments, it increases the chance of investing in land and it may enable some households to break in to agriculture. The fact that the amount received at once matters more than the total amount received annually suggests a potential role for savings institutions in mediating how much households choose to invest in land. I discuss how these results contribute to debates about whether land markets in Africa favor redistribution or land concentration and whether non-farm income takes pressure off land.

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CHAPTER 1.

Mapping properties to monitor forests: Landholder response to a large environmental registration program in the Brazilian Amazon

Abstract

Across the tropics, development banks and conservation donors are investing millions in property mapping and registration projects to improve accountability for deforestation. An evaluation of the effectiveness and accuracy of existing environmental registries is crucial to assure the success of future efforts. This study presents an evaluation of deforestation and registration behavior in response to one of the largest of these property registration programs to date — the Rural Environmental Registry (CAR) in the Amazonian state of Pará. From late 2007 to 2013, approximately 100,000 properties covering 30 million hectares of self-declared claims were entered in this digital registry. We used fixed effects regression models and property level data to assess how registration influenced deforestation on different sizes of properties. Registration had little impact on deforestation behavior, with the exception of a significant reduction on “smallholder” properties in the size range of 100-300 ha. We link this reduction to interacting incentives from forest protection and land regularization policies and suggest that desire to strengthen land claims motivates these landholders’ response to the environmental registry. We also present evidence that some landholders may be registering incomplete or inaccurate parcels into the self-declared system to strategically benefit from policy incentives. Our results for smallholder properties indicate that environmental registries may have potential to facilitate reductions in deforestation if combined with a favorable combination of incentives. However, in places where land tenure is still being negotiated, the utility of environmental registries for forest policy enforcement and research may be limited without ongoing investment to resolve uncertainty around land claims.

1. Introduction

1.1 The importance and challenge of clarifying land ownership

Many of the world's most biodiverse and carbon-rich forests are located in places where land tenure is uncertain. It is difficult to design programs that reduce deforestation without knowing *who* is making land use decisions, and landscape level conservation initiatives require information about private lands beyond protected areas. Reliable property maps are now a requirement for many REDD projects because property boundary data help signal whom to reward for ecosystem services (Larson et al., 2013, Naughton-Treves and Wendland, 2014, Duchelle et al. 2014). Property maps also aid environmental monitoring by indicating whom to penalize for land use violations. Beyond facilitating the allocation of carrots and sticks, property maps can improve understanding of the drivers of land use change by illuminating different patterns among different types of actors (Geoghegan et al., 1998, Liverman and Cuesta, 2008). For these reasons and others, conservation and development organizations, from The Nature Conservancy to the Inter-American Development Bank, are investing millions in large scale land registration programs in Brazil, Colombia, Haiti, Peru, Guatemala, Rwanda, Ecuador and many other tropical countries.

Despite the potential benefits, clarifying land ownership is not without risks. For forests, these include hastened deforestation to establish claims (e.g. De Oliveira, 2008), conflict induced deforestation accompanying land reform (e.g. Alston et al., 2000), and heavier investments in forest-displacing agriculture under greater tenure security (e.g. Liscow, 2013). Risks for people include loss of informal collective access, exacerbated conflict, and capture of land by elites (Araujo et al., 2009, Rajão, 2013, Paulino, 2014). Many of these risks are associated with the act

of establishing or *changing* rights to land (e.g. land reform and land titling programs). Because programs that allocate land rights can be expensive and politically fraught (Deininger & Feder, 2009), and because outcomes for forests can be mixed (Angelsen & Kaimowitz, 1999, Robinson et al., 2015), groups concerned with forest management are experimenting with land registration programs that simply map existing claims. Rather than alter the security of land rights, the goal of this type of environmental land registry is to reveal and systematize information about land users for the purposes of monitoring and planning (Bennett et al., 2013).

Programs to *reform land rights* have received much scholarly attention, but few studies have evaluated the outcomes of programs to *map land claims* in environmental registries, partly because these systems are relatively new and evolving (Gignoux et al., 2013, but see Rajão et al., 2012, Azevedo et al., 2014). Environmental registries are intended to reduce deforestation by facilitating monitoring and enforcement of environmental policies. However, if most land is not registered, if there are conflicting incentives, or when property data are not accessible or reliable, then registries will not necessarily reduce deforestation. There is also a risk that land users may attempt to subvert the system by undertaking clearing prior to registering, by registering only parts of their land, or by interpreting their registration as a permit to clear (Chomitz, 2007, Rajão et al., 2012, Azevedo and Saito, 2013). This paper provides empirical evidence to aid the design of ongoing land registration initiatives and to elucidate discussions about the role of different actors and incentives that affect Amazon deforestation. We address the following questions about environmental registries: first, under what circumstances does registration cause people to reduce deforestation, or perversely, to increase it? next, what are the tradeoffs between information quantity and information quality when land registrations are declaratory?, and finally, what are the implications of mapping properties without resolving land rights if

landownership is still being negotiated, as is often the case at development frontiers? To engage these questions, this study evaluates one of the largest environmental registration programs in the tropics.

1.2 Background: Land registration in Pará's Rural Environmental Registry

Environmental registration initiatives in Brazil are globally important because they cover millions of hectares of forested land and are serving as examples for programs in other countries. Brazil's Forest Code requires land users to maintain forest on a certain proportion of their property — up to 80 % for most of the Amazon biome (Soares-Filho et al., 2014). To facilitate monitoring and enforcement of this policy, the Brazilian government is developing a System of Rural Environmental Registries (Portuguese acronym: SICAR) with the aim of mapping and digitizing all rural properties in the country. The new national system draws from several antecedent state systems, each with somewhat different procedures and objectives, beginning with the System for Environmental Licensing (Portuguese acronym: SLAPR) in the State of Mato Grosso in the early 1990s (Azevedo and Saito, 2013). Expectations for these programs have been high among the international environmental community and within Brazil (Fearnside, 2003, Chomitz, 2007). For example, a recent study quoted a senior Brazilian government official: “[with GIS], deforestation in these areas is going to have a name and a surname. This fact certainly leads to a sensible increase in the governance capability of the environmental agencies in the Amazon states” (Rajão et al., 2012). We evaluate deforestation and registration behavior in response to the largest of the state programs, Pará's Rural Environmental Registry (Portuguese acronym: CAR), which began in 2008 and by 2013 comprised over 100,000 property boundary registrations covering over 30 million hectares of Amazon Forest (Figure 1).

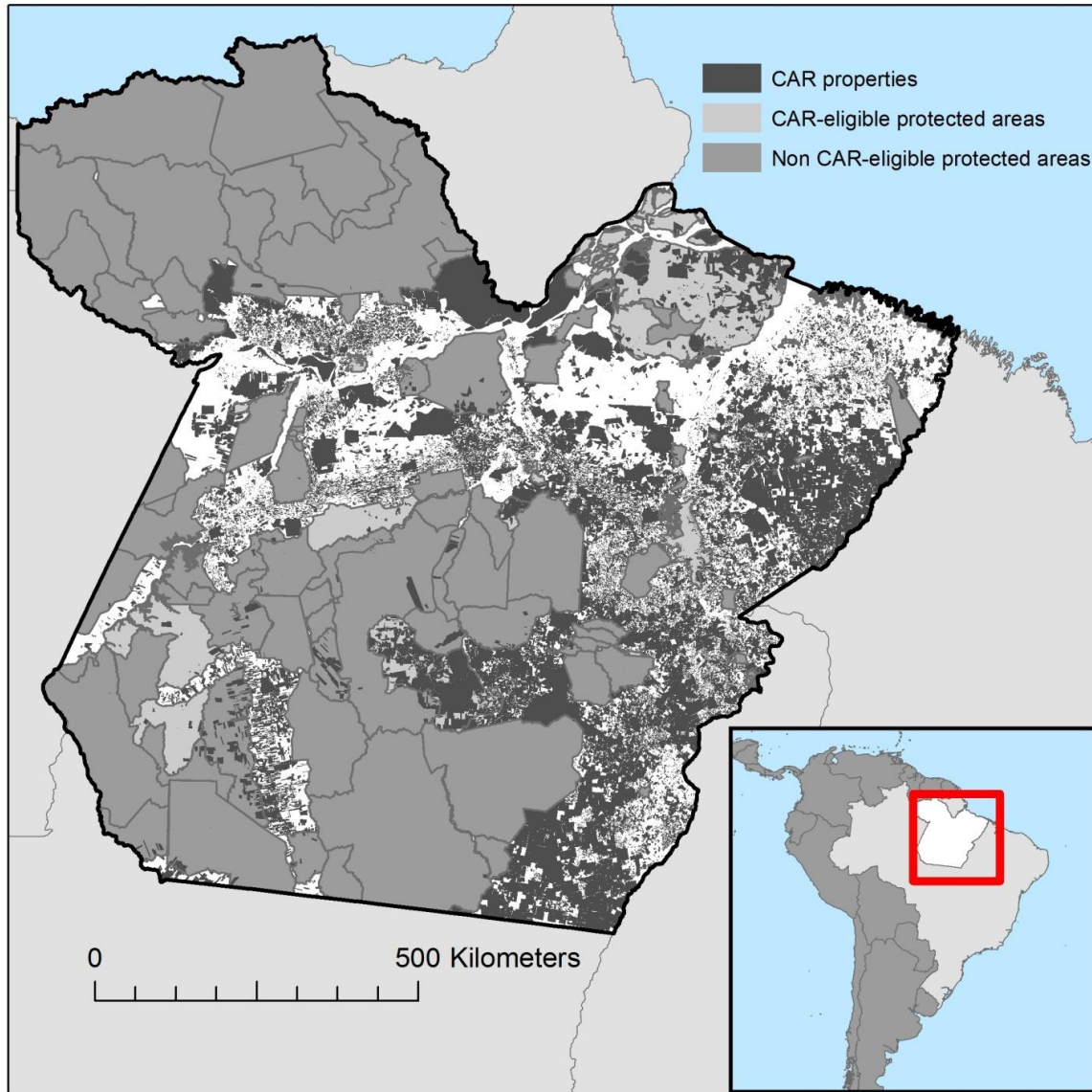


Figure 1. Distribution of land in Pará’s Rural Environmental Registry (CAR). Dark gray shows areas registered in the CAR as of November 2013. White areas are not yet registered but technically eligible. Registrations overlap designated protected areas, both in places where this is legal (some sustainable use areas) and where it is not (strict protection, military, and indigenous areas).

There are several characteristics of the environmental registry in Pará that affect its impacts and how it might apply to other regions. Land distribution in Pará is highly skewed; small properties (here a “small” property can exceed 100 ha) abut ranches of several thousand hectares or more due to waves of agrarian reform settlements and colonization projects targeting

different actors (Pacheco, 2009). Pará is famous for land conflicts and properties continue to be claimed, expropriated, and fought over — sometimes violently (Schmink, 1982, Fearnside, 2001, Wright and Wolford, 2003, Simmons, 2005). Forged titles are common, official titles are rare, and the ability to make and defend claims to land is at the forefront of people's minds, especially in frontier regions (Oliveira, 2013, Campbell, 2014, Reydon et al., 2015). Faced with the challenge of informal and contested land rights in much of the state (one study estimated as much as 53 % as of 2008) (Barreto et al., 2008), the designers of Pará's CAR program adopted a two-phased system. In the first phase, the goal was coverage: as many claims as possible would be mapped by land users, who essentially drew the boundaries of properties on high resolution imagery, aided by GIS technicians deployed across the state (SIMLAM, 2008; Benatti and Fischer, 2011). This provisional stage epitomizes the goal of trying to simply map claims without altering or adjudicating land rights. A “definitive” CAR license could later be obtained after a second phase in which property boundaries and ownership were externally verified and owners submitted a plan for complying with environmental laws (SIMLAM, 2008). Five years after the start of the program, as of November 2013, only 2% of the CAR registrations in Pará had advanced to “definitive” licenses. The other 98% of registrations were “provisional” CAR licenses, automatically generated in response to self-declared boundaries entered in an online system.

1.3 Theory: Incentives, perceptions, and property size

A policy's impacts come partly from its design and objectives, but also from the way people respond according to their own aims and agendas. We examine property size patterns in Pará's environmental registry to provide clues about landholder motivations when they registered their holdings.

Why would landholders choose to make their properties more visible to environmental monitoring? Both the government and private sector have offered an array of incentives to encourage registration, including access to certain kinds of credit and markets¹ (Azevedo et al., 2014, Gibbs et al., 2015). Municipalities that register 80% of their area can exit government red-lists that make them targets for environmental enforcement and legal action (Viana et al., 2012). Another strong incentive for mapping a property into a government system in this region is to bolster the strength and legitimacy of land claims, even though a provisional CAR license expressly *did not* signify any change in the legal status of land claims in Pará (Pará State Decree N° 1,148/2008). Nonetheless, field-based studies have described a common sentiment that land policy in this region is in an uncertain stage of rapid formation and as such, claimants have been hustling to gain a favorable position under policies deemed likely in the future; mapped boundaries in a government registry may gain legal status later (Campbell, 2014). Moreover, for properties below a certain size, enrolling in the environmental registry was a required step in a concurrent but less widespread program for obtaining formal land titles through Brazil's land regularization program, *Terra Legal* (Duchelle et al., 2014). *Terra Legal* aims to do what CAR does not - it is program designed to help smallholders acquire land titles. Despite policy-makers' intentions to keep the processes of mapping and claiming separate, landholders may reasonably perceive the processes to be overlapping.

Why would registration induce changes in deforestation behavior? Landholders may reduce deforestation on registered properties because of concern about increased visibility to monitoring and enforcement, or in response to incentives associated with being visibly

¹ Registration in the CAR was technically mandatory in Pará beginning in 2008, but sanctions for non-compliance were seldom, if ever, applied (Azevedo et al., 2014).

compliant. Concerns about enforcement should not apply to only a specific property size class, but policy incentives can be size specific. For example, in the revised Forest Code, clearing that happened prior to July 2008 on small properties is forgiven and smallholders can use all of their remaining forest area for compensation programs, while any deficiencies in the legal reserve on larger properties must be corrected through reforestation or compensation (Soares-Filho et al., 2014). Overlaying the Forest Code provisions, regularizing claims on government land² is contingent on environmental compliance only for properties above a certain size (Benatti and Fisher, 2011). The suites of regulations and incentives applying to different property size classes allow us to explore whether some sets of incentives are associated with stronger responses to the environmental registry.

The self-declared boundaries in the environmental registry may in many instances be the most official record of a property that is publicly available. As such, we also investigate whether incentives lead registrants to declare their property boundaries strategically, in order to fall in a size class with more advantageous policies. For example, in federal and state land regularization laws, the process for obtaining title is easier for smallholders³ — on site inspection may not be required for small properties while approval from congress is required for large properties (Pacheco and Benatti, 2015). Apart from its intended role in facilitating deforestation reduction by enhancing monitoring and enforcement, the registry is also meant to aid policy design by clarifying debates about the extent to which smallholders vs. largeholders bear responsibility for current deforestation (Godar et al., 2012, Godar et al., 2014, Michalski et al., 2010, Richards and

² Much of the land in Pará is still officially held by the state or federal government; this is the default until landholders make it through the process of regularizing their land claims and obtaining formal title.

³ For small properties (<~100 ha), land is donated by the government to the claimant, medium-sized properties can be purchased directly from the government at a discounted rate, and large properties (>~1500 ha) must be purchased at public auction (Pacheco and Benatti, 2015).

VanWey, 2015). Property boundaries that reveal the locations of large and small actors over a wide region could also support efforts to understand how interactions *between* smallholders and largeholders drive deforestation, including displacement of smallholder settlers by incoming ranchers (Fearnside, 2001, Pacheco, 2012) and conflict between smallholders and largeholders during struggles to expropriate and redistribute land (Alston et al., 2000, De Oliveira, 2008, Aldrich et al., 2012). The usefulness of the registry in this respect is contingent on the assumption that registrations reflect the actual sizes of landholdings.

1.4 Objectives

In the remainder of this paper, we evaluate the initial outcomes associated with Pará's Rural Environmental Registry. We focus first on understanding the degree to which land registration has led to near-term changes in deforestation behavior. We test for effects in property size groups subject to different policy incentives, isolate the effects of registration from background trends within these groups, and check for perverse increases in deforestation prior to registration. Next, we assess whether the ease and accessibility of a self-declared registration system comes with tradeoffs in information quality. We inspect histograms of registration size to investigate whether registrations are declared in strategic and potentially misleading sizes, and we measure the extent of overlapping registrations where claims are not resolved. We link behavior to policy and suggest that key aspects of landholder response to the CAR thus far may be motivated by desire to stake and strengthen land claims, even though CAR was specifically designed to be an environmental registry and not a land titling program. We conclude by discussing broader implications of these findings for land registration initiatives.

