

Does secure land tenure save forests?

A review of the relationship between land tenure and tropical deforestation

Working Paper No. 7

Brian E Robinson
Margaret B Holland
Lisa Naughton-Treves



Working Paper

Does secure land tenure save forests?

A review of the relationship between land tenure and tropical deforestation

Working Paper No. 7

CGIAR Research Program on Climate Change,
Agriculture and Food Security (CCAFS)

Brian E. Robinson
Margaret B. Holland
Lisa Naughton-Treves

Correct citation:

Robinson BE, Holland MB, Naughton-Treves L. 2011. Does secure land tenure save forests? A review of the relationship between land tenure and tropical deforestation. CCAFS Working Paper no. 7. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. Available online at: www.ccafs.cgiar.org

Titles in this Working Paper series aim to disseminate interim climate change, agriculture and food security research and practices and stimulate feedback from the scientific community.

Published by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

CCAFS Coordinating Unit - Department of Agriculture and Ecology, Faculty of Life Sciences, University of Copenhagen, Rolighedsvej 21, DK-1958 Frederiksberg C, Denmark. Tel: +45 35331046; Email: ccaafs@life.ku.dk

Creative Commons License



This Working Paper is licensed under a Creative Commons Attribution – NonCommercial–NoDerivs 3.0 Unported License.

Articles appearing in this publication may be freely quoted and reproduced provided the source is acknowledged. No use of this publication may be made for resale or other commercial purposes.

© 2011 CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) 2011 CCAFS Working Paper no. 7

The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) is a strategic partnership of the CGIAR and the Earth System Science Partnership (ESSP). CGIAR is a global research partnership for a food secure future.

The program is supported by the Canadian International Development Agency (CIDA), the Danish International Development Agency (DANIDA), the European Union (EU), and the CGIAR Fund, with technical support from the International Fund for Agricultural Development (IFAD).

The views expressed in this document cannot be taken to reflect the official opinions of these agencies, nor the official position of the CGIAR or ESSP.

DISCLAIMER:

This Working Paper has been prepared as an output for the Pro-Poor Mitigation Theme under the CCAFS program and has not been peer reviewed. Any opinions stated herein are those of the author(s) and do not necessarily reflect the policies or opinions of CCAFS.

All images remain the sole property of their source and may not be used for any purpose without written permission of the source.

The geographic designation employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of CCAFS concerning the legal status of any country, territory, city or area or its authorities, or concerning the delimitation of its frontiers or boundaries.

Working Paper layout: Vanessa Meadu and Alison Nihart

Other Related CCAFS Working Papers

This paper was produced in collaboration with Arun Agrawal and Lauren Persha at the University of Michigan for the project *Governing Mitigation Trade-offs in Agriculture-Forestry Landscapes*. See other related titles:

CCAFS Working Paper no. 8. Börner J, Wunder S, Wertz-Kanounnikoff S, Hyman G, Nascimento N. 2011. REDD sticks and carrots in the Brazilian Amazon: Assessing costs and livelihood implications.

CCAFS Working Paper no. 9. Fox J, Castella J-C, Ziegler AD. 2011. Swidden, Rubber and Carbon: Can REDD+ work for people and the environment in Montane Mainland Southeast Asia?

CCAFS Working Paper no. 10. Barbier EB and Tesfaw AT. 2011. Overcoming tenurial constraints to carbon forestry projects in Africa.

CCAFS Working Paper no. 11. Cohn A, Bowman M, Zilberman D, O'Neill K. 2011. The Viability of Cattle Ranching Intensification in Brazil as a Strategy to Spare Land and Mitigate Greenhouse Gas Emissions.

All papers available online at: www.ccafs.cgiar.org

Abstract

Deforestation and degradation are tied to a complex array of socioeconomic and political factors. As noted in studies focusing on large-scale policy interventions such as REDD+ and payment for ecosystem services programs, among the most important of these factors is land tenure and land tenure security. This paper reviews past literature connecting forest outcomes and land tenure to better understand broad relationships between land tenure form, land tenure security and forest outcomes. From a theoretical perspective, clear and secure forest tenure can have either a positive or negative impact on forested land, depending on political and economic conditions. We review over 100 empirical cases of forest outcomes under specific land tenure conditions and find that land tenure security is associated with less deforestation, regardless of the form of tenure. State-owned protected forests are associated with more positive forest outcomes relative to private, communal and public land. We discuss consistency and identification issues in the current literature around deforestation and land tenure, and provide suggestions for future studies and implementation issues for policymakers.

Keywords

Land tenure; land tenure security; deforestation; degradation; meta-analysis.

About the authors

Brian E. Robinson, Research Fellow, University of Minnesota; brobinson@umn.edu.
University of Minnesota, Institute on the Environment, 1954 Buford Avenue, St. Paul,
MN 55108; University of Wisconsin-Madison, Land Tenure Center, Room 122
Science Hall, 550 North Park Street, Madison, WI 53706.

Margaret B. Holland, Assistant Professor, University of Maryland-Baltimore County;
mholland@umbc.edu. University of Maryland-Baltimore County, Department of
Geography & Environmental Systems, 211 Sondhiem Hall, 1000 Hilltop Circle,
Baltimore, MD 21250; University of Wisconsin-Madison, Land Tenure Center, Room
122 Science Hall, 550 North Park Street, Madison, WI 53706.

Lisa Naughton-Treves, Professor, University of Wisconsin-Madison;
lnaughto@wisc.edu. University of Wisconsin-Madison, Department of Geography,
Room 355 Science Hall, 550 North Park Street, Madison, Wisconsin 53706;
University of Wisconsin-Madison, Land Tenure Center, Room 122 Science Hall, 550
North Park Street, Madison, WI 53706.

Acknowledgements

We thank Jessica Long, Marty Pfeiffer, Lisa Maas, Nicole Mathews and Emily Matson for their aid in reviewing cases and their productive discussion. Also, thanks to Daniel Bromley, Kelly Wendland, Susana Lastarria-Cornhiel, Matthew Turner, Lauren Persha and Kurt Brown who provided valuable comments on earlier versions of this paper. Any errors of interpretation or omission are solely the authors' responsibility. This work was supported by the University of Wisconsin-Madison Land Tenure Center, United States Agency for International Development (USAID) Translinks Agreement #EPP-A-00-06-00014-00, the National Science Foundation – IGERT program (NSF-IGERT), International Forest Resources and Institutions (IFRI), the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) and Conservation International (CI).