2. Methods

2.1 Defining the dataset

Our analysis is based on registrations in the CAR database as of November 2013 (n=101,654)⁴ (SIMLAM-PA 2013). In its raw form, the registry contains many instances of identical and overlapping properties. We removed all exact duplicates⁵ from the data set so that properties would not be double-counted. Summary statistics were calculated over the remaining set of 98,058 properties. We used PRODES data for land cover and deforestation (INPE 2014). For the models assessing impacts of registration on deforestation behavior, we excluded properties with no remaining primary forest at the beginning of the study period where continued deforestation was no longer possible (n=20,373). We also excluded properties smaller than five ha to mitigate resolution issues when assigning deforestation to individual properties (n=2,421). We excluded properties in locations that were not fully covered in the preliminary release of the 2014 PRODES forest cover map, the most recent available at time of analysis (n=3,261). Finally, to avoid double-counting deforestation and to circumvent model identification problems from assigning multiple registration dates to one place, we excluded properties when more than 5% of their area overlapped with another registered property (n=34,596)⁶. In combination, these restrictions reduced the number in the model sample to 45,942 properties. We present model results from this entire sample as well as from two samples with additional restrictions.

⁴ This was the most recent version available at the time of analysis. Additional properties continued to be registered after this date, and in 2014 the new Federal system began to replace the state system.

⁵ Duplicates were defined as properties whose spatial footprint was > 95% identical. In cases where multiple registrations were issued to the same landowner for the same area, we kept the observation with the earliest registration date. In cases where registrations were issued at multiple dates to multiple entities for the same land area, we assumed these may have been cases of sales and kept the earliest registration date. We removed registrations of outer boundaries of land reform settlement areas but kept any individual properties registered within settlements.

⁶ Because this group was so large, we performed robustness checks without this restriction and with higher overlap thresholds. The model results were not sensitive to variations in this restriction.

Additional restrictions hone in on areas with greater potential for influence from land titling policies: properties whose majorities were outside of land reform settlements (INCRA 2014) and properties whose spatial footprints were >95% identical to properties that were also enrolled in the *Terra Legal* land titling program (Terra Legal 2015).

We defined size classes based on a standard definition in Brazilian land policy (Federal Law 8,629/1993) used in other studies from this region (Azevedo et al., 2014): properties less than four fiscal modules⁷ are “small,” properties between four and 15 fiscal modules are “medium,” and properties greater than 15 fiscal modules are “large.” Module sizes vary with municipality (between 50 and 75 ha in rural Pará) and we used the appropriate municipal definition when classifying registrations. However, as an approximation for the reader: small properties are less than roughly 300 ha, medium properties range up to about 1000 ha, and large properties are generally greater than 1000 ha. There are many more small properties than medium and large properties, and we further divided this group into “small” properties of less than 100 ha and “semi-small” properties between 100 ha and 4 modules. One hundred hectares is often the maximum parcel size allocated in land reform settlement projects, and four modules is the legal cut-off when defining a small family farm for economic purposes (Federal Law 11,326/2006). Thus our small category captures most land reform settlers and what would traditionally be thought of as “smallholders,” and our semi-small category could be settlers who have acquired additional land, wealthier “smallholder” colonists, or partially declared properties of larger landholders.

⁷ Land and property laws in Brazil often refer to the concept of a ‘fiscal module’. This is a size unit that is defined for each municipality according to the amount of land required for the primary economic activities of that region (Federal Decree 84,685/1980).

2.2 Modeling the impact of registration on deforestation behavior

To assess deforestation outcomes related to property mapping, we modeled the effects of registration timing on the amount of deforestation occurring on a property in a given year⁸. Essentially, we assess how registration changes the behavior of those who enroll in the program by comparing the rates of deforestation on registered properties to the rates of deforestation on properties that were not yet registered but that eventually registered by November 2013. This approach ensures that we measure effects associated with the act of registration and not effects associated with differences in the kinds of landholders that choose to participate in the system or the kind of land that gets enrolled (i.e. selection bias). With the panel data, we used fixed effects linear regression to control for the average levels of deforestation on each property due to time constant factors like distance to market or geographic characteristics, and we included additional year level fixed effects to control for background temporal trends occurring across the sample due to factors like fluctuations in commodity prices. The combination of property level information with fixed effects regression helps to isolate changes in deforestation behavior due to registration from the suite of other dynamics affecting forest clearing. Models followed the two structures shown below, for property i in time t .

$$(1) \quad \text{Defor}_{it} = \gamma_i + \gamma_t + \beta * (\text{if registered before or during year } t)_{it} + \varepsilon_{it}$$

$$(2) \quad \text{Defor}_{it} = \gamma_i + \gamma_t + \beta_1 * (\text{if registered in year } t+1)_{it} + \beta_2 * (\text{if registered in year } t)_{it} + \beta_3 * (\text{if already registered before year } t)_{it} + \varepsilon_{it}$$

⁸ We used the listed date of registration in the system — provisional CAR licenses were granted almost instantaneously in Pará. Registration dates were aggregated into years beginning in August and running through July in order to synch more closely with the time window considered in the maps of annual deforestation released by the PRODES satellite monitoring program (e.g. 2010 = August 2009-July 2010).

We examined annual deforestation on a property (Defor_{it}) using both a continuous indicator for the amount of deforestation occurring in a given year⁹ and a binary indicator of whether or not any deforestation occurred in a given year. We consider any deforestation within the boundaries of a property, regardless of whether it is inside or outside of a property's legal reserve area. The variables γ_i and γ_t are the property and year fixed effects, respectively. Standard errors are clustered at the municipality level to account for spatial autocorrelation of properties. For Equation 1, the 'treatment' variable is a binary indicator for whether a property was registered in a given year, including properties that were already registered in prior years. We ran this model over the time period from Aug. 2009 to July 2013, when the bulk of registration occurred. For Equation 2, the 'treatment' variable is broken into three categories, where we separated the effects of the year immediately prior to registration, the year of registration, and the years after registration, relative to the reference level of over a year prior to registration. We ran the Equation 2 model for August 2008 to July 2012, the years with sufficient properties in each category of registration timing (Table 1). This model allowed us to check for increases in deforestation immediately prior to registering that could potentially have been induced by knowledge that properties would be monitored after registration. To allow for heterogeneous registration effects and background trends according to property size, we ran separate models for our four size-classes of properties.

⁹ We used the inverse hyperbolic sine transformation for our continuous measure of the amount of deforestation. This behaves almost identically to the more common log transformation, except that it is also defined for values of zero (Burbidge et al. 1988). This allows for handling the frequent cases of no deforestation in a given year similar to a binary measure, but also varies with extent of deforestation when it occurs. We also modeled the proportion of remaining forest cleared in a given year; patterns were basically the same as the binary and continuous measures. For all deforestation measures, we used linear models for ease of interpretation with panel data.

Table 1. Timing of registration for each size class in the model sample of properties

Year^a	Small	Semi-small	Medium	Large	Total
<i>2008</i>	<i>31</i>	<i>14</i>	<i>10</i>	<i>16</i>	<i>71</i>
<i>2009</i>	<i>95</i>	<i>40</i>	<i>67</i>	<i>82</i>	<i>284</i>
2010	1,716	1,275	1,334	834	5,159
2011	3,684	1,975	1,018	595	7,272
2012	5,895	2,646	1,293	666	10,500
2013	8,420	2,988	1,393	726	13,527
<i>2014</i>	<i>6,638</i>	<i>1,519</i>	<i>650</i>	<i>322</i>	<i>9,129</i>
Total	26,479	10,457	5,765	3,241	45,942

^a Year follows the PRODES calendar and includes the previous August through July of the indicated year (e.g. August 2007-July 2008 = “2008”). Italicized years (2008 and 2009) were excluded from impact models because there were very few registrations. Our dataset only contains registrations from the first 4 months of 2014 (Aug.-Nov. 2013).

2.3 The search for evidence of strategic registration

We examined the distribution of registrations using a histogram plotting the frequency of properties of different sizes. Peaks indicate relatively common sizes. We would expect a high frequency of properties allocated at standard sizes in colonization and resettlement programs (e.g. 100 ha), with clustering around these standard sizes due to imprecise surveying and other technical factors. In contrast, much denser distributions on only one side of a peak suggest that land is acquired, or is simply being registered, with an eye toward property size thresholds related to policy incentives. For example, if up to 100 ha of land can be claimed for no cost, one might expect more 98 ha parcels than 102 ha parcels to be registered. Landholders might declare only 99 ha of a larger piece they use, or might register a 190 ha parcel as two 95 ha units. We test for strategic registration by investigating instances where properties were registered disproportionately frequently at sizes just below policy thresholds. We calculated the ratio between properties that registered just below and those just above threshold values along a scale

based on increments of one hundred hectares, and along a scale based on increments of fiscal modules¹⁰. Based on our review of pertinent land and forest laws, Table 2 summarizes which of these incremental thresholds corresponds with actual policy thresholds and incentives. If people register to strategically qualify for the benefits of one of these policies, we would expect disproportionate registration below the corresponding size thresholds. Though the environmental registry is not directly connected to several of the policies in Table 2, we include them because landholders may think of the registry as an opportunity to officially delineate boundaries in a way that may help them in other arenas (e.g., future land regularization efforts).

Table 2. Summary of legal thresholds

Threshold	Summary of policies relevant to property size thresholds	Relevant law
1 fiscal module (50-75 ha)	Below this amount, federal lands are donated to claimants.	Federal Land Regularization Law (11,952/2009)
100 ha	Below this amount, state lands are donated to claimants.	Pará Land Regularization Law (7,289/ 2009)
4 fiscal modules (200-300ha)	Below this amount, forest cleared prior to 2008 is forgiven and claims for federal lands are not subject to onsite inspection if the property remains free of additional violations.	Federal Forest Code (12,651/2012); Federal Decree on Land Regularization (6,992/2009)
300 ha	In 2010 the state made it easier for properties below this size to obtain a CAR license by lowering the amount of required data and increasing the number of institutions authorized to register boundaries.	Normative Instruction Amending Pará CAR Law (37 /2010)
500 ha	Above this amount, property claims require an economic use plan and are subject to verification by an outside agency.	Pará Decree on Land Regularization (2,135/2010)
15 fiscal modules (750-1125ha)	Below this amount, land claims can be regularized through the Terra Legal program and purchased at discounted rates; above this amount federal land must be purchased at public auction.	Federal Land Regularization Law (11,952/2009)
1500 ha	Above this amount, approval from the state assembly is required for purchase of state lands.	Pará Decree on Land Regularization (2,135/2010)
2500 ha	Above this amount, congressional approval is required for purchase of both federal and state lands.	Federal Land Regularization Law (11,952/2009); Pará Decree on Land Regularization (2,135/2010)

¹⁰ We tested within a range of ± 5 ha. In the absence of threshold effects, the ratio of properties just under vs. just over a certain size should be close to 1:1 within a narrow window of 10 ha.

3. Results

3.1 Summary statistics for deforestation trends and landholdings

As of late 2013, roughly half of the eligible land in Pará was registered in the CAR system. Small properties accounted for the majority of registrations, yet most of the registered land area and even more of the registered forest area was held in larger properties (Table 3). Across all size classes, the amount of deforestation declined from 2007-2011 and then stabilized (Figure 2). Properties in the largest size class still clear more on average than properties in the smallest class, but absolute deforestation rates declined most steeply on large properties – thus, the mean annual amount of deforestation on small and large properties has become more comparable over the past decade. In fact, while deforestation at the beginning of the study period in 2007 was much more likely to occur on larger properties, by 2014, deforestation was just as likely to be found on small properties (Table 3). These general trends are related to processes other than CAR registration. The panel models seek to identify additional reductions in deforestation associated with enrolling in the environmental registry, beyond these significant background trends.

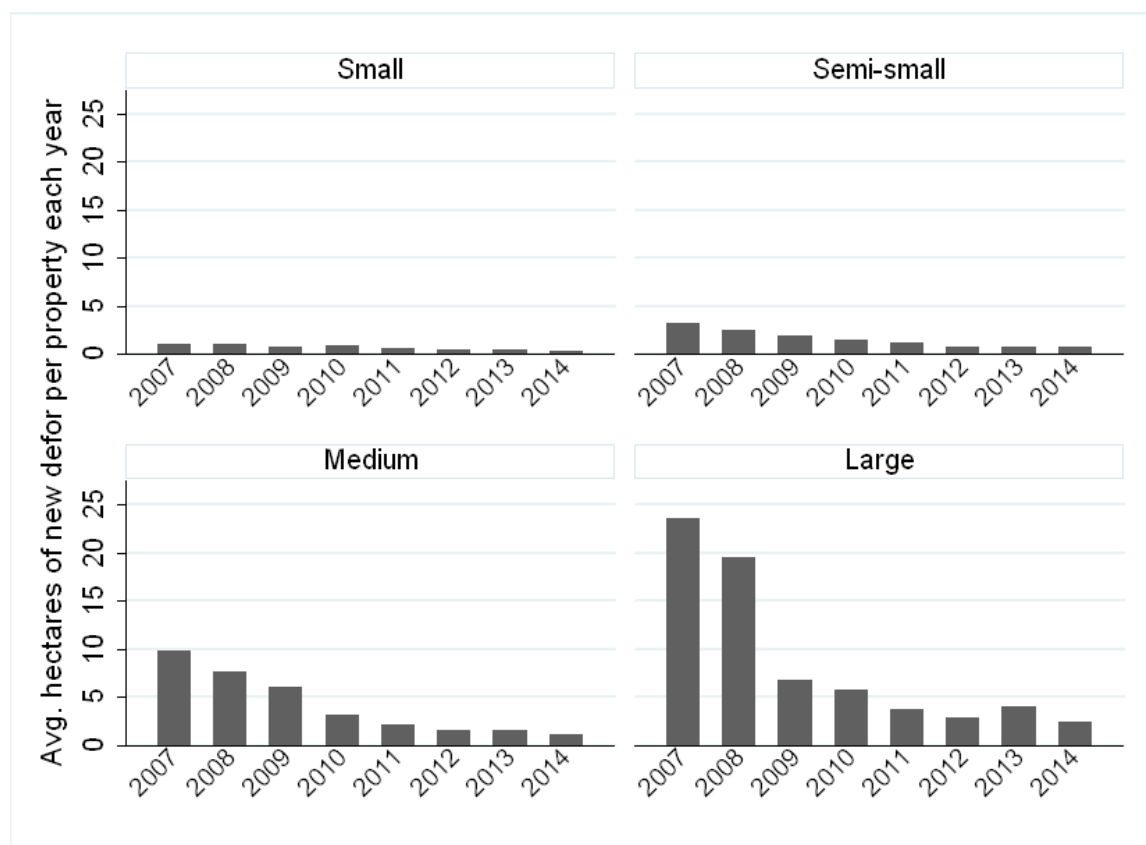


Figure 2. Falling background trends for deforestation by size class. Averages are shown for the 45,942 properties in the deforestation models, which exclude properties with no forest remaining in 2007.

Table 3. Relative importance^a of different size classes in the environmental registry

	Portion of registrations (%)	Portion of registered land (%)	Portion of registered primary forest (%)	Portion of registered deforestation in 2007 ^b (%)	Portion of registered deforestation in 2014 ^b (%)
Small	63.5	10.6	6.1	13.2	29.1
Semi-small	21.1	11.0	7.5	15.4	25.1
Medium	10.2	20.0	18.2	24.9	20.6
Large	5.2	58.4	68.1	46.4	25.2

^a Percentages are based on the larger set of 98,058 properties, after duplicates were removed but before restricting sample to properties that still contain forest. However, trends are similar when calculated for the restricted model sample and all values differ by less than five percentage points.

^b The portion of deforestation that falls within each size category, out of the total detected by PRODES for that year within the area registered in the CAR by Nov. 2013 (INPE 2014).

3.2 Effects of registration on deforestation among different property size classes

Registration had little effect on deforestation behavior overall¹¹. However, responses to registration varied by property size-class. Among semi-small properties, reductions were modest but statistically significant. On these properties, registration reduced the probability of any deforestation by nine percent and reduced the extent of deforestation by 5.3 %, relative to unregistered properties (Table 4). This pattern persisted when we excluded properties that overlapped land reform settlements. No significant effects were evident for other size classes¹².

The modest but statistically significant effect of registration for semi-smallholders was greater among the subset of registrants known to be seeking land titles. We found that the deforestation-reducing effect was about three times larger on CAR properties that were also part of the Terra Legal land titling program, but again, only in the semi-smallholder class. In this program, during the mortgage period when landholders are purchasing the property from the state, environmental infractions can trigger cancellation of the process. For the subset of semi-small smallholders seeking land titles in Terra Legal, the chance of deforestation drops by almost 30% after property registration.

¹¹ This result is sensitive to the time window used in the model. Including deforestation from years prior to 2010 leads to a larger, significant overall effect. Our focus on the years in which the bulk of properties registered is conservative and may underestimate the effect of the program.

¹² We also tested for the effect in properties at the small end of the medium size range (those between four and seven modules) as a robustness check that the difference in registration effects represents a discontinuity at the legal threshold defining smallholders and not a gradual difference corresponding to property size. Even among the smaller properties in the medium category, registration did not cause a decrease in deforestation behavior in the way that it did for the properties under the legal smallholder cut-off.

Table 4. Effect ^a of registration in CAR system on annual deforestation by size class

		Overall	Small	Semi-small	Medium	Large
Full Sample of CAR registrations	Effect on probability of defor (% change)	-2.6	-2.3	-9.2*	4.3	3.2
	Effect on extent of clearing (% change)	-1.9	-1.4	-5.3***	1.2	-1.3
	n	45,942	26,479	10,457	5,765	3,241
Set of CAR registrations excluding land reform settlement areas ^b	Effect on probability of defor (% change)	-4.4	-7.4	-8.7 [†]	2.8	3.2
	Effect on extent of clearing (% change)	-1.9 [†]	-2.1	-5.2**	0.6	-1.3
	n	29,571	13,680	7,745	4,905	3,241
Set of CAR registrations in Terra Legal titling process ^c	Effect on probability of defor (% change)	-9.4	4.4	-28.6*	3.2	N/A
	Effect on extent of clearing (% change)	-4.7	2	-13.8*	-2.3	N/A
	n	2,328	1,156	822	330	N/A

^a Significance levels indicated by [†] : p<0.1; * : p<0.05; ** : p < 0.01; *** : p<0.001. Results are from models using a binary outcome for deforestation (probability) and a continuous transformed measure of deforestation (extent). Percent change was calculated relative to the modeled deforestation outcome for unregistered properties. Results are based on analysis time window from Aug. 2009 - July 2013.

^b This is the subset of properties that fall outside areas identified as INCRA land reform settlements. Land reform settlements are subject to different and additional land governance policies and procedures.

^c This is the subset of the properties registered in the CAR whose spatial locations align with properties in the Terra Legal database; i.e. those known to be actively seeking title. Large properties are not eligible for titling through this program.

3.3 Strategic registration and ambiguous ownership

To test for strategic clearing before entering the system, we explored how deforestation changed for properties about to register, those in the midst of registering, and those already registered in a previous year, rather than making a simple before-and-after comparison (Equation 2). We find no significant increase in deforestation in the year immediately preceding registration for properties of any size class (Table 5). In concordance with earlier results, only semi-small properties show a significant decrease in clearing behavior during the year of registration and in subsequent years.

Table 5. Effect ^a of registration timing on deforestation ^b

	Overall	Small	Semi-Small	Medium	Large
Year before registration	0%	1%	0%	-4%	0%
Year of registration	-3%	-1%	-7%*	-1%	-5%
After registration year	-2%	3%	-11%*	-2%	1%

^a *: $p < 0.05$

^b Results from the model using the continuous (transformed) measure of deforestation. Results are expressed as the % change from the reference level of deforestation over a year prior to registration.

Though we do not find evidence for strategic clearing behavior, we do find evidence for strategic registration. As expected, we see high frequencies of properties allocated at standard sizes in colonization and resettlement programs (e.g. 100 ha), with clustering around these standard sizes due to imprecise surveying and other technical factors. We also see places where there are denser distributions on only one side of a peak, suggesting that land is registered with an eye toward property size thresholds related to policy incentives. A histogram of registered property sizes (Figure 3) reveals several locations where property size frequency stacks disproportionately below particular peaks. Thresholds are evident at 300 ha, 1125 ha¹³, 1500 ha, and 2500 ha. Visually, it is difficult to tell whether other peaks in the histogram exhibit disproportionate stacking, but ratio tests revealed additional threshold effects (Table 6). Significantly more properties register just under¹⁴ 1, 2, 4, and 15 fiscal modules, as well as 100, 200, 300, 500, and 1500 ha. Almost all of these sizes correspond to specific legal thresholds¹⁵,

¹³ 75 ha is one of the most common fiscal module sizes, which means that for 45 % of the properties in our sample, 1125 ha and 15 fiscal modules represent the same threshold, as do 300 ha and 4 fiscal modules. There are no municipalities in Pará where a fiscal module is equal to 100 ha, so, for example, 1500 ha and 15 fiscal modules are never equivalent.

¹⁴ The only instance where significantly more properties register just *over* a threshold occurs in the small group around 900 ha. This is likely due to reasons apart from regularization and forest policies; we found no references to this size cut-off in our research.

¹⁵ There are no corresponding legal thresholds that we are aware of to explain the moderately higher proportions registering areas just under 2 fiscal modules and 200 ha unless there is intent to later split the properties.

which are largely about tenure regularization and not directly connected to the environmental registry (see Table 2).

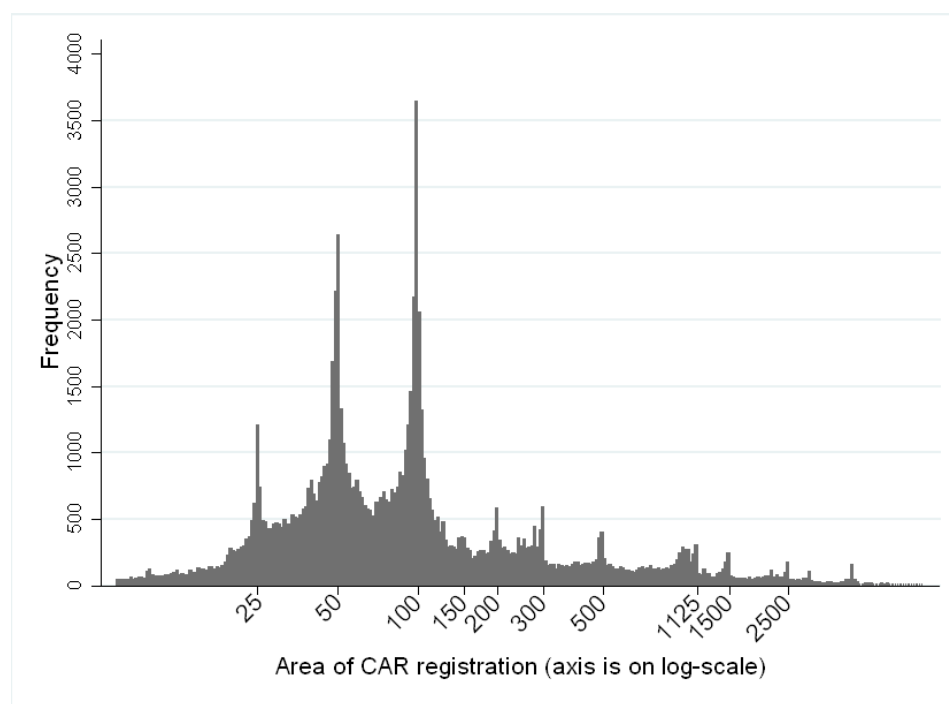


Figure 3. Histogram of registered property sizes. The distribution evinces distinct modes and propensity to stack below certain size thresholds.

Table 6. Proportion of properties just under ^a vs. just over ^a a range of size thresholds ^c

threshold (modules)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Ratio ^a	1.2	1.4	1.1	2.3	1.1	0.9	0.9	1.3	0.9	1.0	1.1	0.8	1.1	0.9	2.8	1.1
Count ^b	4,818	1,063	587	834	205	167	226	118	110	89	70	64	89	120	252	56
P-val ^c	0.00	0.00	0.22	0.00	0.49	0.16	0.57	0.07	0.28	0.88	0.74	0.16	0.65	0.44	0.00	0.70
threshold (hectares)	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600
Ratio ^a	1.2	0.9	1.9	1.0	1.2	0.9	0.9	0.8	0.6	0.9	0.8	1.4	1.0	0.9	1.7	1.3
Count ^b	9,919	1,044	697	215	330	101	78	69	67	161	89	49	24	30	83	23
P-val ^c	0.00	0.02	0.00	0.92	0.03	0.67	0.34	0.23	0.01	0.44	0.18	0.07	1.00	0.61	0.00	0.38

^a The ratio of the properties in the five hectares just below a threshold compared to the five hectares just above a threshold.

^b The number of registrations within ±five hectares of a threshold

^c The probability that the proportion just under is equal to the proportion just over, given the number of properties within five ha of the threshold. Known legal thresholds are in highlighted columns with boldface.

Finally, we found a substantial amount of overlap among land registrations in the declaratory system. When intersecting the spatial dataset of registered property boundaries with itself, 27,991 (27.5 %) of property registrations overlapped by more than 5% with another registration¹⁶. These overlapping registrations may signal inaccurately drawn boundaries, contentious land claims, or accumulated versions of properties that were re-registered with different shapes for a variety of potential reasons.

4. Discussion

4.1 Has the environmental registry caused landholders to reduce deforestation?

Though deforestation fell in the region during our study period, most of this decline was not a direct result of the environmental registry. The majority of registrants did not substantially alter their clearing behavior immediately following (or preceding) registration, in our time-window of analysis. Note that our study was designed to measure how registration affected individual landholder behavior, which is different than the effect of the program on deforestation overall¹⁷. We can speak to the impact of registration on enrolled properties, but we cannot speak to deforestation and land claiming dynamics on land that was not enrolled. For enrolled properties, a weak or neutral initial effect on deforestation is not surprising since the primary aim

¹⁶ We defined “considerable overlap” as greater than 5 % but less than 95 % of spatial overlap with another registered property. Overlapping areas greater than 5 % are not easily explainable by small mapping errors, and overlap less than 95 % excludes cases of multiple registrations of the same property due to system errors and sales, or small individual properties registered within larger settlement boundaries.

¹⁷ Because registrations are the unit of analysis, changes in deforestation on small properties count as much as changes on large properties. This tells more about how the CAR is working as a suite of incentives (i.e. how many people have changed their behavior) and less about how much reduced deforestation the program has stimulated.

of the CAR program in Pará thus far has been to gather boundary information to facilitate *future* monitoring and enforcement. Though in theory it made properties publicly visible, few organizations had full access to the CAR database, and it was rarely used for enforcement against illegal deforestation (possibly to avoid discouraging future registrations). If property holders did not feel that registration increased the likelihood of enforcement, they would have had little reason to change deforestation behavior. This may especially be the case for larger properties whose boundaries were more likely to be publicly documented by other means outside of the CAR (Rajão and Vurdubakis, 2013, Reydon et al., 2015) and thus were already vulnerable to enforcement associated with monitoring programs that preceded the CAR, such as the DETER satellite monitoring program (Assunção et al., 2014, Arima et al., 2014). A report from the Amazon Environmental Research Institute (IPAM) found a similar result of little overall impact from Pará's CAR, though they report larger reductions on small and medium properties and an increase in deforestation on large properties (Azevedo et al., 2014). This may be due in part to different time windows of analysis and in part to use of fixed effects models rather than year-by-year comparisons among registered and unregistered properties. Evaluations of the antecedent environmental licensing program (SLAPR) in the neighboring state of Mato Grosso also indicated that registration did not decrease deforestation and in some instances increased it (Rajão et al., 2012, Azevedo and Saito, 2013). We found no evidence for significant effects of increased deforestation before or after registration in Pará.

Despite the lack of a strong overall effect on clearing behavior thus far, our results demonstrate that registration did lead to a decrease in deforestation for one particular size class: the semi-small properties (100 to ~300 ha). The discontinuity between behavior on semi-small properties and those in neighboring size classes suggests that the explanation is related to

policies that treat these groups differently rather than inherent differences among large and small actors. The deforestation responses of different property size classes could be explained if some landholders enrolled in the environmental registry in hopes that it would facilitate land regularization. This is supported by the fact that the deforestation reduction effect is three times larger for the semi-small properties known to be already involved in the *Terra Legal* titling program¹⁸. These properties may have reduced deforestation after registering because they fell in an unintended policy "sweet-spot" created by an interaction of land regularization and forest protection policies.

Semi-small properties are at the larger end of Brazil's legal definition for "small family farms." They are larger than typical land reform settlement allocations, but could be owned by wealthier land reform settlers who have acquired additional land. Semi-small properties could also be owned by settlers with historic claims on land that still officially belongs to the government, or semi-small properties could belong to landholders with more extensive properties registered in smaller pieces for strategic reasons¹⁹. Semi-small properties are large enough that landholders must pay to purchase the land from the government if they want to regularize their claims²⁰, though they pay a rate below market value and can pay it off over a 10-year period (Pará State Decree 2,135/2010, Federal Decree 6,992/2009). The right to gain title might be

¹⁸ Far more properties are registered in the CAR than there are to date in the slower moving *Terra Legal* land titling program. However, the presence of the *Terra Legal* in the region may have significantly influenced landholder behavior, especially since a CAR was required to be eligible for regularization through *Terra Legal*. Properties not yet involved in the titling process might still have seen a CAR registration as a potential step toward strengthening property claims.

¹⁹ Although technically these properties would be ineligible for most smallholder benefits, which apply only to producers with small *total* landholdings, we are not aware of any measures that prevent families from registering areas up to particular limits in the names of various relatives and pooling their use.

²⁰ In the absence of an official title, land in the Amazon falls in the category of "unassigned public land" held by the government. Though it is technically unassigned, much has long been used and occupied. The 2009 Land Regularization Law establishes a procedure for occupants to purchase their land claims from the government (Oliveira 2013).

cancelled if environmental infractions are detected on the property during this pay-down period (Pará State Decree 2,135/2010). Environmental infractions can also trigger an external inspection of the property claim that is otherwise waived for properties in this size class (Federal Decree 6,992/2009). This means that, at least until a property is paid down, obtaining a title is facilitated by compliance with environmental policies. This does not apply to properties less than 100 ha; these are donated to claimants by the government and thus do not have a sensitive mortgage period, which may explain the lack of response in the smallest size class. Nor does it apply for large properties over ~1500 ha that must go through other legal channels outside of the *Terra Legal* program to receive title. Medium-sized properties should still be subject to the government mortgage period, but we do not see evidence that registration affects deforestation behavior in that size class. Perhaps property owners in this class are wealthy enough to buy their land without a government mortgage, but we would not expect wealth to be discontinuous between semi-small properties and medium properties. An alternative explanation is that, for the medium-sized properties, the cost of coming into compliance may overwhelm any benefits that such compliance might confer on easing the titling process (Stickler et al., 2013). There is a discontinuous cost of compliance between semi-small and medium properties: in the 2012 Forest Code, areas cleared prior to mid-2008 do not need to be replanted or compensated on properties smaller than four fiscal modules (Law 12,651/2012). Environmental compliance is disproportionately more difficult for properties just over the size threshold for forgiveness. Medium properties must replant or pay to compensate any areas cleared beyond their designated Legal Reserve, which can be as much as 80 % of the property. This means that the semi-small properties are in the unique position where environmental compliance both facilitates receiving a land title *and* does not incur heavy costs. Field-based studies in Pará indicate that many

landholders in Pará are aware of legal thresholds, especially those related to titling and land regularization (Campbell, 2015).

A reduction in deforestation on semi-small properties is encouraging, especially because smallholders can be hard to reach with market-based and command-and-control policies (Coudel et al., 2012), and smaller properties are becoming responsible for an increasing component of the deforestation in Pará as deforestation rates decline more steeply on larger properties. However, while the semi-small properties represent 21 % of registrations in Pará, they contain only 7.5 % of registered forested land. Many small properties contain no forest at all. At the end of 2013, half of the eligible land in the state was not yet registered to any size class. Thus, a substantial amount of unprotected primary forest is not yet captured within the registration system, and the vast majority of forest on registered properties does not fall in the size class that is currently incentivized to reduce deforestation following registration.

4.2 Information quality under declaratory registration

Denser stacking of property sizes just below legal thresholds indicates that landholders may not be registering their entire or exact holdings. This could mean registering parts of their property and leaving the rest unregistered, or registering land in strategically-sized segments under different names, or claiming conveniently-sized pieces that may be unrelated to what they are actually using. Strategic registration could hamper the effectiveness of environmental monitoring. If people do not register their entire landholdings, then it is possible that future deforestation may be concentrated in unregistered places that avoid enforcement, resulting in spatial leakage of deforestation. If people split land into strategically-sized pieces under different names, this could either allow people who are not truly eligible to fall into the

category where deforestation prior to 2008 does not need to be compensated, or allow people to keep a “clean” property as a basis for sales while committing environmental infractions on other properties they are using (Gibbs et al., 2015). One of the objectives of the environmental cadastres in the Amazon is to reduce enforcement expenses by decreasing the need for costly site visits to remote areas (Rajão et al., 2012). However, if there are questions about the extent to which registered boundaries represent actual holdings, or if holdings are overlapping, site visits remain just as necessary as before. Evidence for strategic claim-sizes also raises a red flag concerning the use of CAR to understand the deforestation impacts of smallholders versus largeholders; it is not necessarily safe to assume that formally declared small properties actually belong to smallholders.

The ease of registering claims in the Pará CAR has paid off in coverage; over 30,000,000 ha of land are now registered, at least provisionally. The CAR as it stands represents a dramatic increase in information and its creation has not led to perverse deforestation outcomes. Yet, jumping ahead to map claims without first resolving or legitimizing claims has risks. Use of the database for enforcement will be hampered by lack of certainty about the accuracy of the information it contains, and it is unlikely that the registry can have a large or continuing effect on deforestation without stronger connection to enforcement. It remains to be seen whether Pará’s initiative will prove a worthwhile investment for reducing deforestation. As the new federal CAR system (SICAR) comes on line, state and federal environmental agencies are beginning to move the 98 % of registrations that made it only to the “provisional” phase in Pará through the more stringent verification and environmental recovery planning (PRA) phases of the registration process. This will require all boundary overlaps to be resolved and calls for heavy investment in inspection procedures. In the meantime, care must be taken when using and

interpreting data from what was meant to be an initial phase²¹. Field validations of the registry data should be undertaken to inform efforts to expand or replicate the program elsewhere.