Contents

1	Introduction.....	9
2	Basic terms.....	12
3	Theoretical Literature on Land Tenure and Forests.....	13
4	Empirical Literature on Land Tenure and Forests	14
4.1	Cases	14
4.2	Form of Tenure	16
4.3	Tenure security.....	20
5	Broad Lessons from the Land Tenure Literature.....	25
5.1	The form of tenure does not imply security.....	25
5.2	Communal land.....	26
5.3	Tenure data and measurement	27
6	Conclusion	29
6.1	How does tenure matter?	29
6.2	Future research.....	31
6.3	Addressing tenure issues at the forest-farm interface	32
7	Methods Appendix.....	34
7.1	Framework for assessing empirical studies	34
7.2	Methods.....	36
	References.....	39
	Empirical Studies Reviewed.....	39
	Cited in text.....	42

Acronyms

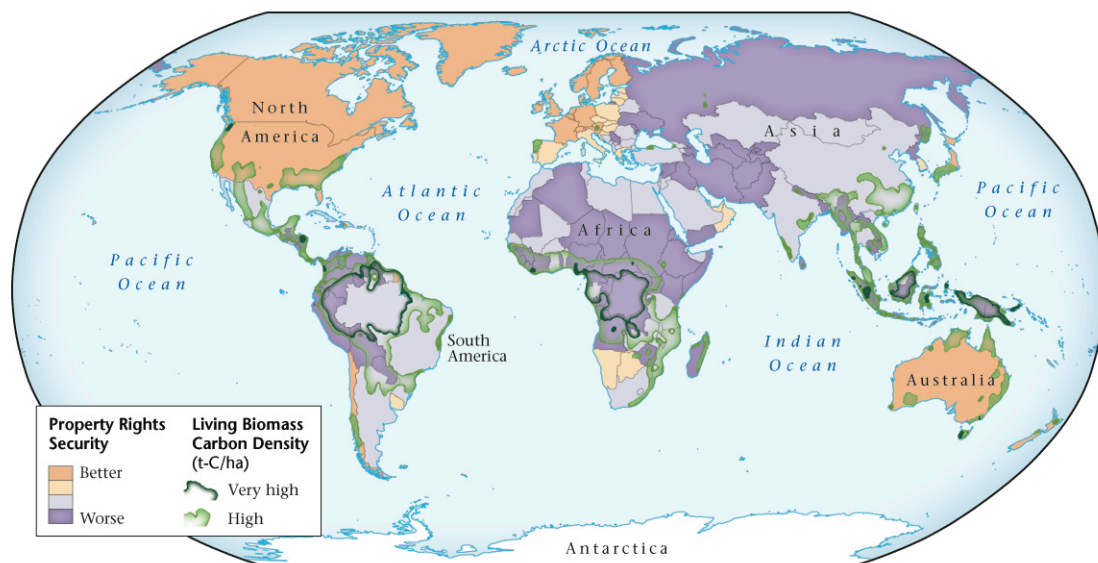
PES Payment for ecosystem services; payment for environmental services

REDD+ Reducing Emissions from Deforestation and Degradation

1 Introduction

Land tenure and forest property rights are critical issues for the new wave of incentive-based policy instruments that aim to safeguard public goods in tropical forests (such as carbon, water, and biodiversity) by paying people to protect them. The most recent and highest profile of these instruments, REDD+ (Reducing Emissions from Deforestation and Degradation¹) is attracting significant international investment. Property rights tied to tracts of land directly determine who is eligible to receive protection incentives as well as who is responsible for meeting programs' contractual obligations. Clear and secure land tenure is critical for an efficient REDD+ program and equitable distribution of benefits (Bruce et al. 2010). Yet the world's most carbon-rich and biodiverse forests are often found in regions where ownership is ill-defined, contested or insecure (

Figure 1 Tenure security and carbon biomass density

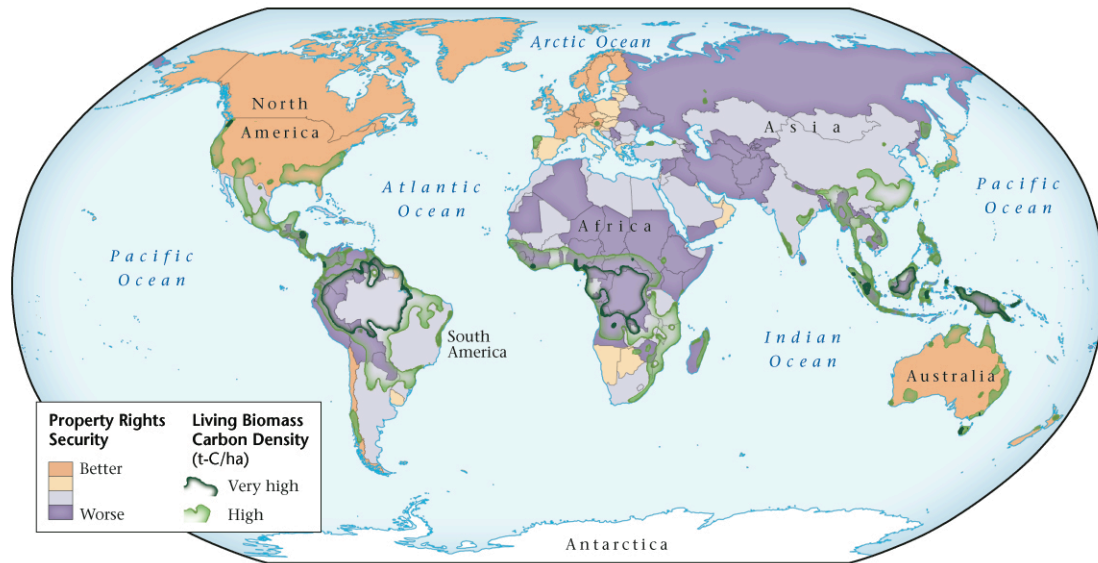


Source: Bruce et al. 2010

). Some describe current 'chaos' in property regimes (e.g. Fitzpatrick 2006), particularly in areas amid transitions from customary norms where legal codified rules are not yet operative.

Figure 1 Tenure security and carbon biomass density

¹ REDD+ is the strategy approved as part of the Cancun Agreements at the recent United Nations Framework Convention on Climate Change (UNFCCC) 16th Conference of Parties (COP 16) to avoid deforestation and/or enhance existing forest carbon stocks.



Source: Bruce et al. 2010

For these reasons, policy makers see tenure as one of the key issues shaping the social and environmental impact of REDD+ and related programs (Sikor et al. 2010, Sunderlin et al. 2009, Unruh 2008). But the basic tenure and deforestation terminology used in studies is often confused or insufficiently defined. Further, it remains unclear whether specific forms of tenure are more “sound” than others, when tenure *security* matters and how communities at the forest-farm interface internalize these concepts.

Yet forest outcomes are connected to a complex array of socioeconomic and political factors. Interventions to “clarify tenure” are rarely a simple administrative or technical challenge, but warrant a cautious approach, especially since some titling programs have shown varied outcomes in improving landholders’ livelihoods (Deininger and Feder 2009). Land is more than an input to agricultural or forest productivity. Land has social, cultural and political value, and is particularly central to indigenous rights movements (Platteau 2000).

That said, tenure directly determines who has the right to benefit from forests and who has duties to protect them. Addressing tenure issues are pivotal for the success of payments for ecosystem services (PES) or REDD+ programs since landholders must have the power to make land use decisions and defend land against outside claimants or other agents of land use change. Thus there seems little alternative to state-recognized land tenure rights.