4.3 Mapping for environmental monitoring or staking land claims

Strategic positioning with regard to land claims is predictable in a system where boundaries are essentially self-declared. Indeed, land holdings and land claims are notoriously chaotic in Brazil, and especially in the Amazon, where there have been competing and fraudulent claims for centuries (Brannstrom, 2001, Jepson, 2006, Bourguignon, 2013). However, it is somewhat surprising to see strategic positioning that is more about land claims than environmental policy in an environmental registry that was meant to be separate from questions of tenure security. Stacking beneath four fiscal modules could signal that owners were responding to the clause in the Forest Code that forgives historic clearing under that threshold. However, none of the other sizes where stacking occurred are mentioned in the Forest Code, while all the thresholds (including four fiscal modules) *are* meaningful in land regularization laws, specifically various criteria that grant an easier titling process. The decline in deforestation for semi-small properties was likely due to its perceived connection with titling. This bolsters the argument that landholders may have come to view the environmental registry as a hopeful step on a path toward a future land title, rather than as a tool that facilitates monitoring of their land use. The process of issuing land titles through *Terra Legal* and other channels has been criticized as being unacceptably slow and having negligible impact (Oliveira, 2013), but our findings suggest that landholders are paying attention to their government's efforts to resolve

²¹ For example, there are reports that some banks and vendors accept a "provisional" CAR license as proof of environmental compliance in order to meet industry policies to restrict loans to or sales from people who practice illegal deforestation (Azevedo et al., 2014).

tenure issues in the Amazon and that the impacts of such programs may be magnified by other policies.

The link between the environmental registry and land regularization means that from the perspective of relevant landholders, the CAR might be perceived as part of a land regularization initiative with tenure incentives contingent on environmental performance. This is despite the fact that during the period under study, there was not yet a legal basis for CAR boundaries to be translated into legal land claims, and both the Pará CAR program and the newer federal SICAR program explicitly stated that environmental registration was not intended to support land claims (Pará State Decree N° 1,148/2008, PortalBrasil, 2015). Nevertheless, local perceptions and expectations may not be unfounded; in 2013, modifications to the state's Green Municipalities program opened the path to title for some properties registered with CAR in municipalities that had achieved certain environmental goals (Pará State Decree 739/2013). Furthermore, there are currently discussions in Pará about the potential to use the CAR database in future official land titling efforts (Monteiro, 2015). This turn of events would certainly legitimize registrants' hopes that the CAR would eventually become a step toward land titles. If this happens, our findings about strategic claiming around size thresholds and interactions between environmental and tenure policy incentives should become even more relevant.

5. Conclusion

Pará's experience with its Rural Environmental Registry program offers several lessons for other environmental registration initiatives. It is possible to map claims prior to resolving them, and the combination of few verification requirements, positive incentives to register, and

an easy declaratory process facilitated a high volume of registrations, including among smallholders who can be under-represented in property mapping efforts. We show that some motivations for enrolling in the registry and reducing deforestation are tied to incentives from a parallel land policy as opposed to the incentives offered directly by the CAR. In particular, some are hoping that boundary maps from the CAR will facilitate the land titling processes. This may also explain registration's impact on deforestation for certain size classes, because the land titling process is also facilitated by avoiding environmental infractions. Our findings highlight the need to pay attention to the interaction of policies and incentives that can produce "sweet-spots," strategic leveraging, and other combinatory effects. Our results suggest that under strong incentives, environmental registries have the potential to reduce deforestation, but without such incentives, their effect on deforestation behavior is neutral. The registry's value for forest conservation depends primarily on the usefulness of the data for future enforcement of environmental regulations, not as a "fix" in and of itself. This means the trade-off between volume of registrations and legitimacy of registrations must be taken seriously, along with the ways that parallel programs can affect registration incentives. Though self-declared registrations facilitate wider coverage, self-declaration of boundaries under differentiated policy incentives may encourage users to make claims that misrepresent their actual land use or landholdings. This may limit the degree to which the registry can facilitate environmental enforcement. In places where land tenure concerns rival environmental pressures, government and conservation sponsors will need to continue to invest in resolving uncertainty related to land ownership.

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CHAPTER 2

Forest edges in western Uganda: from refuge for the poor to zone of investment

Abstract

Western Uganda is home to growing populations of smallholder agriculturalists, expanding commodity plantations, and protected forests. In this setting, we document a shift in who uses forest edge land and how it is used. In developing countries, protected forest edges are traditionally sites where marginalized people can subsist, but increasing land competition has the potential to change this scenario. We used longitudinal field data spanning two decades to characterize the evolution of landownership and land use neighboring Kibale National Park. The number of households has more than doubled since 1993. Land values are rising, and people buying land near the park in recent years are significantly wealthier and have more off-farm income than those who acquired land there in earlier periods. The reverse is true of renters. More people are growing plantation trees and perennial export crops, especially those with larger amounts of land and capital. Some long-term residents are prospering, while others are squeezed onto ever smaller pieces of land and opting for precarious rental arrangements as land competition increases. We discuss the implications of this transition to a wealthier, more unequal park neighborhood, both for conservation and local livelihoods.

1. Introduction

The boundaries of tropical forest parks often mark areas where poor people subsist on economically marginal land (Naughton-Treves et al., 2005). However, as economies and populations grow and physical infrastructure more tightly links remote places to international and urban demand, competition for historically marginal land increases (Lambin & Meyfroidt, 2011). Land competition can lead to *land user change* as some groups compete more successfully, encompassing shifts in the types of people owning, renting, managing, or otherwise using land. Land cover change can result from land user change if new land users have different assets, constraints, or agendas, and if existing users are displaced such that they change the pressure on land elsewhere. If the kind of people using land around protected forests changes from marginalized populations to households who are relatively better off, land cover around protected areas may also change. When land competition increases, do protected forests get a new kind of neighbor and are long-term residents displaced? Does a change in land *users* lead to change in land *use* around the park? The stakes are high for forests and for forest-dependent people.

1.1 Changing livelihood dynamics around protected forests

In the tropics, protected areas often geographically coincide with poorer people, producing the “poor people - rich forests” scenario (Peluso, 1992). The causality of this relationship has been much debated (Naughton et al., 2011). Many studies show that parks can create or exacerbate poverty when they displace people or cut off access to resources. However, parks are also associated with poverty because both parks and the rural poor find room on economically marginal land; parks are typically found in remote places less suitable for

agriculture where land is cheap and more accessible to the poor (Joppa et al., 2008, Zommers & MacDonald, 2012). Crop loss to wildlife is a special concern around parks in the African tropics, especially where elephants abound (e.g. Vedeld, 2012). Yet, even when parks themselves cause nearby land to be marginal for agriculture (e.g. through risk of crop damage), this makes land near parks cheaper and thus more accessible to the poor (Naughton-Treves, 1997). At the same time, poorer people may be attracted to park edges because they benefit from forest resources (Byron & Arnold, 1999, Angelsen & Wunder, 2003, Naughton et al., 2010) or income from integrated conservation and development projects, forestry, or tourism (Wittemyer et al., 2008, Sims, 2010). Whether they find room near parks when they cannot compete for better land elsewhere or are attracted there by pro-poor opportunities, poor households are often disproportionately represented at the edges of protected forests.

The role of the forest edge as a haven for the poor may not last. Where populations or economies are growing rapidly, the value of formerly marginal land may rise faster than the incomes of the people currently using it, especially as land becomes scarce. If park edges become frontiers for migration (Wittemyer et al., 2008), the associated population growth may lead to increased land competition. Park-edge land values could also rise if markets get stronger for crops unpalatable to wildlife (e.g. eucalyptus) (Foster & Rosensweig, 2003). Furthermore, if park-edge land values start rising rapidly, then land itself attracts investment from those with extra income. Land is an especially attractive investment when imperfect financial institutions limit other opportunities for investment (Shackleton et al., 2001). In sum, growing land scarcity together with lucrative markets for inedible perennial crops could make cheap land around parks more attractive to land investors (Jayne et al., 2014).

In addition to the livelihood concerns raised above, land dynamics surrounding protected areas are also important for biodiversity conservation. Protected areas are an important strategy for maintaining forested areas and the species that depend on them, especially in regions with high potential for agriculture or other land uses (Naughton-Treves et al., 2005). Yet while they are generally effective at slowing habitat conversion within their boundaries, tropical parks are becoming isolated leaving biodiversity more vulnerable to climate change or other threats (DeFries et al., 2005, Hall et al., 2009). Sharp park edges are especially evident in the highlands of East Africa, where deforestation rates have soared in past decades (Oluka, 2014, Twongyirwe et al., 2015). A shift toward wealthier land users around protected forests may mean intensified land use at the park edge and a displacement of poorer land users to land still unclaimed and unprotected. Alternately, wealthier neighbors growing non-edible crops could mean less extraction from natural forests and less wildlife conflict. As has been documented at broader scales, the impacts of increasing wealth on forests can work in multiple directions (Foster & Rosensweig, 2003, Rudel et al. 2005, Alix-Garcia et al., 2013).

1.2 Study site: Uganda's Kibale National Park

The area around Kibale National Park in Western Uganda is an apt microcosm for examining the dynamics associated with increasing land competition around protected forests. The park has high conservation value; e.g. it boasts one of the highest primate densities in the world (Chapman et al., 2005). Its tropical pre-montane climate and fertile volcanic soils favor rain-fed agriculture, and several commercial tea plantations neighbor the park. The park attracts high-paying tourists and forest researchers, and the government is investing in the tea industry and improvements in local infrastructure. Meanwhile, many smallholder farmers also own and

use land bordering the park. Like other East African highland sites, population density around Kibale is high: ~ 300 people/km² (Hartter, 2010), and growing at a rate of over 3% per year (Naughton-Treves et al., 2007). Recent decades have been marked by rising household incomes and declining forest cover around Kibale (Naughton-Treves et al., 2011). Today, little closed canopy forest remains outside the park boundaries (Southworth et al., 2010). These local trends mirror the rapid economic change and deforestation found elsewhere in Western Uganda and the East African highlands (Plumptre, 2002).

In the 1960s and 1970s, local chiefs gave or sold land immediately adjacent to Kibale forest to poor immigrants, thereby buffering their communities' farms from wildlife (Naughton-Treves, 1997). Migrant agriculturalists arrived from land-scarce regions and often worked on nearby tea plantations before purchasing cheaper land near the park and resuming independent farming activities (Mulley & Unruh, 2004, Hartter et al., 2015). Land has been bought and sold at least informally in Western Uganda since the 1960s (Chimowu & Woodhouse, 2006, Hartter et al., 2015), and the Ugandan government has promoted the transition from customary to market-based freehold tenure (Deininger & Mpuga, 2002). At present, the overwhelming majority of households using land around Kibale acquired their land through market transactions, through inheritance from parents or kin, or through formal or informal rental agreements. In this study, we examine how the socioeconomic characteristics and land use patterns of households have changed among households acquiring park edge land through these different means.

1.3 Study Objectives

We use longitudinal field data to explore park-edge land use dynamics in a region of rapid population growth and economic development. Specifically, we aim to: 1) document who

is buying land, 2) compare land use practices of recent buyers and other residents, and 3) track changes in the value of land near the park. Our results shed light on demographic and land cover transitions associated with economic growth and land competition in formerly low-value lands, and suggest ways that forest-people relationships may be changing around protected areas in the East African highlands and elsewhere in the tropics where high biodiversity, historically cheap land, and rapid growth coincide.

2. Methods

2.1 Study Design, Focal Area, and Timing

Our study offers an unusual opportunity to draw on detailed data spanning a generation, to provide insight about trends in land use and ownership (Guyer et al., 2007). Additionally, our study design triangulates information from household surveys, land-cover transects, property maps, landholding inventories, and employment histories, thus providing a robust view of property dynamics within this region (Jick, 1979). Multiple methods and extended repeated site visits for fieldwork (over a year in 1993, 4 months in 2011/2012 and 2 months in 2015) improved validity of information and helped to gain a better understanding of land use decisions.

Our focal area is set in agricultural land bordering Kibale National Park where 60 original transects were established in 1993 in 5 hamlets to study crop-raiding by wildlife²². In each hamlet, transects were spaced 50m apart extending perpendicularly from the park boundary into neighboring agricultural land. The small hamlets are located in 3 wards: Kanyawara (containing

²² Socio-economic conditions vary along the 766 km² park (Naughton-Treves, 1997, Hartter, 2015). Because these sites are located in the quadrant of the park nearest the city of Fort Portal, the land dynamics we document are most likely representative of those where protected land occurs near greater development pressure.

the hamlets of Kanyansohara and Kabucikire), Rurama (containing Kyakiheka and Kijonjomi), and one hamlet in Nyabubale (Figure 1). The transects extend a quarter to a half kilometer from the edge of the park²³. In 2011 we re-established the 1993 transects using landowner maps, natural landforms (e.g. streams), and roads for reference. Two members of the 1993 research team helped to maintain consistency in location and methods. We used the area under transects in both time periods to measure crop types, map landholdings, and survey land users. In this region, agricultural field sizes are frequently as small as 20m on an edge and often intercropped. Field mapping allowed us to document highly heterogeneous cover such as newly planted tea intercropped with maize, or 30 Eucalyptus seedlings in a fallow. In 1993, transects were walked at the beginning of each of the year's two planting seasons to map the distribution of crop types. Crops were recorded every 10 meters for the 25m on either side of a transect. All crop types (e.g. maize, cassava, 1 year-old fallow, etc.) were mapped along transects in 2011 and 2012, and transect cover maps were updated in July 2015 using broader categories of land cover: food crops²⁴, brewing bananas, fallow, pasture, natural forest, and the four main perennial inedible crops - Eucalyptus, pine, tea, and coffee. Thus, we calculate crop cover on the transects as presence or absence of a given crop on a grid with a 10x25m resolution and measure changes in frequency of cells containing each category of land cover in 1993 and 2015.

In both time periods, we mapped parcels and recorded owners of individual fields to track changes in people using land on the transects. For socioeconomic data, our unit of analysis is the

²³ When the transects were first established in 1993, they covered practically all locations where agriculturalists were living immediately adjacent to the park in the park's northwestern quadrant; since that time, intervening areas have been cleared.

²⁴ Includes annual food crops along with sweet and edible bananas

household²⁵. The inclusion criteria was owning or using land that was part of a parcel that intersected the transects in 1993, whether or not the household was located on that land. This identification was possible because our research assistants were members of the communities in question and aware of absentee owners and rental arrangements. Further, because our research assistants traversed farms weekly to monitor crop raiding (separate study) they regularly encountered people working in their fields. Our 1993 maps of land users allowed for backtracking and triangulation when creating the more crowded and complicated maps of 2011 and 2015 land users by providing a point of reference and credible authority when seeking village participation in updating the maps²⁶. Household surveys of associated land users were conducted in each period to document socioeconomic characteristics of land users. Surveys were conducted by a team of research assistants in respondents' local language. We surveyed all households possible in the five sites over a period of 6 months in 1993 and 2 months in 2015²⁷. In total, we collected household surveys for 54 of 63 mapped land users in 1993 and 129 of 153 mapped land users in 2015. Non-response bias leans toward under-sampling of wealthier absentee owners.

²⁵ We defined a household as a group of people sharing a compound: people living in two different households are counted separately and people living in the same household are counted together, regardless of familial relationships.

²⁶ For example: "Who is using the land that Katuramu once owned next to Okwilo's place?" yields better information than "Who owns this land?"

²⁷ Pilot survey work and initial parcel mapping were carried out over 4 months in 2011.

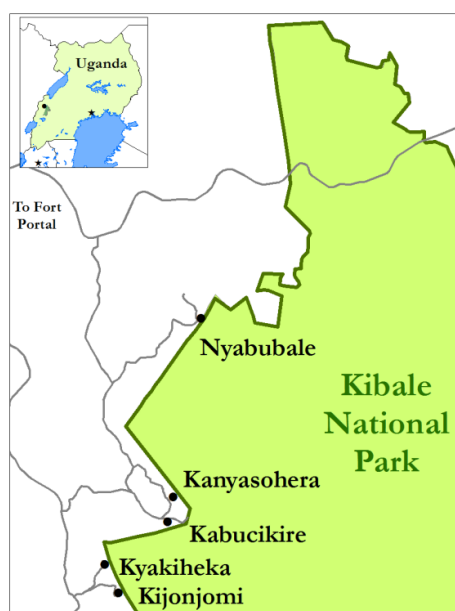


Figure 1. Map of the Study Region. Location of Kibale National Park and 5 park-edge sites where transects are located.