In practice, the outcomes of forest tenure studies seem to show little consistency in how any particular type of land tenure affects forests. There is increasing evidence that indigenous groups and those acting collectively can be successful at managing forest resources, but this also requires security in their land claims (Nepstad et al. 2006, Sandbrook et al. 2010, Wynberg and Laird 2007). Parks generally help avoid tropical deforestation over other land tenure forms (Andam et al. 2008, Joppa and Pfaff 2011), but insecure “paper” parks are common in areas with limited capacity for governance and, moreover, extensive tracts of carbon-heavy, biodiverse forest lies outside of areas under strict protection (Agrawal A 2007, Soares-Filho et al. 2006, Sunderlin et al. 2008). We need a better understanding of how the form of tenure and tenure security interact to affect forest outcomes.

Our aim is to better understand the relationship between land tenure form, land tenure security and forest outcomes. In doing so, we hope to aid in identification of sites and situations where land tenure interventions can help slow deforestation. By *land tenure* we broadly mean the set of institutions and policies that determine how land and its resulting resources are accessed, who can benefit from these resources, for how long and under what conditions (USAID 2008). To gain analytical traction for our study we construct two null hypotheses: 1) there is no association between the *form* of land tenure and the likelihood of forest conservation, and 2) there is no association between the *security* of land tenure and the likelihood of deforestation. We evaluate these hypotheses in relation to existing theoretical and empirical literature.

We first briefly review tenure terminology and distinguish the form of tenure (i.e. norms and rules governing access to land and forests) from tenure security (the assurance that these norms and rules will be enforced). Section 3 reviews the theoretical economic literature on tenure security and deforestation, and describes the practical limits of these models for providing guidance in program implementation. Turning to the empirical literature, in Section 4 we look for an empirical relationship between the form and security of tenure and forest outcomes. In light of the notable variation in tenure forms and level of tenure security between regions (Sunderlin et al. 2008), we examine variation in the tenure-forest relationship between geographic regions. We conclude by discussing the most likely contexts in which tenure might influence emissions via land conversion at the forest-farm interface in the tropics.

2 Basic terms

The debate regarding the impact of tenure on forest conservation is hindered by uncertain terminology. *Property rights* and *land tenure* are often used interchangeably. Here we make the distinction that *property rights* refer to a bundle of rights guiding the use, management, and transfer of assets. *Land tenure* is the set of institutions and policies that determine locally how the land and its resources are accessed, who can hold and use these resources, for how long and under what conditions (Bruce et al. 2010, USAID 2008). Land tenure, then, is a set of property rights associated with the land, and the institutions that uphold those rights.

The *form* of land tenure refers to the rules and norms associated with any number of entities, such as an individual, a public institution (e.g. the national park service), a private company, a group of individuals acting as a collective, a communal or common-property arrangement or an indigenous group. Public and communal tenure are prominent in the tropical forest management literature given that they often constitute large land areas (e.g. $\geq 10,000$'s ha). Such scale is important for REDD+ initiatives to lower transaction costs of implementation and maintain ecosystem functions. Public and communal landholdings are generally nontransferable, which also has significance for REDD+ as carbon contracts are designed to be long-term.

While land tenure can take on a number of forms, we define *security* in land tenure as the assurance that land-based property rights will be upheld by society. Security does not refer to the duration, marketability or the breadth of rights over a piece of land; these are all components of a particular form of tenure (Sjaastad and Bromley 2000, van den Brink et al. 2006). Further, the ability of a government to expropriate land does not necessarily imply insecure tenure, as long as just compensation is assured. In this sense, "security" can be over the physical asset itself (the parcel of land) or the right to the value of that asset (monetary compensation).

There is increasing recognition among development scholars that formal or legal tenure is not always sufficient to impact landholders' decision-making, but how one *perceives* tenure is what matters (Broegaard 2005); a reaction, in part, to the long-held assumption that land titling equaled tenure security (e.g. Deininger and Feder 2009, Feder and Feeny 1991).

Therefore, the influence of tenure security – both *de facto* and *de jure* – has become the focus of many recent discussions.

3 Theoretical Literature on Land Tenure and Forests

Development economists have used economic theory to explore the effect of land tenure security on forests through at least four different frameworks: game-theory, the Faustmann optimal timber rotation model, a model of optimal investment and land use cost-benefit analysis. Game-theory models (e.g. Clarke et al. 1993, Hotte 2005) analyze optimal enforcement of costly property rights. In these models tenure insecurity unambiguously increases the costliness of protection, resulting in a lower optimal resource stock (i.e., more deforestation).

The other three types of models incorporate tenure insecurity as the probability that land will be expropriated (without just compensation) at some point in the future. In a Faustmann framework (Reed 1984, Zhang 2001), this serves to shorten the optimal timber rotation and may decrease the value of forested land, making agriculture more attractive. In a model of optimal investment and resource use, Bohn and Deacon (2000) find that increased insecurity also results in lower overall forest stocks.

The fourth type of model, land use cost-benefit analyses that compare the net present value of alternative land uses, has less clear implications. Mendelsohn's (1994) seminal paper shows that tenure insecurity has an ambiguous impact on forest conversion to agriculture. Barbier and Burgess (2001) extend this model to show the potential rationality of "timber mining," but tenure insecurity can ultimately promote or protect forests depending on parameter values. Angelsen (2007) uses a spatially explicit (von Thünen) model in which tenure insecurity is actually protective of forests. Amacher et al. (2009), which is the most complex but also most complete model, incorporates migration and illegal timber harvesting in the presence of tenure insecurity. They derive some general lessons, but show that better approximations of reality result in complex outcomes with respect to tenure security.

As a whole, the theoretical economic literature shows that the relationship between tenure insecurity and forests depends on local context. One contextual factor could be the way one frames the investment decision. If forest is assumed a productive investment in the model (i.e.

an industrial timber forest) then tenure insecurity promotes more deforestation (Bohn and Deacon 2000). Alternatively, if agriculture is modeled as a productive investment relative to (unproductive) forest, insecure tenure results in protection of forest (Angelsen 2007). An earlier review of economic tropical deforestation models by Kaimowitz and Angelsen (1998) concludes the most salient contextual factors that increase deforestation are increased agricultural and timber prices, decreased cost of labor, easy access to forest lands and opportunities for long-distance trade. They similarly conclude that the impact of tenure insecurity depends on local conditions.

Even when we identify contextual conditions where the theoretical impact of tenure security is clear, it may be difficult to derive empirical lessons about particular forms of tenure or the mechanisms through which tenure insecurity works. Theoretical economic models deal with the form of tenure and tenure security in relatively crude ways. In most cases, models use a profit-maximizing framework and tenure security is a probability of expropriation of property. Profit-maximization implies no specific form of tenure, so these models provide no insight on how to compare, say, freehold, leasehold and customary tenure arrangements. No studies deal with the complex incentives that arise from different forms of tenure, much less the conflation of how the security of that form affects decisions (see Kaimowitz and Angelsen 1998:68).

Nevertheless, the general lesson from this literature is that tenure security matters, but whether its effect is positive or negative on forests is dependent upon the context of the model and other model parameters. Further, tenure and tenure security are dealt with in ways that are too stylized to provide much guidance on what particular forms of tenure might work best on the ground. Therefore, we turn to the empirical literature to look for evidence of a relationship among different forms of tenure, tenure security and forest outcomes.

4 Empirical Literature on Land Tenure and Forests

4.1 Cases

We selected studies that analyze land use change over time and discuss property rights or land tenure, targeting publications that use primary or secondary remote sensing data to measure forest cover change over time. For each study we use a standardized questionnaire to code all cases including questions regarding the effect of several key variables on deforestation such

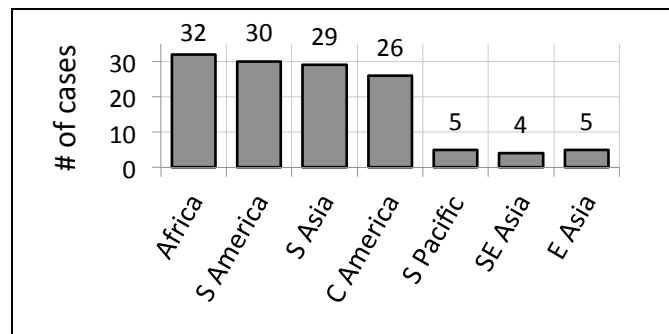
as: owner type, the form of tenure, tenure security (assurance), governance, collective action and other proximate causes (infrastructure, agriculture, demographics, technology, etc.). Studies were disaggregated into the number of geographic sites analyzed and then into the forms of tenure present at each site. Our fundamental unit of analysis is then a particular form of tenure at a specific site, which we call a “case.”

For a detailed description of the methods, see the Methods Appendix. But here we briefly explain the major steps for our review of the empirical literature. We first record the form of tenure for each case. The review of studies results in the following basic categories: unmanaged public land (frontier or open access), public land managed by a government agency (parks or reserves), communal, private and customary/traditional land. Where governments explicitly restricted the conversion of forests to other land uses and restrictions, we categorized these as managed public land. Where such restrictions were absent, but land still fell into the general public realm, we categorized these as unmanaged public land.

Second, we use the context of the discussion or authors’ explicit recognition of the tenure security for that particular site. Finally, we record whether the forest outcome for this case is positive or negative relative to other cases in the study. Therefore, “slowed deforestation” is a positive outcome relative to “accelerated deforestation” on a different tenure form, although forest is lost in both cases. “Forest lost,” however, is a negative outcome relative to another form of tenure where we see “forest maintained.” Although such measure of tenure security and forest outcomes are sometimes subject to interpretation, this allows for meaningful comparison of various studies.

We initially identified over 100 peer-reviewed publications as candidates, from which we drew 39 publications that ultimately fit within our selection criteria. Within these, we identify 83 sites where forest cover was analyzed. Some sites contain multiple forms of tenure, resulting in 131 cases of tenure conditions tied to a specific site. Although we aimed to have a geographically balanced sample, the majority of our cases come from Latin America, Africa and South Asia (Figure 2). We first review the association between the form of tenure and forest outcomes, and then investigate the interaction of tenure security and forest outcomes. We conclude our results with a regression model that takes into account these factors simultaneously.

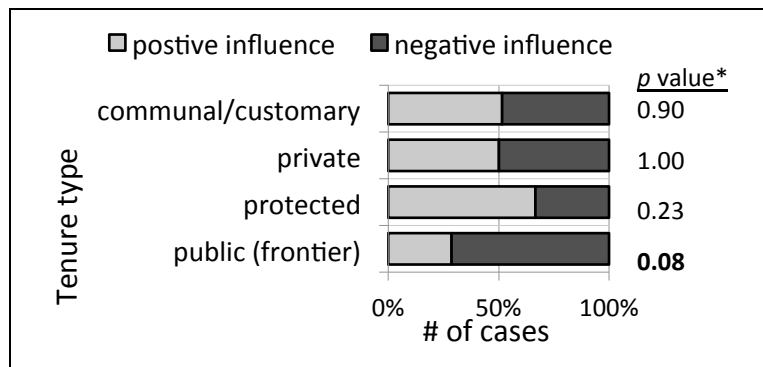
Figure 2 Frequency of cases by region



4.2 Form of Tenure

We group the tenure form into four categories: public, private, protected and communal/customary land. The literature often conflates communal and customary forms of tenure, so we are restricted to categorizing both into a “communal” category.

Figure 3 Forest outcomes and type of tenure



* the *p* value for a two-sided binomial probability test that the outcome is random (that is, that the proportion = 0.50)

The study set reveals both positive and negative outcomes for forest cover across all the most common types of tenure (

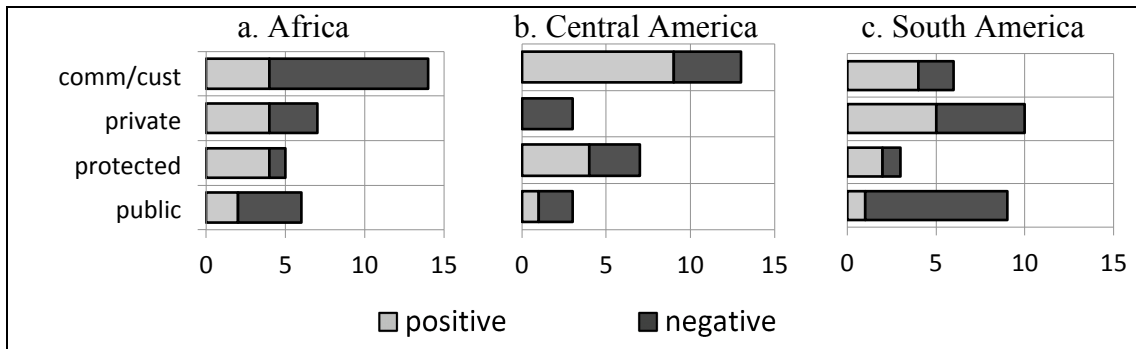
Figure 3 Forest outcomes and type of tenure

). Positive outcomes (64 cases) refer to slowed deforestation rates, maintained forest cover or regenerated forest cover. Negative outcomes (67 cases) generally include increased deforestation rates or loss of forest.

Figure 3 Forest outcomes and type of tenure

also shows that, in general, we find no clear evidence to suggest one specific tenure type is optimal for protecting forests. Negative outcomes pervade all tenure types. However, we do see that public frontier land is associated with more negative forest outcomes and that protected land seems to also have slightly more positive outcomes than negative ones.