2.2 Comparing new and existing land users

The 1993 surveys and 2015 surveys were not identical but shared questions that allowed for broad cross-sectional comparison of variables like household size, and basic indicators of wealth, off-farm employment, and landholdings. We also examined more detailed socioeconomic characteristics of land users in 2015, and used 1993 landholder maps to help assign 2015 land users into categories. We defined “recent buyers” as households who have purchased land on the transects since 1993 (even if they already owned other land on the transects). We defined “current renters” as those renting or using land on the transects who do not own other parcels on the transects (though they may own other parcels elsewhere)²⁸. “Legacy households” are those using land on the transects that they already owned in 1993 or that they

²⁸ We defined rental arrangements as households using land belonging to other households, with no expectation of future ownership rights to that land. Often this does not mean that households actually pay rent - “using freely” on a temporary basis is common, as is payment in crops rather than cash.

have since inherited from their parents (or other relatives) - they haven't bought any additional land. By these definitions, there are 47 recent buyers, 23 current renters, and 83 legacy households²⁹. Our aim with these categories was to separate the people recently choosing to invest in park edge land from those who made that decision in decades past under different economic circumstances. We compared socioeconomic characteristics (defined in Table 1) among these groups to test for significant differences between recent investors and legacy park neighbors. Variables of primary interest are landholdings, wealth, off-farm employment, and education of head of household as these are proxies for investment capital and human capital. We used binary measures of many variables to minimize the influence of outliers. To account for patterns associated with generational turnover among existing land users, we included additional demographic factors: household size and age of household head, which are often associated with land use decisions through household lifecycle processes (de Sherbinin et al. 2008)³⁰.

Table 1. Socioeconomic characteristics examined for 2015 land users

Characteristic	How Measured
area of land owned	binary: recorded whether total land owned surpassed one hectare (2.5 acres) based on respondent's estimates (as per previous studies, e.g. Naughton-Treves et. al., 2011).
wealth indicator	binary: turns to 1 if HH had either a brick house, a cow, > 5 goats, or > 2 pigs. Livestock thresholds based on 90 th percentile in distribution of the data.
off farm employment	binary: used coded version of employment histories to indicate whether a member of the household had off-farm employment at some point during the previous 5 years.
high off-farm income	binary: defined as off-farm income of more than 100\$ a month (within the past 5 years) as reported in employment histories.
household size	number of people currently living in the respondent's primary house
household head educ.	max year of schooling reached by household head
household head age	age of head of household

²⁹ We were able to survey 32/47 recent buyers, 22/23 renters, and 75/83 legacy households. The under-sampling of recent buyers may mean that some socio-economic characteristics are underestimated for this group, since it was especially difficult to sample wealthier absentee owners.

³⁰ In land use prediction models, age and age² are often used to describe a nonlinear relationship in which very young and very old households are at a different stages than households in their prime working years.

2.3 Socioeconomic predictors associated with new land cover types

To explore the extent to which changing land cover types near the park may be associated with changing land user types, we examined the socioeconomic predictors of planting the crops that increased most notably on the transects between 1993 and 2015 - plantation trees and perennial export shrubs (as opposed to annual food crops). We used logistic regression to test how “recent buyer” status affects the likelihood of planting these alternative crops at the household level, both in a basic model controlling only for site, and in a fuller model with other socioeconomic covariates described in Table 1 (Equation 1). We ran separate models predicting plantation trees, export shrubs, or any combination of perennial inedible crops; the outcome is binary based on whether each surveyed household plants the crop of interest on any of their landholdings³¹. We excluded renters from these models— no renters planted inedible perennials. We used robust standard errors and include a dummy variable for each ward (Kanyawara is the reference group) to control for any potentially omitted site-specific geo-historical factors.

Eqn 1: Grow Inedible Perennial Crop [Type X]_h = β_1 *Recent buyer_h + β_2 *Land_h + β_3 *Wealth_h + β_4 *Off-farm Emp._h + β_5 * High Off-farm Income_h + β_6 * Household Size_h + β_7 *HH Edu._h + β_8 *HH Age_h + β_9 *HH Age²_h + β_{10} * Nyabubale Ward_h + β_{11} * Rurama Ward_h + β_0 + ϵ

We present the results of the quantitative models of factors associated with planting decisions, as well as respondents’ qualitative responses to the question “Why do (or don’t) you plant eucalyptus / pine / tea / coffee? ”. We use both angles to shed light on constraints around planting alternative crops and the extent to which households consider these crops as investments vs. crops to plant for lack of other options.

³¹ Buyer status is based on households’ transect land, but the land cover outcome variable is based on survey data and can include landholdings not on the transects.

2.4 Modeling Rising Land Values

Land values in the study area were calculated based on information collected from our 153 surveys in 2015. Respondents were asked how and when they acquired all land parcels that they use (including parcels not on the transects), and in cases where land was purchased, they were asked to report the year of transaction, the price they paid, and the estimated area of the parcel. The final data set included 64 observations³² of land transactions spanning the decades from 1985-2015. To correct for the effect of significant monetary inflation in Uganda during this period, prices were divided by a consumer price index produced for Uganda (IMF, 2014). This deflates nominal prices to real prices, normalized to a base year of 2005/2006. Prices were then converted to US Dollars using the 2005/2006 exchange rate of 1 USD = 1,810 UGX. To detect whether land values are changing over time, we used a simple OLS regression model:

Eqn 2: $\ln(\text{price per acre}) = \beta_1 * \text{Year} + \beta_2 * \text{Nyabubale Ward} + \beta_3 * \text{Rurama Ward} + \beta_0 + \varepsilon$

where log-transformed price per acre is a function of transaction year, controlling for potential differences in wards (Kanyawara ward is the reference group). In one version of the model, year was measured as a continuous variable. In a second version, year is measured as a categorical variable separated into 5-year increments, in case of a nonlinear relationship between time and land values during the study period. β_0 is a constant term and ε is an error term using robust standard errors. If land values are rising, the coefficient on the year variable(s) should be positive and significant.

³² Of the 370 parcels that respondents reported using, 175 were purchased (vs. inherited, rented, or used under other arrangements). We dropped transactions affiliated with “commercial plots” (small roadside strips in commercial centers, n=20) to focus primarily on agricultural land, as well as transactions with incomplete information on price, year, or area (n=87). Many respondents did not remember at least one of these parameters or did not know because they were not party to the transaction. Of the 68 observations with complete data, 95% of reported transactions yielded per-acre values substantially lower than \$5,000. We excluded four implausible outliers where reported transactions yielded per-acre values > \$20,000.

3. Results

3.1 Changing land users and land use arrangements

In the last two decades, the number of households affiliated with park edge land has increased, but the nature of affiliations between households and land has become more complicated. Between 1993 and 2015, the number of households using land intersected by our transects went from 62 to 153 - an increase of about 250%. However, average household size has decreased (from mean of 6.8 to 4.6 members, $p < .001$ in an unpaired t-test with unequal variances)³³, and instances of absentee ownership and rentals have become more common. One third of 2015 households are the grown children of 1993 respondents who have started their own households on their parents' land. Intra-family land sharing arrangements vary. In some families, children are “given boundaries” within the family land once they start their own household, which means the parcel essentially splits and they have the right to sell the land and make decisions about planting more permanent crops. In others, the older generation retains selling and permanent cropping rights³⁴. Rental arrangements between unrelated households increased from ~7% of transect households in 1993 to ~16% in 2015. Use of multiple land parcels also became more common. In 1993, 25% of surveyed households reported owning a parcel elsewhere, while in 2015, 40% report owning another parcel and 78% report either owning or using another parcel (including rented and family land). In 2015, parcels on our transects frequently had no house on them; they were part of a land portfolio affiliated with households sited elsewhere in the village

³³ Some of the decrease may be related to household lifecycles. Many households settled the land near the park edge in waves in the 1970s as young adult migrants seeking land and employment (Hartter et al., 2015). As children of these households begin to start their own families, household sizes decline.

³⁴ There is variation from family to family in the way intra-family land rights and inheritance are negotiated. Several older respondents reported that they did not want to “show boundaries” to their children because then the children might sell their parcel for quick cash and then move back on to the family land when they got into financial trouble, increasing pressure on a shrinking land base. Some even talked of forbidding that family land be split or sold after their death, on penalty of haunting children who defied their wishes.

and as far away as Fort Portal or Kampala. This was particularly true for parcels immediately bordering the park. By 2015, the traditional situation of a household living and farming on a single parcel of land has become more the exception than the rule in this site.

As a group, land users at the park edge have become wealthier but also more unequal. In the 1993 household survey, having a metal roof instead of a grass roof was an indicator of wealth. In the intervening decades, the proportion of households living under grass roofs dropped from 54% to 2.5%, while the proportion hiring others to work for them at least occasionally rose from 5% to 30%³⁵. Wealthier households in 2015 owned brick buildings, motorcycles, and cars - things that were extremely rare or nonexistent in 1993. Yet, some of the changes between 1993 households and 2015 households are associated with turnover in land users rather than just changing circumstances for existing land users and their families. The majority (67%) of households in 1993 have sold at least some of their land near the park³⁶, though they have often stayed in situ on smaller plots. As for those who have bought, socioeconomic characteristics of households that have come in or expanded their park-edge holdings since 1993 are significantly different than households using park-edge land through legacy (see Table 2). What's more, the direction of these differences flips, depending if new users have purchased or are renting the land near the park. Recent buyers are wealthier and own more land compared to legacy households, while the inverse is true of renters. Recent buyers also have more years of education, are more

³⁵ Livestock ownership was relatively constant, though the average number of goats decreased somewhat and was offset by an increase in pig ownership.

³⁶ The timing of sales and circumstances around selling were quite variable and the sample size of 1993 owners is small for testing the many dimensions associated with this outcome, which limits our ability to measure displacement that may have already occurred. There is no clear evidence that households that were poorer in 1993 were more likely to sell. Our evidence can only point to the fact that poorer households (and their heirs) are no longer able to buy.

likely to have had recent off-farm income (during the past 5 years), and much more likely to have had *high* off-farm income (over 100 USD per month) than legacy households. Though recent buyers are not all newcomers to the region (~ 25% are children of legacy owners and ~ 60% had a head of household born within the sub-county), systematic differences between the types of households buying land today and those who acquired it earlier indicate that constraints and agendas associated with park edge land use may be changing.

Table 2. Comparing incoming households vs. legacy owners (including heirs)

	Recent buyers	Current Renters	Legacy HHs	Overall ^c	Group means are sig. different? ^a	2-way Difference (buyers vs. legacy) ^b	2 way Difference (renters vs. legacy) ^b
Own >1 ha	63.4%	13.6%	39.7%	42.5% (n=141)	Y ***	23.7%**	-26.1%**
wealth indicator	58.1%	13.0%	31.3%	31.0% (n=146)	Y ***	26.9%***	-18.2%
off farm income in past 5 years	81.4%	52.2%	51.2%	60.3% (n=146)	Y **	30.2%***	0.9%
high earner (from off-farm income)	62.8%	8.7%	16.3%	28.8% (n=146)	Y ***	46.5%***	-7.6%
household size	4.8	4.6	4.4	4.6 (n=129)	N	0.4	0.2
household head edu	6.7	4.0	5.3	5.4 (n=129)	Y **	1.4*	-1.3
household head age	39.7	40.1	43.9	42.2 (n=129)	N	-4.1	-3.8
have any inedible perenn. crops	57.4%	0%	51.9%	45.8%	Y ***	5.6%	-51.9%***
have tea or coffee	38.3%	0%	22.9%	24.2%	Y ***	15.4%*	-22.9%***
have plantation trees	42.6%	0%	45.8%	38.6%	Y ***	-3.2%	-45.8***
<i>num obs</i>	47	23	83	153			

^aTest for equal means using Fisher's Exact test in the case of the first four binary variables and one-way analysis of variance for the last three continuous variables.

^bSignificant differences for two-way means comparisons were calculated using Fisher's Exact test in the case of the first four binary variables and unpaired t-tests for the last three continuous variables. Probabilities that means are equal are indicated with the following symbols: * : $p < 0.1$, ** : $p < .05$, *** : $p < .01$

^c The total number of households differs because for some variables we obtained information from other sources about households that we were unable to survey. Sample size is 129 otherwise.

3.2 Changing land cover

Land cover change was marked by an increase in Eucalyptus and perennial investment crops, a decrease in fallow land, and the disappearance of brewing bananas and natural forest. The extent of food crop production remained relatively stable (Fig 2, Supplementary Table 1). In 1993, households tended to plant annual food crops on the parts of their parcels furthest from the park boundary. Intervening land was often fallow or planted with bananas for brewing beer. Brewing banana was one of the most abundant land cover types near the park in 1993 but the crops were decimated in the intervening years by a banana weevil. In 1993, natural forest extended beyond the park boundary in several places, on steeper land, in ravines or wetlands. The land that formerly hosted brewing bananas and natural forest has largely been converted to perennial investment crops, particularly Eucalyptus and tea. Eucalyptus was present in 1993 only as sporadic trees marking parcel boundaries but by 2015 it covered >20% of park-edge land. Tea was also completely absent on the smallholder land in the study sites in 1993 but tea now covers 10% and has nearly doubled in the past five years alone³⁷. Coffee has expanded to a lesser extent, while smallholder woodlots of pine still exist in the same low proportions. The prominence of different types of inedible perennial crops varied by ward, but in combination, these alternative crops increased on land near the park in all sites, from essentially 0% to between 15% and 50% (Table 3).

³⁷ Tea area was also canvassed on the transects in 2011 - at that point it occurred in 5% of cells.

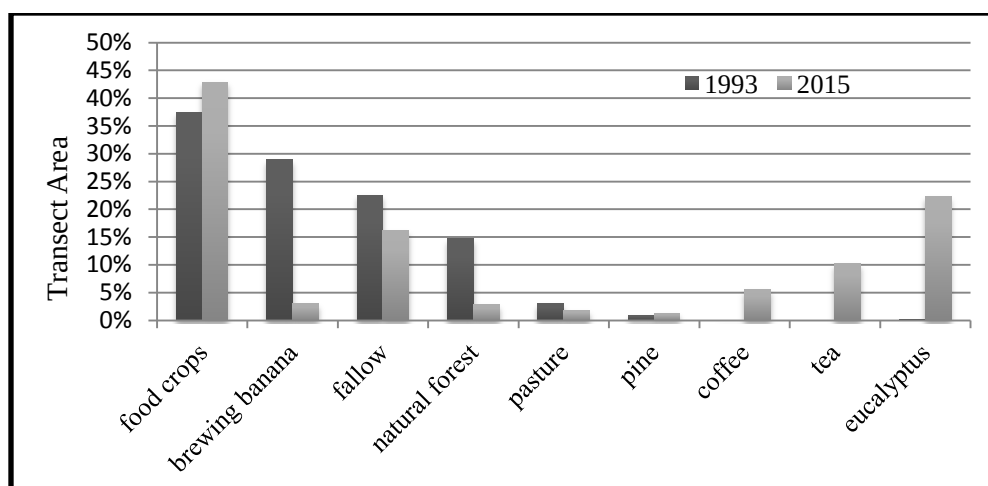


Figure 2. Changes in Land Use at the Park Edge. Coverage based on crop-mapping in 1993 and 2015 along transects in 5 hamlets: ~100 total ha of smallholder land within 0.5 km of the park boundary.

Table 3. Crop coverage on transects broken out by year and ward

	Ward I: Kanyawara			Ward II: Rurama			Ward III: Nyabubale			All Wards		
	2015	1993	Diff	2015	1993	Diff	2015	1993	Diff	2015	1993	Diff
any inedible perenn. crops	54%	2%	53%	31%	0%	31%	16%	0%	16%	39%	1%	38%
<i>eucalyptus</i>	35%	0%	35%	15%	0%	15%	6%	0%	6%	22%	0%	22%
<i>pine</i>	2%	2%	0%	1%	0%	1%	0%	0%	0%	1%	1%	0%
<i>tea</i>	17%	0%	17%	3%	0%	3%	4%	0%	4%	10%	0%	10%
<i>coffee</i>	1%	0%	1%	12%	0%	12%	8%	0%	8%	6%	0%	5%
<i>other</i>	0%	2%	-2%	1%	0%	1%	0%	0%	0%	0%	1%	-1%
food crops	25%	32%	-6%	64%	51%	13%	56%	36%	21%	43%	37%	5%
fallow	14%	27%	-13%	10%	19%	-9%	26%	18%	8%	16%	23%	-6%
brew. banana	1%	14%	-13%	5%	38%	-33%	4%	48%	-44%	3%	29%	-26%
pasture	0%	0%	0%	8%	1%	7%	0%	11%	-11%	2%	3%	-1%
natural forest	6%	27%	-22%	0%	3%	-3%	0%	2%	-2%	3%	15%	-12%

Respondents in 2015 offered a variety of reasons for their decisions to plant inedible perennial crops. At least half said they chose to plant one of these crops because they are not eaten by wildlife. People also talked about perennial crop options as though they were interest bearing accounts. In the case of Eucalyptus, many people appreciated the fact that it had several markets, which gives flexibility in the timing of sales and provides some robustness against

fluctuating prices in any given market. “I can use [Eucalyptus] after 3 years for firewood at home or sell to local traders, I can sell it at age 5 to brick makers or for poles for construction, between 5 and 10 years I can sell it to UMEME (Uganda government body in charge of rural electrification that uses Eucalyptus for utility poles), and after that I can sell for timber” (female legacy owner, Kabucikire). People also liked Eucalyptus because it yields large cash sums at once, and several landholders said they use Eucalyptus to pay school term fees or keep it as a buffer in case of a health crisis. Tea has a different investment profile: it requires the most money to establish and maintain, but it pays more regularly once established, yielding income from harvested leaves every ~2 weeks according to season. “I chose tea because of animals, and I wanted to invest in tea because when I stop working, it will get me school fees. Tea is a good crop to plant when you have money because you use money planting and when it's harvesting time, you don't use much money you just sit and eat your cash” (male recent buyer, Kanyansohara). Not having enough land or money were the most common reasons given for not planting any inedible perennial crops.