Figure 4 Regional forest outcomes by tenure

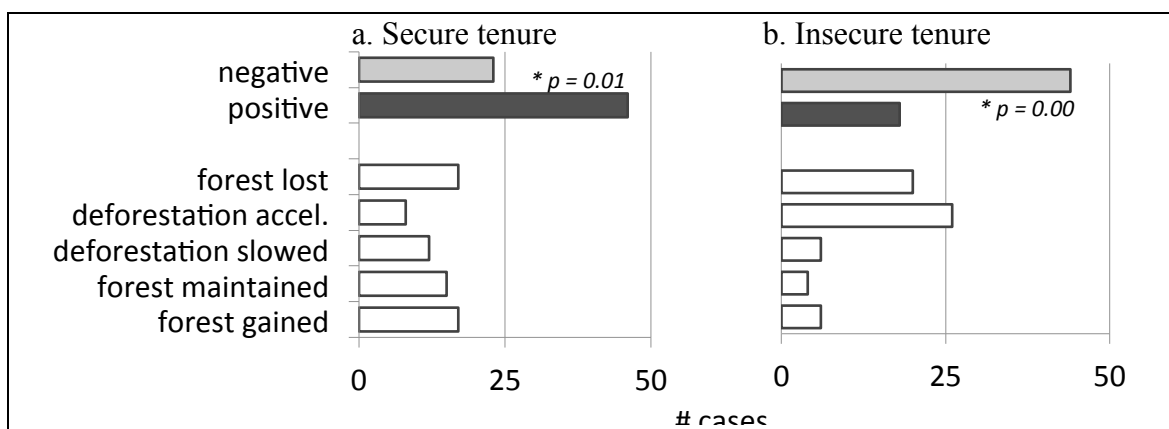


Regionally, we see patterns emerge for some tenure forms in the three most heavily researched regions (we exclude South Asia due to almost exclusive analysis of communal land in publications from that region). Though we cannot make strong conclusions due to our limited sample size within regions, communal tenure seems to perform somewhat poorly in Africa (Figure 4a), somewhat well in Central America (Figure 4b) and has more mixed effects in South America (Figure 4c). Overall, private land also leads to mixed outcomes, but seems to perform worse in Central America. Protected areas, uniformly, have slightly more positive than negative results within each region, but the opposite is true for public frontier land. The negative result for public land reflects cases of illegally occupied land at the forest-farm interface and encroachment into the frontier, the majority of which occur in studies from the Amazon. These results give us some reason to question our first null hypothesis, that the form of tenure has no relationship with forest outcomes, especially when we look at public and protected land.

4.3 Tenure security

Tenure security, alone, does not guarantee the preservation of forest cover. Figure 5 shows that even with secure tenure², negative cases are common, but positive outcomes occur significantly more often than negative ones. Similarly, when tenure is insecure, a negative forest outcome is significantly more likely than a positive one. Tenure security seems to help keep forests in tact, but we find no discernable results by region with respect to tenure security.

Figure 5 Forest outcomes with and without secure tenure



* The p value for a two-sided binomial probability test that the outcome is random (the proportion = 0.50).

Figure 6 generally shows that not only are positive and negative outcomes possible over all tenure types, so are secure and insecure tenure conditions. Notably public and protected areas seem particularly prone to insecure conditions³ and, for communal land, insecurity seems most closely associated with negative outcomes.

Using a probit regression model, Regarding the second null hypothesis, we see empirical evidence to reject the null hypothesis that tenure security is not important. Although greater implied tenure security seems to improve the probability of positive forest outcomes, tenure security by no means prevents changes in forest cover, as can be seen in Figure 5. Payments

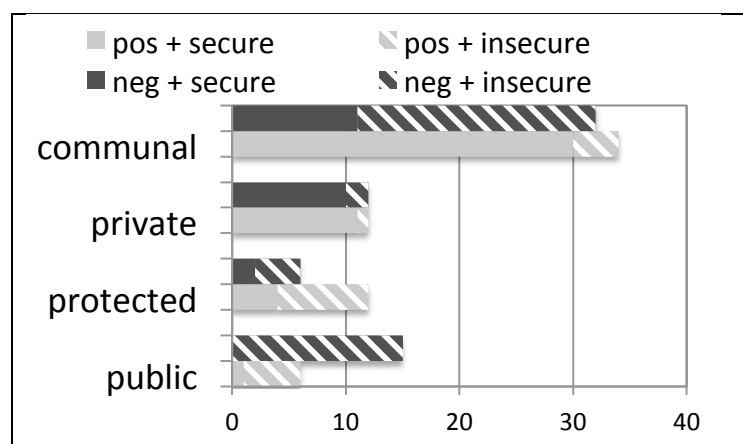
² Of our cases 42 out of 95 had (implied) tenure security.

³ This is possibly due to publication bias. Protected areas receive more attention when they are insecure, and public frontier areas have received attention for encroachment into the forest-farm interface via illegal occupation, which is a condition of insecurity.

or policies must take into account conditions that determine the value of alternative land uses relative to forest for local landholders.

Table 1 presents the marginal effects for multiple factors that influence positive (1) or negative (0) forest outcome, including a binary measure of tenure security (1=present, 0=absent) and dummy variables for the form of tenure. The first model (I) controls for tenure security and form, model (II) includes regional controls and model (III) adds interaction terms shown important in the descriptive results above. These models perform relatively well, correctly predicting 71-73% of the observations. The results are qualitatively consistent with equivalent linear probability (ordinary least-squares) and logit models (the sign, significance and relative magnitudes are all similar).

Figure 6 Form and tenure security



Irrespective of controls for the form of tenure and other regional effects, tenure security has a consistent positive effect on forest outcomes. On average our results imply that having secure tenure improves the probability of a positive forest outcome by about 40%.

Encouragingly, forests that are protected (parks and forest reserves) are about 40-50% more likely to be associated with positive forest outcomes relative to private land rights. After controlling for other factors, the effects of public and private land are not statistically different. The same is true for communal land until we specifically account for communal land in Africa. After including this interaction term (model III) the coefficient on communal land increases in magnitude and significance. This also statistically confirms the association between negative forest outcomes on communal land in Africa, noticeable in Figure 4a, which decreases the probability of a positive outcome by 50% in our sample. Other regional dummy variables show little influence on our forest outcome measure relative to the reference group of sites in Africa.

With regard to our first null hypothesis that the form of tenure does not matter, these results imply a mixed message. When controlling for other factors, namely tenure security, the effect of protected areas have a consistently positive impact on forest outcomes over the other forms of tenure.⁴ However, the outcomes from private and public land are statistically indistinguishable. Most simply, this makes sense because the “protected” class is the only form of land tenure that *dictates* a particular land cover, that is, that the land remains forested. All other forms of tenure give use rights and decision making to the landholder(s), who(m) may or may not find it beneficial to keep a particular piece of land in forest.

Regarding the second null hypothesis, we see empirical evidence to reject the null hypothesis that tenure security is not important. Although greater implied tenure security seems to improve the probability of positive forest outcomes, tenure security by no means prevents changes in forest cover, as can be seen in Figure 5. Payments or policies must take into account conditions that determine the value of alternative land uses relative to forest for local landholders.

⁴ The constant, whose marginal effects are not calculated, represents the reference group of private property (I) or private property in Africa (II, III). In models I and II, the constant was negative and borderline significant ($p \approx 0.09$ in both cases). In model III, the sign was negative but not significant ($p \approx 0.22$).

Table 1 Marginal effects for the predictors of the probability of observing negative (0) or positive (1) forest outcomes

	I		II		III	
Tenure security	0.41	(0.09)***	0.42	(0.09)***	0.39	(0.10)***
Communal	0.12	(0.13)	0.11	(0.15)	0.26	(0.15)*
Protected	0.38	(0.18)**	0.41	(0.18)**	0.47	(0.16)***
Public	0.15	(0.17)	0.17	(0.17)	0.29	(0.18)
<i>Private (reference)</i>						
Central America			0.04	(0.08)	-0.13	(0.15)
South America			0.02	(0.10)	-0.03	(0.18)
East Asia			-0.08	(0.08)	-0.23	(0.16)
South Asia			0.06	(0.09)	-0.08	(0.20)
Southeast Asia			0.38	(0.18)**	0.21	(0.18)
South Pacific			-0.09	(0.13)	-0.22	(0.14)
<i>Africa (reference)</i>						
Communal*Africa					-0.52	(0.26)**
Public*S America					-0.30	(0.25)
Duration of analysis (yrs)					0.00	(0.00)
<i>n</i>	129		129		119	
log psuedolikelihood	-77.0		-75.4		-63.3	
pseudo-R ²	0.14		0.16		0.23	
% correctly predicted	71%		71%		73%	

Coefficients reported represent the marginal effect of a discrete change in a variable from 0 to 1.

Robust standard errors are in parentheses, clustered by publication.

* p < 0.10; ** p < 0.05, *** p < 0.01

5 Broad Lessons from the Land Tenure Literature

5.1 The form of tenure does not imply security

The results of our analysis show that all forms of land tenure are susceptible to tenure insecurity. However, often land tenure security is mistakenly linked with particular forms of land tenure. Perhaps born out of concepts embodied in *The Tragedy of the Commons* (Hardin 1968), open access resource models (e.g. Gordon 1954) and early assumptions that titling land would solve deforestation problems (van den Brink et al. 2006), property rights over natural resources are often naïvely viewed along a spectrum of “strength” from unstable open access systems to strong private ownership. Common property resource systems are seen as middle ground (Cheung 1970, Dasgupta and Heal 1979). Private property rights are conceptualized as the most secure, where owners are able to maximize profits and harvest sustainably. In areas with no formal property rights, so the story goes, resources are overharvested and profits dwindle because tenure is insecure. This view promotes the idea that individual forms of land tenure are more secure, while tenure granted to larger groups are assumed inherently weak. The empirical cases reviewed here show that these assumptions are incorrect.

Decades of common property research shows that informal social controls and local collective action can mitigate the “tragedy” resulting from competition over common-pool resources (Agrawal Arun 2001, Bromley DW 1992, Ostrom 1990), and even systems that have no operating rules over resource use can perform quite close to private systems depending on local context. It is a fallacy to categorically ascribe security to any particular form of land tenure.

In our view, it is an oversimplification to empirically equate land tenure security with private property rights or the possession of land title. Many forms of tenure are legitimate when properly recognized by national and/or local legal systems (Bruce et al. 2010). Yet scholars constrained by data collection limitations and time may assume private rights are the most secure (e.g. Pichón 1997), and use title as a basis to infer the effect of tenure security. But legitimate communal land, public property and leased property can also be secure and, in some cases, private holdings may be suboptimal for other reasons. For instance, Wainwright (2009) describes a process of privatizing communal land that instigated land speculation and

clashed with local cultural and spiritual beliefs. Others have argued that tenure security can, at times, have negative consequences for environmental public goods (Garnett et al. 2007).

5.2 Communal land

More than one billion people depend on forests for their livelihoods (FAO 2008), and large fraction live in communities with communal or customary rights to forest (Agrawal A 2007). Thus communal land is a special category of interest. Further, agencies are exploring initially targeting communal land for REDD+ programs to avoid high transaction costs associated with identifying, contracting with and monitoring individual landowners.

Looking at the body of studies reviewed, communal and customary land tenure have mixed effects on forest outcomes (

Figure 3 Forest outcomes and type of tenure

), but some patterns begin to emerge at the regional level (Figure 4). In African communities, communal and customary land tenure systems seem to have a negative association with forest outcomes. In part, this could be due to our inability to distinguish between communal systems and customary ownership. In many African cases, customary rights are more common and had much historical significance but, recently, enforcement of traditional rules has been difficult due to population growth, poverty and emerging market and political forces (e.g. Kakembo 2001, Mwavu and Witkowski 2008). Further, Africa has been especially wrought with civil conflict and related changes in governance structures. These have likely had an impact on natural resource use.

An emerging body of “large- N ” research is documenting how communities can engage in collective action to prevent degradation of common pool resources, particularly when a community has recognized property rights. Van Laerhoven (2010) finds community monitoring and maintenance among the most important predictors of forest stability, and Gibson et al (2005) argues that rule *enforcement* is important for positive community forest outcomes. Hayes (2006) highlights the importance of communal rules, and forest governance is linked with positive forest outcomes in Persha et al’s (2011) study of Asian and African communal forests and Hyde et al’s (2003) study of forests in China. Similarly, Pagdee (2006) finds a positive correlation between tenure security and positive forest outcomes in a meta analysis of common property studies.

Our review shows a mix of outcomes for forests held in common, highlighting the fact that communal settings face land use pressures just like any other form of land tenure. Other work shows that degradation of the commons can rightfully be attributed to conditions from outside a user group as well, acknowledging the need to address larger institutional incoherence (Bromley DW 2008). Therefore even when rights to common lands are secure, collective decision-making may find it desirable to convert forest to some other land use.

5.3 Tenure data and measurement

In reviewing the empirical literature, it is apparent that over the past twenty years data on forest cover and forest conditions is increasing in both quantity and quality, but the same is not true of land tenure data, which require physical delineation and demarcation of social

relations, which are sometimes contested. The quality of remotely sensed data increases with technology, but measuring tenure often involves knowledge of intangible relationships or agreements between communities. Analysis of forest cover change is evolving to explore temporal dynamics and spatial patterns, yet investigation of the drivers of forest cover change is lagging, often due to insufficient data on spatially explicit land tenure at various points in time.

Spatial land tenure datasets are rarely available, requiring researchers to create maps from proxies. At the regional or national scale, often the best source for tenure data is an agricultural census, which focuses only on certain types of landholdings (mainly lands managed for cultivation or livestock, with limited forested areas), and neglects local nuance in communal and customary rules and norms. At a more local scale, household surveys and participatory mapping are key method for deriving spatial definitions of land tenure. This translates into datasets that may be consistent with community perceptions but may not, in fact, be recognized by the state or surrounding communities. Therefore, external validity can be an issue. For these reasons, it can be difficult to find agreement with locally-derived tenure data and regional or nationally-defined land tenure systems.

As a specific example we note our difficulties parsing communal and customary land tenure for this review (noted above, communal and customary forms of tenure were often conflated, restricting us to categorize both in a “communal” category). Communal land is the label often used to categorize a range of tenure forms related to customary and common property rights that do not fit neatly into other categories (Ankersen and Barnes 2004). Communities with customary land rights may have complex rules and overlapping forms of tenure that apply to different land based resources (e.g., Long and Zhou 2001) and are a complex of open and communal regimes. How are researchers to categorize such systems for comparability with other areas? Without a good way to deal with these issues, studies tend to use “common property” as a catch-all term for what can be a set of wildly diverse governance systems.

Key challenges remain in conceptually linking and spatially modeling human dimensions that influence or drive tropical deforestation. “Tenure” is sometimes simply noted as a deforestation risk factor or driver, but without a causal explanation (Rudel et al. 2005).

“People and pixels” issues are of particular concern for studies attempting to match forest

cover change results based on remotely-sensed imagery with locally-derived forest tenure and governance variables (Liverman and Cuesta 2008, Ostrom and Nagendra 2006).