Our quantitative survey data supports respondents’ qualitative explanations regarding which land users are in a position to plant these alternative crops (Table 4). As a group, inedible perennial crops are more likely to be planted by households with more land, education, wealth, and off-farm income. These are the same factors that are significantly higher for recent buyers (Table 2). Interestingly, when controlling for these signals of being better off, being a recent buyer is only significantly positively associated with planting export shrubs, while it is significantly negatively associated with growing plantation trees. Plantation trees are more common for older households with larger landholdings. Having current or recent off-farm employment is not a good predictor of inedible perennial crops and actually trends toward lower

likelihoods of planting them, unless off-farm income is high. Higher levels of education and higher levels of wealth or income increased the likelihood of planting all types of inedible perennial crops. Eucalyptus was planted by 40% of recent buyers and 44% of legacy households, while tea was planted by 23% of recent buyers and 12% of legacy households. Renters never plant tea or investment crops on rented land, but landlords sometimes do. Renters are encouraged to clear land, work the soil, and keep the weeds down - this provides free labor while Eucalyptus, tea, or coffee seedlings are getting established. Once seedlings are large enough to shade out food crops, renters have to find another site to use. This arrangement was reported in all of our study wards.

Table 4. Predictors of planting inedible perennial crops - (logistic regressions among 2015 land owners)^a

	have any inedible perennial crops		have tea or coffee		have plantation trees	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	basic	full	basic	full	basic	full
Recent Buyer (reference is legacy HH)	1.26	0.35	2.23*	1.07	0.92	0.14**
Owns >1 ha		4.98***		2.05		6.67***
Wealth indicator (livestock & housing based)		2.16		2.67*		1.78
Off farm emp. in past 5 years		0.97		0.73		0.82
High earner (>100 USD / month)		3.38*		2.71		4.80**
Household size		1.14		1.12		0.98
Household head education		1.12*		1.17**		1.13*
Household head age		1.14		1.24		1.20*
Household head age ²		0.999		0.998		0.998
Ward (reference is Kanyawara)						
Nyabubale	0.67	0.20**	3.16*	1.88	0.8	0.27*
Rurama	0.78	1.05	1.39	2.4	0.48*	0.59
<i>num obs</i>	130	107	130	107	130	107
<i>model psuedo-r²</i>	0.01	0.29	0.04	0.28	0.02	0.33

^a Models are based on Equation 2 and use robust standard errors. Models are only for land owners - renters are excluded because they predict failure in the outcome variable(s) perfectly. Cells contain coefficients expressed as odds ratios - for example, the coefficient of 1.26 in the top left cell can be interpreted as “holding the other factors constant, recent buyers are 1.26 times as likely to plant perennial crops compared to legacy households.”

Significance of coefficients are indicated with the following symbols: *: $p < 0.1$, **: $p < .05$, ***: $p < .01$



Figure 3. A Rise in Eucalyptus. A member of the field research team (F. Mugurusi) stands on a hillside property in 1993 and 2011 - the natural forest fragment and brewing bananas in the background have been replaced with eucalyptus.

3.3 Rising Land Competition

In conjunction with increasing numbers of affiliated households and wealthier recent buyers, we found signals of increasing land competition in rising land values around the park. Based on respondents' reported land transactions during the past 3 decades, we found that time is positively and significantly correlated with land values, even after using a price index to account for inflation in Uganda during this period. Controlling for site, if one assumes a linear increase, per-acre land values have been increasing in value at a rate of about 3% per year (Table 5). The increase has been steeper in recent years; between 2010 and 2015, per-acre values rose 25% per year. In 2015, residents described the local land-market as ever more expensive and even subject to land speculation, e.g. "one can buy land at 5 million shillings today and turn around and sell it tomorrow at 6 million shillings" (recent buyer, Kanyansohara).

The intensifying land market is differentially affecting households. One long-term resident spoke of plans to move to the opposite side of the park, away from the regional capital of Fort Portal, the tea estates, and the park research and tourism infrastructure, where land was reportedly still cheap. She was worried that their present inherited parcel was too small to leave for their several teenage children and land in the study site was too expensive for her children to buy more. In contrast, the 30-year old nephew of this household who also inherited a small parcel nearby has purchased more than 5 additional pieces of land from his relatives and neighbors using income from jobs with the Ugandan government. He grows food crops on the land he still shares with his family and land that he rents away from the park, and has planted Eucalyptus and tea on the other parcels. Another recent buyer moved to the area to work in the management of the park's biological research station. He owns considerable land in several locations immediately neighboring the park, which he prefers because it is cheaper. He purchased some of the land in large pieces from earlier investors who wanted to shift sites, and acquired other land bit by bit from families who came to him to trade land for cash to pay for school fees, health care emergencies, prison fines, etc. He plants his land in tea or Eucalyptus or rents it out. Meanwhile, households who no longer have enough land for crops (through splitting with inheritance or selling and cashing in) are renting land from others, often in clusters from the large landholders. Near one of our sites, there is a 25 ha parcel of land where at least 48 households rent plots for food crops. It is owned by a retired government employee who is in the process of establishing a Eucalyptus plantation there and is collecting rent in the meantime. In the words of one wealthy respondent who had also recently bought two pieces of land near the park and planted Eucalyptus: "the area is booming, but I feel bad for the people without cash – they are falling behind."

Table 5. Changing Land Values from Transactions Reported by Respondents Since 1985

OLS regression on ln(price per acre)	Model 1 full sample	Model 2 since 2010	Model 3 categorical
Year [Continuous]	0.03 *	0.25 *	Year [Category]
			1985-1990 0.00 (base)
			1990-1994 0.49
			1995-1999 0.68
			2000-2004 0.59
			2005-2009 0.70
			2010-2015 0.86 *
Site			Site
Kanyawara Ward	0.00 (base)	0.00 (base)	Kanyawara Ward 0.00 (base)
Nyabubale Ward	-0.15	-0.62 **	Nyabubale Ward -0.13
Rurama Ward	-0.29	-0.17	Rurama Ward -0.26
num obs	64	23	64

Price is log-transformed, so coefficients can be interpreted as a percent change in price, i.e. price per acre increases 3% per year over the full time range, but 25% per year since 2010. For the categorical version of year, the interpretation is the percent change compared to the reference category of “1985-1990”. Models use robust standard errors and * = $p < .10$, ** = $p < .05$, *** = $p < .01$

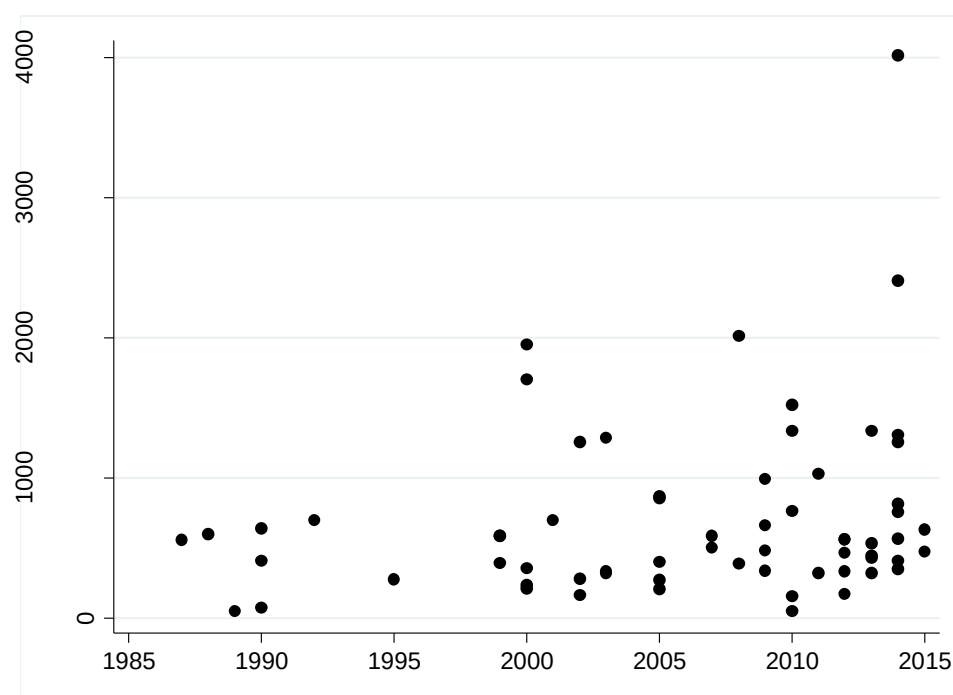


Figure 4. Reported land values around Kibale National Park, 1987-2015. Prices are divided by reported acreages, adjusted with an IMF consumer price index using a base year of 2005-2006 to account for inflation, then converted to USD based on the 2005-2006 exchange rate of 1 USD = 1,810 UGX.

4. Discussion

In regions of rapid economic and population growth, land competition and markets for alternative crops may be changing who is using land around protected areas and what the land is used for. Our study site illuminates how the context around protected forests can change from a more conventional case of poor people abutting rich forests to an area of increasing investment. We document a shift toward wealthier park neighbors planting perennial investment crops while subsistence agriculture persists on increasingly smaller parcels and on rented land. Land dynamics in these sites along Kibale National Park's northwestern edge are conditioned by presence of crop-raiding wildlife, active land markets, and their location near off-farm employment opportunities (e.g. tea plantations, park headquarters for research and management, and Fort Portal). Crop-raiding wildlife are a special circumstance of park edges, but mounting land competition and emerging land markets are commonplace in East Africa and elsewhere in the developing world (Jayne et al., 2003, Holden et al. 2009, Lambin & Meyfroidt, 2011). In places where crop-raiding by wildlife is less of a problem, different relative values of inedible perennials and food crops may shift land use in other directions, but our results support the idea that changes in the circumstances of existing land users and turnover in land users with land markets can both lead to changes in land cover. In this case, land cover at the park edge shifted toward perennial inedible crops, partly associated with wealthier recent buyers (in the case of export shrubs) but also associated with wealthier legacy households (in the case of plantation trees). This shift has implications for land cover trajectories and connectivity around parks, socio-political relations between protected area managers and neighbors, and the role of protected forests in the livelihoods of the rural poor.

4.1 Changing land users: who will neighbor protected areas?

In our study site, the people now buying park edge land are primarily wealthier individuals with money to invest, while the same site received more marginalized and land-poor households in earlier decades (Naughton-Treves, 1997, Hartter, 2015). Most recent buyers enjoy relatively well-paying off-farm employment, as teachers, clinicians, government workers, tea estate managers, or with the park itself, for example. Some of these are sons and daughters of 1993 owners who have found good income opportunities; others live nearby or in Fort Portal town and have connections to the park edge through social networks. Many see park-edge land as an investment opportunity. Meanwhile, lower wage earners such as tea pluckers can no longer afford to buy land. For the renters, the park edge continues to represent a place of marginality. Renters are obliged to plant annual food crops, a risky proposition where wildlife, including elephants, abound (Naughton-Treves, 1997). Their condition is made more precarious still by the fact that the owners they rent from are planting eucalyptus and tea seedlings on the very same plot, indicating intent to phase them out entirely. The potential for rising incomes to be accompanied by rising inequality is an important conundrum associated with international development (Ravallion, 2001), as is the divergent potential of off-farm employment (Reardon et al., 2000).

Though protected areas have been criticized for estranging local people from land and resources that they depend on (Adams & Hutton, 2007), the process we are describing is not driven by the park – conditions at the park edge are connected to broader socioeconomic shifts that results in loss of access for some and benefits for others as land competition rises. If anything, the presence of the park may have been slowing this process in the past by making land

at the very edge less desirable for agricultural crops. With the expansion of perennial crops unpalatable to wildlife, there's less to discourage wealthy investment. A potentially promising aspect of the dynamics at Kibale is that legacy households are as likely as recent buyers to plant eucalyptus, and far more so when controlling for wealth. Eucalyptus requires less initial capital than export shrubs like tea and coffee but still generates good returns (Jagger & Pender, 2003), making it possible that eucalyptus could be playing a role in increasing wealth or maintaining land among legacy households. If existing land users are riding the wave of economic development and becoming wealthier themselves, then there is at least the possibility that some pressure is taken off natural forests. However, if new, wealthier land users are competing with existing land users, there is the danger of rising inequality and simply adding to and displacing land pressure. There is no clear evidence of significant displacement as yet, but we document heightened vulnerability for those whose properties are getting smaller with no room for the next generation.

4.2 Changing land cover and expanding investment crops

Near the park's edge, we documented a notable increase in inedible perennial crops, primarily at the expense of brewing bananas, fallow land, and natural forest fragments. The area devoted to food crops has remained relatively constant. This is consistent with remote-sensing based reports of land cover change around the park that note a reduction in forest fragments, an increase in tea, and no clear trend in the amount of land under annual crops (Southworth et al. 2010). It also accords with aerial photo analyses showing an increase in tea and Eucalyptus at the expense of natural forest (Majaliwa et al., 2010). Our field-based methods allow for more

accurate identification of eucalyptus (vs. native trees) and a variety of intercropped fields, thus we detected more change than that reported from remote sensing studies at Kibale.

It is noteworthy that the area of non-food crops is increasing faster than food crops, given the rising number of households at least partly dependent on subsistence agriculture and the growing scarcity of land, though some researchers have predicted that as land parcels continue to be subdivided in East Africa, tree cover will actually rise due to incentives to plant eucalyptus (Patel et al., 1995). In this site, the increase in inedible perennial crops seems to be primarily a sign of increasing wealth and investment. Though inability to plant palatable crops due to wildlife was an oft mentioned factor, people discussed plantation trees and export shrubs more like investments than like last resorts, and they are planted by households that are better-off. With rising demand for fuelwood and other wood products at local and national scales, there are many indications that eucalyptus is becoming more lucrative (Wasake, 2012). According to a Ugandan businessman, “You could invest \$50,000 and in 10 years you’re harvesting trees worth five million dollars. As long as you’re willing to wait for about 10 years for a return on your capital employed, it’s pretty amazing” (Heuler, 2012). So far, except where edge land was rented out, most inedible crops are not replacing land that was used for annual food crops, rather, they’ve replaced fallow lands, forest fragments, and brewing bananas. In the case of brewing bananas, there was no choice but to find a new crop due to a severe outbreak of banana weevil (Gold et al., 1996, Speijer et al. 1994). Farmers’ ability to shift from brewing bananas to alternative crops has been shaped by socioeconomic factors - inedible perennial crops all require longer lead-times before they yield profit and require more up-front costs to establish. This accords with other research showing that assets of landowners strongly influence response to

shocks and new opportunities, and wealthier land users can often access options out of reach to the poor (e.g. Takasaki et al., 2001, Ebanyat et al., 2010). There is now a more marked buffer of inedible crops planted between many food fields and the park. It is possible that this will aid food production, but decreased abundance of fallow land and shrinking parcel sizes suggest potential difficulty in future production of food crops using rotational methods. Eucalyptus is expanding along other Ugandan forest edges, stirring concern that its demands on water and soil nutrients can inhibit cultivation of food crops (Watkins, 2009).

The increase of investment crops around parks has mixed implications for biodiversity conservation. Planting unpalatable monoculture crops (like tea) reduces habitat connectivity if they replace a matrix of inter-cropped rotational fallow farming and forest fragments. But paradoxically, lowering connectivity also reduces crop-raiding by wildlife, a conflict serious enough to lead to de-gazettement of parks elsewhere in East Africa (Pienkowski et al., 1998). The replacement of brewing bananas, a prime raiding target for non-human primates (Naughton-Treves, 1998), with inedible crops may also decrease the likelihood of disease transmission between human and non-human primates (Chapman et al., 2005). Unlike tea, eucalyptus woodlots may serve as viable corridors for some species (Kimambo, *in prep*, DeFries et al., 2007). Wood from eucalyptus may also relieve pressure on natural forests by providing a substitute source for wood products (Ainembabazi & Angelsen, 2014). Tea and eucalyptus plantations are biodiversity wastelands compared to natural forests, but nonetheless these perennial crops slow soil erosion and store carbon (Rudel et al., 2005). Given that some organizations have invested great sums in creating tea buffers around other East African

highland parks (Masozera & Alavalapati, 2004), it is interesting that at Kibale, the transition seems to be happening without formal intervention.