Correctly documenting the form of tenure is challenging, but measuring tenure *security* is even more difficult since security can be legitimate or perceived and security is largely determined by intangible characteristics that influence decision-making. For these reasons, few empirical articles explicitly aim to measure tenure security (Arnot et al. 2011). Further, the form of land tenure is fundamentally a static concept while land tenure security is inherently forward-looking, expressing the expectation that the benefits and duties provided by the rules and norms that make up land tenure will be upheld in the future (Sjaastad and Bromley 2000). Tenure security reflects a perception of risk.

6 Conclusion

6.1 How does tenure matter?

The main goal of this article is to better understand when tenure and tenure security are likely to be important factors in the conversion of forest to farmland. First, we emphasize that land tenure is inextricably linked to many socioeconomic and governance factors, thus it is difficult to disentangle tenure from other direct and indirect causes of deforestation. Most fundamentally, the *form* of land tenure can be composed of many different property right bundles, and specific bundles affect forest outcomes in different ways. Further, the review of empirical studies reveals that no form is immune from deforestation pressure.

At an aggregate level, the form of land tenure seems to matter in different ways in different regions of the world. We cannot rule out selection bias given our relatively small sample of case studies in each region, but these outcomes seem to emphasize the importance of local factors. Overall, protected land is associated with the positive outcomes in all regions, but public land seems to be taken advantage of particularly in South America. Communal land seems to perform well in Central America but worse in Africa, possibly due to the effects of regional conflict. However, in particularly poor areas, common property can be advantageous in other ways: community members can access common land for farming when external shocks would otherwise induce crises (van den Brink et al. 2006).

Table 2 Does Tenure Security Slow Deforestation? Sample Explanations from the Literature

Yes (clearly important)	Helps, but inadequate	Insignificant
<p>“The main outcome of this paper is that insecure property rights in land drive deforestation in the Brazilian Amazon.” - (Araujo et al. 2009)</p>	<p>“Defined land tenure is not enough to guarantee a successful settlement that combines intensive forms of agriculture and conservation of forest.” - (Futemma and Brondizio 2003)</p>	<p>Threats from outsiders - colonists, Shining Path guerrillas, road crews - continued to plague the Yanasha, even after they had official title to their land. - (Morrow 1996)</p>
<p>As the above findings show, all things being equal, titled farmers deforest less than those without title. ...thus [no title] causes negative environmental effects whenever it leads farmers to forgo investment in the agricultural resource base they would otherwise have undertaken.” - (Pichón 1997)</p>	<p>It is unclear whether, alone, the common property institutions of Tziscaco would be sufficient to prevent overuse of the common pool forest resource; the needs of the growing population of Tziscaco may perhaps exceed their managerial scope. At present, joint regulations [communal and national park] are robust enough to respond to the needs of current residents of the community.” - (Johnson and Nelson 2004)</p>	<p>“The results of this study suggest that interactions between land use factors may be more important in determining miombo woodland regeneration and re-growth structure than land tenure type. Accordingly, it is recommended that future management of miombo woodland should emphasize more the regulation of land use activities than the changing of land tenure systems.” - (Chidumayo 2002)</p>

Further, while we have argued that the form of tenure can take many shapes, ensuring that tenure is *secure* is perhaps more important for designing policies to influence forest outcomes. Theoretical economic models demonstrate that decreases in tenure security decrease the net present value of all land uses, but can impact forested land uses more than agriculture. This is not always the case, as land use decisions are fundamentally determined by the evaluating the value of land use options, so surely we would never expect safeguarding tenure security alone to stop deforestation. However, security does seem to increase the empirical probability of positive forest outcomes, even after controlling for regional factors and the form of tenure. Table 2 gives sample explanations for the connection between tenure (security) and deforestation from some of the empirical literature we review above. Some studies claim tenure is of the utmost importance, while others find it marginal or insignificant.

In sum, land tenure and tenure security are not, in and of themselves, perfect safeguards for forests. Tenure and tenure security enable landholders, whether individuals, household or communities, to take into account future values into current decision-making. This matters not just for forests, but for any benefit accruing from the land over time. However, in light of PES programs and REDD+, where future incentives are tied to particular land use-based duties (e.g. maintain forestland), the security of tenure is crucial to influence landholders’ decision-

making. Therefore, tenure security is necessary to prevent deforestation through market-based mechanisms, but alone does not necessarily protect forests. A quote by Garnett et al (2007) captures this nicely:

... tenure is not always an effective means of protecting natural capital. When equitable tenure is established, it can provide incentives to invest in built capital rather than conserve natural capital. Although sustainable management of natural resources is seen as one of the benefits of land reform, the capacity to invest in agricultural intensification is an even more desirable consequence... Nor does secure communal tenure necessarily protect natural values... Thus, secure tenure and land title may not be a universal panacea for poor management of the commons.

6.2 Future research

Future empirical studies should be clear in describing how they conceptualize issues around tenure form and security. What forms of tenure exist in the study area? What is the respective security of each land tenure form as perceived by landholders? To simply use land title as a metric for tenure security should be avoided, at least without proper justification relative to other factors that might affect tenure security in the study area.

As better data become available, we see a need for more studies that analyze site-specific land use change over time or account for covarying land qualities across tenure types. Joppa and Pfaff (2010) describe the advantages of statistical “matching” techniques for land cover datasets that addresses the latter concern. Most studies reviewed compared forest cover trends for different areas that have different tenure regimes, but this ignores the potential endogeneity of tenure choice that may be based, at least in part, on existing forest characteristics. For example, productive forests near urban centers might be under private management to protect that productivity. Communal holdings may be in rural areas simply because competition is weaker and enforcement of borders is not as costly. Additionally, with time series data studies should increasingly be able to use techniques to control for time-varying factors through difference-in-difference methods or a combination of difference-in-difference and matching. Looking at changes in deforestation trends on the same piece of land with a change in tenure, while controlling for other time-varying factors and endogeneity, better captures tenure’s *ceteris paribus* effect.

A better understanding of how the larger suite of economic and social pressures impact forest users is needed. These macro conditions often create incentives that induce encroachment into forests, but are not often given credit for “explaining” deforestation activity. Documenting and understanding such linkages is largely missing, and addressing the larger institutional factors underlying these problems is a much more challenging issue (Bromley DW 2008).

Most important, research is needed to better understand how to strengthen tenure security. In many areas, communities have legal land rights, but do not feel secure that other policy changes or political maneuvers will compromise those rights. Land tenure insecurity is likely a symptom of more broad political and economic systemic incoherence that individuals face. We must often look beyond forests themselves to find the final causes of deforestation in a region (Bromley Daniel W. 1999). With regard to the implementation of REDD+, communities need assurance that current land use decisions will result in future benefits. What are options to promote landholders’ security in current tenure arrangements, and which are most likely to be effective in what situations? In general, likely the most important is the hard work of strengthening legal and social institutions. Some interim steps may include promotional campaigns, prosecuting more cases against land claims and dialogue among communities and agents of the state to ensure claims will be upheld.