While effects on biodiversity within the park may be ambiguous, natural forest has been largely eliminated outside the park with severe consequences for the region's primate populations, particularly endangered species (Chapman et al., 2005). Many of the fragments cleared beyond the park edge have been converted to small plots of eucalyptus and tea. We are not claiming that growing populations of rural poor do not clear forest, but our results raise the possibility that wealthier land investors are playing at least an equally important role in current land use change near the park. This could happen if wealthier owners are able to use marginal land for harder more capital intensive crops, or if subsistence agriculturalists are displaced by wealthier households onto land elsewhere. The fact that wealthier land owners often use renters to clear and prepare unworked land in initial years before planting investment crops is often missed in remotely sensed analyses of deforestation. Rather than seeing an either-or scenario, we may be seeing a both-and scenario in which particular combinations of population growth, commodity markets, and changing landholder relations together drive local change. A regional-scale study recently reported significant associations between forest loss in the Albertine Rift area and *both* population growth and tea production (Ryan et.al., 2014). Our longitudinal field study contributes to an understanding of the mechanisms that link these factors.

4.3 Land competition and land values

Both interviews and reported transactions reveal rising land values in the study site. Empirical information about land transactions and land values is hard to come by, particularly in

East Africa (Benjaminsen & Lund, 2002, Holden et al., 2009). Though we do not have enough data to control for many factors that affect land price and our information based on recall is imprecise, we nevertheless see evidence of increasing land competition in the fact that inflation-adjusted land values increase over time. Transaction and interview data also agree that land values are rising more steeply in recent years- as much as 25% per year since 2010.

Other research points to land scarcity around Kibale (Hartter et al., 2015). Our study reveals that land pressure has increased not only as a function of population growth and migration of the poor, but also as a result of investment and speculation by wealthier buyers. Several respondents indicated they aim to accumulate land even if they are not yet profiting because they know land prices will rise. Landholdings are seen as an excellent place to invest wages, especially since banks and financial markets are not easily accessible and considered risky. There is a polarized debate among development economists about whether land markets in Africa will help alleviate poverty through market efficiency or further impoverish those who are priced out (Colin & Woodhouse, 2010). In some African countries, land sales are banned because of concern that they will lead to conflict but in others they are promoted as a non-violent mechanism for achieving an optimal land distribution (Berry, 2009, Deininger & Mpuga, 2009). A study in eastern Uganda concludes that land markets can operate as an equalizing force that counteracts inequality in land inheritance practices when farms become too small to be split equally among the next generation (Baland et al., 2007). But the authors go on to caution that if land is used primarily as a savings mechanism, this can lead to increasing inequality in land distribution. In our site, we see evidence that the latter case may be happening.

5. Conclusion

As increasing land competition puts greater pressure on formerly low-value land, the context changes for forest conservation and for the people who have traditionally lived near forests. Land markets, rising values for agricultural commodities (including plantation trees), and opportunities for off-farm income facilitate this transition. The land neighboring Kibale National Park is changing in character, from a place of marginalization to a place of investment opportunity. As such, it is becoming less of a refuge for poorer households, but is also providing more opportunities for households with means to ‘ride the wave’ to commodity production. Where forests with high conservation value occur in regions experiencing rapid development, we should consider the possible implications for forest management and pro-poor land use planning if forest edges become sites attracting investment. Those seeking to understand land and poverty dynamics at park boundaries must address broader socioeconomic processes to reveal causal relationships.

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Chapter 3.

Do households invest non-farm income in rural land in Uganda?

Abstract

Conservationists and development economists look to nonfarm employment for its potential to reduce pressure on rural land. Yet, smallholders often have diversified income portfolios including farm and non-farm activities. Whether non-farm employment leads to land-sparing will depend in part on how often income from non-farm sources is reinvested in farm activities and the extent that investment in land is conditioned by local savings institutions. I examine the impact of non-farm income on land investments by smallholders in Uganda. Specifically, I ask whether non-farm income increases the likelihood that households purchase rural land, and whether this depends on the total amount of non-farm income received annually and the amount received at once. I use publicly available data from the Living Standards Measurement Study conducted by the World Bank and the Ugandan Bureau of Statistics in 2005 and 2010. Analysis thus far shows that at low-levels, non-farm income may pull households away from buying rural land, while in large increments, it increases the chance of investing in land and it may enable some households to break in to agriculture. The fact that the amount received at once matters more than the total amount received annually suggests a potential role for savings institutions in mediating how much households choose to invest in land. I discuss how these results contribute to debates about whether land markets in Africa favor redistribution or land concentration and whether non-farm income takes pressure off land.

Introduction

As resource consumption by the human population continues to climb, so do concerns about future land scarcity. Particularly in tropical regions with fast-growing rural populations, the prospect of increasing land competition connotes regional impacts on food security and social conflict (Jayne et al., 2014), along with global effects on biodiversity and stores of forest carbon (Lambin & Meyfroidt, 2011). Development economists and conservationists alike look to non-farm income as a promising mechanism for relieving pressure on rural land in the tropics (Rudel et al., 2005, Uchida, 2007). Perhaps a stronger non-farm economy can spare land for nature or more efficient production by offering other opportunities for income to rural land users. However, the relationship between non-farm income and rural land pressure could work in multiple directions (Mulley & Unruh, 2004). Non-farm income could potentially *increase* land competition if individuals use such income to purchase land, whether for expanded production or as a savings tool (Baland et al., 2007). This study examines whether non-farm income increases subsequent purchases of rural land in Uganda and explores factors that condition this relationship.

A shift away from land-based livelihoods has occurred repeatedly as nations have experienced economic growth, a phenomenon theorized to be associated with forest transitions (Rudel et al., 2005). However, the ultimate impacts of income changes, migration, and urbanization on land use are attenuated by many factors, and the results for rural land and forests are not obvious (Lambin & Meyfroidt, 2011). In general, increased non-farm income opportunities are predicted to decrease small-holder “pressure” on land by decreasing dependence on farm-based production to meet households’ needs (Ellis & Freeman, 2004). People can also be “pushed” into non-farm sources of income when land becomes relatively

scarce or more difficult to access (Bezu & Holden, 2014, Marenya et al., 2013). Difficulty accessing land, along with more concentrated or more lucrative non-farm income opportunities in cities, is associated with hastening urbanization. Yet, there is not always a clean separation between urban “nonfarm households” and rural “farm households.” Recent work suggests that rural land in sub-Saharan Africa is increasingly owned by urban-based households (Jayne et al., 2015), and non-farm income has long been shown to play an important role in rural livelihoods strategies (Reardon et al., 1998, Haggblade et al., 2010). At the level of the household, then, the effect of non-farm income on demand for rural land is not clear. Do people use non-farm earnings to invest in agricultural inputs (including land), or do they use it to move out of agriculture (Kilic et al., 2009)? A pre-requisite for determining whether economic growth and investment in non-farm sectors lead to land sparing (for conservation) is understanding the relationship between non-farm income and rural land purchases.

In this study, “farm income” encompasses activities that require the household to own or rent land as a factor of production, while “non-farm income” does not. I do not distinguish between income earned in the agricultural sector vs. other sectors (Barrett et al., 2001). Rather, the main distinction is between income a household earns from its *own* crops or livestock and income earned by working for others or through non-agricultural household enterprises. Thus, non-farm income is defined in such a way that it needn’t be related to future acquisition of rural land, at least from a production standpoint. Yet, households commonly pursue diversified livelihood strategies and often engage in a combination of farm and non-farm activities (Barrett et al., 2001, Banerjee & Duflo, 2007, Padoch, 2008). Owning land to grow one’s own food represents an important supplement and safety net for many households (Ellis & Bahiigwa, 2003). Given that livelihood strategies are diverse, non-farm income could increase the odds of

purchasing rural land by providing extra cash to invest in farm activities. Alternatively, it could discourage land purchases by reducing the labor available to work rural land or opening more preferred options. A third mechanism potentially linking non-farm income and rural land is the role of land in household savings and investment (Ray 1998, Zimmerman 2003). Even if a household is not engaged in farm activities, rural land may represent a good place for saving and investing non-farm income, particularly where land markets are active and rural land values are rising (Sitko & Jayne, 2014). Land can also confer social status or political standing (Berry 1989), such that households may desire land for reasons apart from economic strategies per se.

Thus, there is reason to expect that some households earning non-farm income may purchase rural land, but this should vary with the amount of non-farm income. Those individuals paid very little will not be able to purchase land or hire outside labor to tend crops or livestock. Better paid individuals may choose to invest extra income in rural land and hire labor, unless preferable investment options exist. In regions where financial institutions are not well-developed or easily accessible, households struggle to save enough money to purchase land (Reardon et al., 1994, Banerjee & Duflo, 2007). Even if the total amount of non-farm income received over time is relatively high, it may not translate into land purchases if it is paid out in small installments. In this respect, more than the source or the levels of annual income, the size of the non-farm income payments should influence households' odds of using it to purchase land.

I investigate the relationship between non-farm income and land purchases in Uganda, a country experiencing rapid growth in population (3.2% per year) and GDP (5% per year) (U.N., 2015, World Bank, 2014). Uganda's population is still over 80% rural but the percent concentrated in urban centers is growing at 2.1% per year (U.N., 2014). Market-based land

transactions have been occurring at least informally in Uganda since the 1970s and the national government is promoting the transition from customary forms of tenure toward market-based freehold tenure (Deininger & Mpuga 2002, Holden et al., 2010). A study in eastern Uganda concludes that land markets can operate as an equalizing force that counteracts inequality in land inheritance practices when farms become too small to be split equally among the next generation, but cautions that if land is used primarily as a savings mechanism by households investing non-farm income, land-markets can lead to increasing inequality in land distribution (Baland et al. 2007).

In this study, I explore the extent to which households are investing and saving non-farm income in rural land. I examine the impact of non-farm income in 2005 on odds that a household purchases rural land in the next 5 years. I test the probability of land purchases versus presence of non-farm income, the annual amount of non-farm income, and the size of payments of non-farm income, with basic controls for wealth and existing landholdings. My expectation is that higher levels and increments of non-farm income should increase odds of buying rural land. My aim is to learn the point at which income effects outweigh substitution effects and nonfarm activities increase investment in rural land, as opposed to only increasing the opportunity cost of farm activities. I also look at the way that income effects may be attenuated by a savings effect - where the amount of income received at once may matter more than the total amount of income received annually.

Methods

To examine the impact of nonfarm income on households' land purchases, I used nationally representative household survey data from Uganda's publicly available Living

Standards Measurement Study (LSMS), conducted as a partnership between the World Bank and the Ugandan Bureau of Statistics. This survey was conducted as a panel, administered to the same households in 2005/2006 and five years later in 2010/2011. LSMS survey protocol selected enumeration areas with probability proportional to size within a stratification based on rural-urban and regional levels, then randomly selected households within each enumeration area. The survey instrument includes sections on income, consumption and expenditures, health, agricultural activities, land holdings, and many other elements. I focused on income, which the survey instrument collects separately for each sector and household member, and landholdings, which are collected for each parcel owned or used by any household member. My procedures for choosing land and income measures and for aggregating income and land data to the household level are outlined below.

From the LSMS data, I built a basic model using the household as the unit of analysis to predict the odds that a household purchased rural land between 2005 and 2010 (derived from 2010 survey data) as a function of the household's non-farm income status and various controls derived from 2005 survey data. I used a household multiplier sampling weight included in the 2005 dataset and clustered standard errors by enumeration area.

$$\begin{aligned} \text{Purchased land since 2005}_{2010h} = & \beta_{[1]} \cdot \text{ann. non-farm income}_{2005h} + \beta_2 \cdot \text{if wages received in lg. increments}_{2005h} + \beta_3 \cdot \text{if urban}_{2005h} \\ & + \beta_4 \cdot \text{if very poor}_{2005h} + \beta_5 \cdot \text{if low land endowment}_{2005h} + \beta_6 \cdot \text{if farm activities}_{2005h} + \beta_0 + \varepsilon \end{aligned}$$

The binary outcome variable was derived by combining acquisition method and acquisition year. If parcels were purchased (as opposed to inherited) in 2005 or later, the outcome variable was 1, otherwise it was 0. I used this measure rather than the difference in area of land owned by households between 2005 and 2010 surveys because it was less likely to yield

false-positive signals of land change through differences in imprecise estimation, and because purchasing land is a household's decision while inheriting land can happen as a result of external factors. An important note is that the 2005 LSMS survey instrument asked about agricultural landholdings in its agricultural sub-module, which was only administered if a household reported engaging in farm activities (cultivation or livestock rearing) at some point during the previous 12 months. This means there was potential to undercount households that owned farmland but did not engage in farm activities themselves (i.e. those renting out to others).

There were 3,123 households surveyed in 2005. However, only 2,411 were re-surveyed in 2010, and of these, 1,748 had complete data on land acquisitions. The number of observations with complete data for all questions I used to generate the final models ranged from 1,471 to 1,732, depending on the model. The ~ 700 households that were not resurveyed in 2010 represent a potential source of bias. Households with higher nonfarm income in 2005 were less likely to be resurveyed. Among those who were resurveyed, the bias runs in the opposite direction - households with higher levels of non-farm income are more likely to have complete data on their land acquisitions (Table 1).

Table 1. Chance of Being Surveyed in Both Years vs. Non-farm Income Level

Annual Non-Farm Income	Percent of all HH's surveyed in 2005		Percent of HH's surveyed in both years	
	Not resurveyed	Surveyed in 2010	Complete data on land acquisitions	Missing land acquisition measures
no non-farm income	16.45	83.6	69.2	30.8
10th percentile	19.54	80.5	66.2	33.8
25th percentile	16.75	83.3	62.3	37.7
median	20.44	79.6	70.0	30.0
75th percentile	26.79	73.2	77.7	22.3
90th percentile	25.86	74.1	82.2	17.8
top 10 percent	30.45	69.6	84.3	15.7
Total	22.19	77.8	72.6	27.4

Two model specifications used a subset of the full sample of available households. First, because Uganda hosts several overlapping and transitioning land tenure systems, only some of which are formally compatible with land sales, Model 5 was restricted to households located in enumeration areas where the Local Commissioner (LC) reported that “agricultural land was available for sale” (other choices were “not available, not practiced, or not permitted”). This restriction was not applied to all models because it greatly reduced the sample size and many land sales were reported from areas where LCs indicated land was not available for sale (Table 2). Second, in Table 6 I parsed the sample by households that reported engaging in farm activities in 2005 and those who did not (20% of households) in order to look at investment dynamics in groups of households with presumably different reasons for investment. Since the land questions resided in the agriculture module, all households with known purchases engaged in agricultural activities in 2010.

Table 2. Household-reported land purchases (2005-2010) vs. LC-reported suitable areas (2005)

	Land Available for Sale	Land Not Available for Sale	Land Sales Not Practiced	Land Sales Not Permitted	Total
Households did not Purchase Land (%)	86.9	90.7	98.4	90.0	89.6
Households Purchased Land (%)	13.1	9.3	1.6	10.0	10.4
Total (Household Count)	747	815	123	10	1,695

Predictor variables were based on households’ characteristics in 2005 to reduce problems with endogeneity; using 2005 income to predict subsequent land purchases means that incomes should affect probability of purchase and not the other way around. I considered whether a household was classified as urban or rural to control for households’ ease of accessing rural land and different range of employment opportunities. To try to disentangle the effect of low non-farm income from the effect of being poor, I included a control for poverty-status. Of the available indicator options, the one that seemed least likely to be correlated with sources of

income and be most widely applicable as a sign of duress was the answer to the question “Does every member of your household own at least two sets of clothes?.” Finally, I included the amount of land a household owned³⁸ in 2005 (summed over all parcels to which households hold ownership rights) to control for households’ existing endowments. Acreages were based on respondents’ estimates, which were fairly imprecise (Carletto et al., 2013) but were more complete than the GPS-based area estimates in the LSMS dataset. For this reason, I collapsed acreage into groups above and below the median (2.5 acres). Trends were similar using quartiles.

The main predictor variable of interest was non-farm income status. To measure non-farm income, I calculated the amount of income reported for the previous 12 months from the different categories of 1) *wage or salary*, 2) *household business or enterprise*, and 3) *transfers, remittances, or pensions*. Income from labor on *other* people’s farms was counted as non-farm income. The LSMS survey instrument collected information on income from different sources using different units of analysis to make estimation and reporting simplest for respondents. Thus, estimating annual income in each category required different procedures. I calculated income from *transfers* by summing the answers to the question: “Amount received during the past 12 months” over the categories for pensions, local remittances and assistance, and international remittances. I included in-kind estimates. For income from *household enterprises*, I multiplied the answer to the question: “What is/was the average monthly gross revenues during the months when the enterprise is/was operating?” by the question “In the past 12 months, how many months did the enterprise operate?” and summed this over all enterprises listed for a given household. A household enterprise was defined by answering “Over the past 12 months, has

³⁸ Existence of ownership rights are as reported by households- it does necessarily mean that a household has formal title; it is contrasted to land over which households have only use rights that belongs to other people. The survey asks about these categories separately.

anyone in our household operated any non-agricultural enterprise which produces goods or services (for example, artisan, metalworking, tailoring, repair work) or has anyone in your household owned a shop or operated a trading business or profession?" I used gross income rather net income because gross income was a good proxy for a household's level of investment, and because net income involved introducing noise and potentially missing data from 4 more fields of data on expenditures. *Income from wages or salary* involved the most extensive calculations, described below:

For each job of each member of the household who earned a wage or salary during the previous 12 months:

- 1) "How much was your last cash payment and the estimated value of what you last received in-kind for this work?" [Summed cash payment plus any estimations for in-kind payment]
- 2) "How many hours did you work for the pay you just reported?" [Divided this into answer above to get estimated pay per hour]
- 3) "How many months did you work as {job X} in the past year?" "During these months, how many days did you usually work per month?" "During these days, how many hours did you usually work per day?" [Multiplied to get estimated hours worked in the year. Examined histogram. Converted reports > 8,760 (24*365) to "missing".]
- 4) Multiplied estimated hours worked in the year by estimated pay per hour to get total estimated pay.
- 5) To reduce unnecessarily compounded error, I used "What period of time did this payment cover?" {Choices: Hour, Day, Week, Fortnight, Month, Quarter, Year} to replace estimated pay based on hours to estimate pay based on larger pay-period increments when these were mentioned.
- 6) Summed over all jobs and all household members to get annual wage earnings for the household.

I summed these household-level annual *wage earnings* with *transfer income* and *household enterprise income* to arrive at a total raw value for non-farm income. Although the

LSMS survey instrument was designed to encourage respondents to make reasonably accurate estimates about income, time, and other quantities, in practice this can be very difficult for many respondents (Deaton, 1997, Grosh & Glewwe, 2000). Notwithstanding the high chance of estimation errors, sectoral income distributions were also very non-normal. For example, many households had no wage income at all, and among households that did earn wages, the distribution was very skewed where a few households earned much more than the bulk of the other households. To deal with these distribution challenges and to minimize the influence of outliers, I separated non-farm income into categories based on percentiles. Percentile cut-offs and the proportion of households with 0-values are summarized in Table 4.

Non-farm income *increment* was a simpler calculation and was only possible for *wages and salary* (and not *transfers* or *enterprise income*); this was the only category asking respondents to tell the last amount they received in a single payment. I used the maximum amount last received in cash (not in kind) by any member of a household. I used a threshold of 100,000 UGX (~ 55 USD in 2005) to define a “high increment”. Households with high cash increments fell above the median of annual nonfarm earnings, but many households earning above the median annual amount did not earn in increments that large (see Table 3).

Table 3. Tabulation of Annual Non-Farm Income Levels and High Wage Income Increments

Annual Non-Farm Income	Increment > 100K		Total
	no	yes	
no non-farm income	462	0	462
10th percentile	261	0	261
25th percentile	382	0	382
median	634	2	636
75th percentile	554	88	642
90th percentile	254	125	379
top 10 percent	182	84	266
Total number of households	2,729	299	3,028

Finally, to contextualize the land purchase outcome variable, Table 4 also summarizes the area of purchased parcels (based on respondents' area estimates in 2010), and the 2005 value of land (per-acre). The latter was coarsely calculated over households' total holdings from summing the question in the 2005 survey: "if you were to sell this parcel, how much could you sell it for?" over parcels and dividing the answer by the estimated total area (when there was complete information provided). It was also derived from LC's answers to the question "What is the average agricultural land price (per acre) in the community?"

Results

Among the 3,123 households surveyed in 2005, 75% engaged in farm activities, and 60% earned at least some cash income from sale of crops or livestock. 80% of households with farm activities also earned non-farm income. 38% of households owned no rural land in 2005 while 27% of households were classified as urban. Roughly a third (36.5%) of urban households still engaged in farm activities. 49% of households reported using agricultural land belonging to someone else.

The majority (85%) of households earned at least some amount of non-farm income from wages, household businesses, or remittances. Income from transfers and remittances was generally low among sampled households (median ~ 40\$), but wage and business incomes were appreciable (median values around 300\$). About 45% of households earned income from wages or salary and a similar proportion earned income from household businesses. Non-farm gross cash incomes were ~ 4 to 6 times higher than cash generated by on-farm activities (but on-farm activities also generated subsistence income for households).

Ten percent of households in the sample reported purchasing land between 2005 and 2010 (n=180). The median amount purchased during this period was about one acre (range 0.05 to 60 acres), which at the 2005 median land value would cost about 300 USD. As a point of reference, in 2005, the estimated median total annual gross cash income among sample households was 415.43 USD.

Table 4. Summary Statistics for Income, Land, and Control Variables

	% of HHs with non-zero val.	(for nonzero values)				
		10 th percentile cut-off	25 th percentile cut-off	median: 50 th percentile cut-off	75 th percentile cut-off	90 th percentile cut-off
Total Annual (Gross) Non-farm Income	85	26.52	88.40	368.23	1,200.00	3,480.66
<i>Income from wages or salary</i>	45	19.89	74.59	278.45	861.88	1,856.35
<i>(Gross) Income from HH business</i>	42	33.15	104.42	464.09	1,591.16	5,171.27
<i>Income from remittances & gifts</i>	42	3.98	11.49	41.44	157.46	552.49
Total Annual (Gross cash) Farm Income	60	8.31	27.07	82.87	231.49	575.91
<i>(Gross cash) Income from livestock</i>	23	8.84	22.10	66.30	165.75	388.40
<i>(Gross cash) Income from cultivation</i>	57	6.63	19.34	59.28	165.75	424.31
(Gross) Total Annual Income	98	45.30	135.64	415.43	1,271.22	3,440.33
Max cash income increment from wages	45	0.55	1.10	8.29	44.20	110.50
Area of land owned in 2005	62	0.50	1.00	2.50	5.00	9.00
Area of land purchased btw. 2005-2010	10	0.25	0.30	0.90	2.00	4.00
Per-acre land value (based on respondent area est.)		73.66	165.75	368.32	810.04	1,812.15
Per-acre land value (based on GPS area est.)		65.25	142.88	404.26	920.81	2,249.16
Per-acre land value (based on LC reports)		55.25	110.50	276.24	552.49	1,657.46
Bought land since 2005? (from 2010 survey)				10.3 %		
Poor household? (clothing indicator)				13.0 %		
Urban household?				27.5 %		

Note: Income values are expressed in USD using 2005 exchange rate of 1 USD = 1,810 UGX

Areas are expressed in acres. Data is from surveys in 2005 unless otherwise specified.

Model Results

On average, the presence of non-farm income in 2005 was associated with decreased odds that a household subsequently purchased rural land (Table 5, Model 1). However, the amount of non-farm income and the increment of non-farm income conditioned this effect (Models 2 - 4).

Odds of purchase appear to be non-linearly related to non-farm income, but the relationship was only statistically significant for the smallest (non-zero) amounts of non-farm income. At these low levels, households were about half as likely to buy land compared to households with no non-farm income, despite including a control for poverty. At higher levels of non-farm income, the downward effect on purchase probability diminished but then deepened again at the highest levels of non-farm income (though relationships at higher non-farm income levels were noisy and not statistically significant).

In contrast to annual *amount* of non-farm income, the *increment* of non-farm income was positively and more consistently related to purchasing land. Households that received wages in larger increments in 2005 were from ~ 1.5 to 2.5 times *more* likely buy land in the future. This was especially true among households in communities where community leaders reported land available for sale (Model 5). It persisted as a positive association across all model specifications, including controls for annual non-farm income levels. The effect of receiving non-farm income in large increments was over four times larger among households who did not engage in farm activities in 2005 but did engage in farm activities in 2010 (Table 6), potentially representing a boost needed to break in to agriculture.

Unsurprisingly, urban households were less likely to buy rural land. The control for household wealth showed little relationship in any model. Households owning smaller amounts of land (less than 2.5 acres - the median owned acreage) had higher odds of subsequent land purchases, suggesting a redistributive effect of land markets.

Table 5. Predicting whether a household buys land between 2005 and 2010, based on 2005 characteristics

	Model 1 simple	Model 2 levels	Model 3 increment	Model 4 full	Model 5 sale regions	Model 6 2005 ag
Non-farm income level						
0-10 th percentile		0.56 *		0.52 *	0.39 *	0.51 *
10 th -25 th percentile		0.78		0.75	0.58	0.75
25 th -50 th percentile		0.75		0.71	0.74	0.73
50 th -75 th percentile	0.71 *	0.85		0.74	1.02	0.80
75 th -90 th percentile		1.19		0.94	0.85	1.09
top 10 percent		0.66		0.53	0.53	0.62
Large wage increment			1.80 **	1.83 **	2.54 **	1.91 **
Urban household		0.30 ***	0.29 ***	0.26 ***	0.30 **	0.37 ***
Poor household		0.93	0.91	0.92	1.11	0.91
Land endowment < median				1.40	1.22	1.59 **
No 2005 farm activities						0.36 ***
num obs	1710	1709	1732	1682	727	1682
sample restrictions	whole sample				only sites where "ag land available for sale"	whole sample

Standard errors are clustered at the community level. * = $p < .10$, ** = $p < .05$, *** = $p < .01$

Table 6. Effect of wage size on odds of land purchase, by 2005 diversification strategies

	Model 1	Model 2	Model 3
sample restrictions	whole sample	2005 farm activities	no 2005 farm activities
Wage increment > 100K UGX	1.84 **	1.45	6.28 **
Total income > median	1.10	1.20	0.53
Urban household	0.24 ***	0.54 *	0.10 ***
num obs	1471	1123	348

Discussion

Findings thus far do not suggest that any level of non-farm income increases the odds of buying land, and at the lower levels there is evidence that it significantly decreases the odds. Counter to expectation, odds of purchase are not higher even among the top 10% of non-farm income earners - if anything, they begin to decline again, perhaps because they have access to alternative investment options. Urban households and households not engaging in farm activities are less likely to purchase land. Together, this paints a picture of non-farm income generally acting more as a substitute for farm income than as an additional source of income to invest to expand farm activities. A similar finding was reported using LSMS data for Albania (Kilic et al., 2009). However, the increased odds of purchase when wage increments are large suggest there is more to the story. One possibility is the raw amount of wages received in a household's most recent payment (the wage increment) is a better proxy for total non-farm income than the estimate generated by my procedure that takes into account the amount of time worked for that wage and the amount of time worked in a year (calculated total annual wages). In that case, higher levels of non-farm earnings do increase purchases of agricultural land. However, if there is a true difference between the effects of annual amounts of non-farm income and amounts received at once, this supports the idea that *difficulty saving* dampens households' likelihood of purchasing land, as predicted by Reardon et al. (1994). Or, it could be that if households receive a large amount of income at once, land is a good option for investing it when financial institutions aren't easily available. Studies have shown that windfall income from remittances is often invested in land (e.g. Moran-Taylor & Taylor, 2010). It is interesting that the increment-effect is much larger among households that are not engaged in farm activities in 2005. For households *already* engaged in farm activities, perhaps lump sums can be invested on *existing*

land, by planting tea or purchasing livestock, for example. For the households *not* engaged in farm activities, perhaps a large lump sum of wages enables them to “break in” to agriculture from a position of little or no inherited land (as reported in a study in eastern Uganda (Baland et al., 2007). This implies that at least some households may use non-farm income to get back into agriculture, not to exit land-based livelihoods.

Because the survey sampling design was population-based (i.e. what are the odds that a household with a certain kind of income characteristics buys land) and not area-based (i.e. for a given piece of land, what is the chance of being bought by a person with particular income characteristics), the results tell us more about how non-farm income affects household decisions than they can ultimately tell us about how it affects land ownership distribution and land pressure. Within the LSMS sampling frame, households with lower existing amounts of land were more likely to buy land in the future, potentially leading to positive distributional effects consistent with those reported in other studies of land markets in Uganda (Baland, 2007, Deininger et al, 2015). However, in a household-based analysis, very large holdings and purchases carry the same weight as small purchases, and purchases by non-households (e.g. corporate entities) aren’t captured at all (Schoneveld, 2014). Large farms and absentee farms are under-represented in LSMS data (Jayne et al., 2015), and by definition, the actions of the majority of land holders do not adequately capture the effects of land concentration by a small elite minority. Drawing from other data, Jayne et al. (2014b) found evidence for land concentration by an emerging group of medium-scale investor land-owners in Ghana, Kenya, and Zambia. Aside from sampling frame, an issue with the LSMS survey design further limits the ability to detect land concentration with this dataset. Questions about owned or rented agricultural land are in the agricultural survey module, which was *not* administered to

households who did not engage in cultivation or livestock rearing in the previous year. Thus, the survey potentially missed households owning rural land with no farm activities, such as investors and landlords. Deininger et al. (2015) pointed out that this could help explain why, in LSMS data, 24% of households in Uganda reported renting land from others, while fewer than 1% of households reported renting out land.

In their recent World Bank study, Deininger et al. (2015) used this same dataset and parallel LSMS surveys from several other African countries to look at smallholder participation in land rental and land sale markets (Deininger et al., 2015). Their descriptive statistics showed that households purchasing land in Uganda during a similar period had higher total incomes, higher agricultural incomes, higher non-farm incomes, *lower* initial landholdings, were better educated, younger, and hired more labor than households “in autarky”. In their econometric model, being younger and more educated increased likelihood of buying land, as did having lower amounts of land to begin with, but their measure of wealth (total value of durable goods) showed no relationship. Our models also showed no relationship between land purchases and our clothing-based wealth indicator variable. It is interesting that more comprehensive measure of material wealth showed a similar trend. A weak relationship between material goods and land investment suggests that there may be divergent types of land buyers. The World Bank group did not include household-level income in their model, but they did include a community-level variable for the share of non-agricultural wage income, which was a strong positive predictor of *renting* but not *buying* land. My study generally concurs with their findings on land endowments and wealth (Deininger et al., 2015), but focused more on household-level impacts of non-farm income levels and “lumpiness”- the amount received at once. Together, the two studies point to recent purchases being made by young households in rural areas with high human capital

(education), relatively high incomes, and relatively low land endowments. This accords with something a woman from the Kabarole district of Uganda told me in 2015: ‘if you invest in your children’s education, you don’t have to worry about land for them to inherit - you give them one or the other because you know that if they are educated they can get land for themselves.’”

The percent of households purchasing land between 2005 and 2010 was relatively small - about 10% - and area purchased during this period was also generally small (< 1 ha). In Chapter 2, I showed that land sales in one region of Uganda have picked up considerably since 2010 - it may be that the LSMS survey window is capturing only the initial stages of an important trend. The stronger investment signal in the places where local commissioners indicated that land was available for sale could mean that land markets (both formal and informal) are unevenly active throughout the country despite national intention toward freehold tenure arrangements (Deininger & Mpuga, 2002). Another possible reason that I detected a relatively small signal of investment in agricultural land is that households may have preferred to invest income in other types of property. In the Kabarole region of Western Uganda, households with extra income will often buy a commercial plot in a nearby trading center³⁹. These types of plots were not counted in the LSMS survey instrument that focused on agricultural land. In some ways, these commercial plots are safer investments because it is a more established practice for rentees to pay rent for rooms for lodging or stores, while “renting” agricultural land often means using without payment or paying in kind. However, as the practice of paying for rented agricultural land becomes more common and as low-maintenance alternatives to renters like Eucalyptus plantations become more lucrative, I expect that agricultural land in Uganda will become an increasingly attractive investment option.

³⁹ Motorcycles and other transport, along with school fees, are other places where extra income is commonly invested before (perhaps additional) agricultural land.

Conclusion

For households in Uganda, the way nonfarm income affects rural landholdings depends on both the level and the payment increment of nonfarm income. If received in larger sums at once, nonfarm income increases the odds of purchasing more rural land. Otherwise, nonfarm income decreases the odds of future land purchases, especially at lower levels. This suggests that both the substitution and investment mechanisms relating non-farm incomes to agricultural land are important. A lower demand for land among a set group of households with non-farm income is a positive sign for those hoping that non-farm income will help take pressure off land. However, it is impossible to truly assess implications for land sparing without taking into account the activities of large and corporate landowners and the effects of growing populations. I did not find evidence for rampant land buy-ups by those with the high levels of non-farm income, high existing land endowments, or residing in urban locations - but the survey design is not well-suited to capture the extent of that type of activity. Instead, there is evidence that relatively land-poor rural households are more frequently purchasing land, and that nonfarm income opportunities lead some households away from investing in agricultural land, especially if it is low-paying or if it is associated with urban migration. However, nonfarm income may also facilitate land purchases for households trying to break in to agriculture when income is received in large sums at once, and difficulty saving cash may be reducing the income effects from non-farm opportunities. A different relationship might arise if mechanisms for saving improve. I add to the evidence that nonfarm income does not have a simple single-path effect on households' subsequent investment decisions. More work is needed to understand how income effects, savings effects, and developing land markets are interacting to condition and change the way that households use land.

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