6.3 Addressing tenure issues at the forest-farm interface

To reduce emissions is to halt expansion of the frontier. Policies that aim to limit further conversion of forest to agriculture must first understand the incentives for conversion. Are there policies favoring agricultural conversion? Are there recent changes in relative agricultural or forest-product prices, access to markets or the arrival of new technologies that might be shaping incentives for greater conversion? If so, these factors may have just as much, if not more, short-term impact on emissions at the forest-farm interface as securing tenure. Moreover, policies that aim to change land use decisions must provide enough incentive to reverse any landholder’s incentive to engage in agriculture. But to understand what quantity of compensation is “enough,” we must understand the context in which land use decisions are made. Additionally, security in such payments is needed. For policies to have any lasting effect, clarifying tenure and developing a supporting institutional environment to back tenure claims is crucial.

That said, where tenure security is currently lacking, transitions can be difficult (Ho and Spoor 2006). In some cases, the process of clarifying tenure can hastened deforestation. Securing tenure may result in increased access to credit, which can positively or negatively impact forests. In another example, Deacon and Mueller (2006) argue that strengthening property rights can encourage competition for land acquisition, resulting in rent-seeking behavior with the potential for violent conflict. Deforestation can also accelerate when securing tenure is tied to “beneficial use” of land (i.e., deforestation), as we see in many of the studies of the Amazonian region (e.g. Mena et al. 2006, Rudel 1995, van Gils and Ugon 2006). In Côte d'Ivoire a process aimed to fully capture the rights tied to communal access to resources, but this proved to be complex and ended in a simplification of rights that strengthened individual rights over common ones (van den Brink et al. 2006).

These anecdotes caution us that efforts to clarify tenure can be risky for people *and* for forests. Tenure interventions likely improve livelihoods for some but may worsen it for others. Clarifying and strengthening tenure are costly and slow, but investment is needed for both social equity and environmental sustainability. Resolving tenure issues is not just about clearly demarcating boundaries, but can sometimes resemble a conflict resolution process. Working both at local- and policy-levels is vital to ensure smooth social and statutory transitions (Garnett et al. 2007).

Our review of studies highlights the complexity of on-the-ground tenure situations. Land tenure and the related issue of “whom to pay” has been widely recognized in the context of REDD+ (Cotula and Mayers 2009, Sandbrook et al. 2010, Sunderlin et al. 2009, Wendland 2008), and the empirical literature shows that complex tenure arrangements should be considered the rule and not the exception (Unruh 2008).

We need a frame of reference for tenure security in any given situation in order to understand its effect on forests. Tenure insecurity is often cited as a cause for resource degradation. But inferring a causal relationship between tenure security, singularly, and deforestation is to ignore the larger context in which tenure is embedded and defines the impact of such an institution. This is certainly one reason for tenure’s varied outcomes regarding forest cover seen in the literature reviewed above. Secure tenure helps prevent deforestation in some areas, but does not change landholders’ underlying right to make land use decisions as they see fit. Indeed, when there are strong benefits to clearing forest, a landholder with secure rights will

need very strong external incentives to keep her forest ecosystems intact. Tenure and tenure security matter, but they matter only in the context of other policy, economic and infrastructural changes. We stress the need for secure and clear land rights, but policy makers and policy promoters must be mindful of the larger context within which communities are embedded.

7 Methods Appendix

7.1 Framework for assessing empirical studies

Our conceptual framework aims to measure whether there is a relationship between tenure or tenure security and forest outcomes using prior published empirical studies. We first record the form of tenure being discussed. Second, we use the context of the discussion or author's explicit recognition of the tenure security of that particular land area or parcel. Finally, we record whether the incentives for forest conservation are higher or lower, relative to forest held in other types of tenure in the study. At each of these three levels, we choose decision rules about how to develop categories. We describe these decision rules in detail below, and then give an example from one of the case studies included in the review.

We first record the form of tenure as described by paper authors. From paper descriptions, it is not always possible to discern *de jure* from *de facto* tenure. When these concepts are both clearly discussed within a study, we opt to use the *de facto* arrangement for analysis, since *de facto* arrangements drive landholders' decisions. The review of studies results in the following categories: unmanaged public land (frontier or open access), public land managed by a government agency (parks or reserves), communal, private, usufruct rights, leasehold/rent, customary/traditional, and concession land. To facilitate comparisons, we re-categorize usufruct rights, leasehold and concession into either private, communal/customary, protected or frontier land, using the context of the paper to determine the best fit. We also collapse communal tenure and customary/traditional tenure into one category. In some cases, we think it is likely that land labeled "communal" would be better described as customary. In our view, the lesser bias is to use one communal category to summarize our findings.

Many empirical studies mention the importance of tenure security, but few explicitly make a claim as to the particular security or insecurity of land parcels. In cases where tenure security

was not explicitly addressed we turn to the context of the study to infer the implied tenure security for that form of tenure. Situations we label “insecure” are where, for example, *de jure* and *de facto* tenure are not the same, communities are adjusting to new tenure arrangements or enforcement and monitoring of tenure arrangements are stated as particularly weak.

At the third level, forest outcomes are reported in various ways. Some studies report relative measures for forest outcomes, e.g. comparing forest conditions under one form of tenure to forest conditions in a different form. Others report absolute changes in forest cover over time. Those that look at relative measures tend to celebrate not only forest regeneration, but also slowed deforestation. Others report any absolute forest loss negatively. Relatively few studies analyze how forest outcomes change with a change in tenure on the same piece of land, but simply report forest outcomes associated with different tenure. Regardless, we treat these equally in our review, which simply discerns the forest outcome associated with a particular tenure type.

For forest cover, we first categorize outcomes as reported by the studies. For relative studies we record whether deforestation accelerated, slowed or if forest regeneration accelerated relative to comparative areas in the study. When only the magnitude of forest stock was reported, we recorded whether forests were maintained, lost or regenerated⁵. We then simplify these categories into a binary positive and negative forest outcome. Relative measures imply a clear normative relationship: accelerated deforestation is negative while slowed deforestation or forest regeneration is positive. However, when studies only report absolute measures, we generally classified forest loss as negative and forest maintained or regenerated as positive, but look to the study for contextual interpretation.

As an example of study coding, Futemma (2003) describes a case in which land users have had *de facto* rights to the land for centuries, but recently the forest was delineated and usufruct rights were granted to households while private titling was in process. We categorize this tenure form as private since the land has been delineated and landholders know title is coming, but we label its tenure as insecure since title has yet to come and the system is in

⁵ We try to focus on relative measures since our focus here is on the relative performance of secure tenure and the relative measures contain the absolute information (i.e., if deforestation is slowed or accelerated, we know there was forest lost in either case).

flux. In this study, Fudemma shows that usufruct rights resulted in forest loss, which we categorize as negative.

7.2 Methods

7.2.1 Case selection

We select cases that analyze land use change over time and discuss property rights or land tenure. We target studies that use primary or secondary remote sensing data to measure forest cover change over time, but include cases where change in forest outcomes is measured using in-field inventories or discussed in careful detail.

To find publications, we searched academic databases with combinations of terms related to forests, land tenure, property rights, land use and remote measurement. Publications selected for analysis are also reviewed for reference to relevant studies. Finally, we asked several key informant academics to review our list of publications and offer suggestions for other studies. We narrow our selection to 39 publications and drop studies that do not meet our criteria.

7.2.2 Coding of cases

We use a standardized questionnaire to code all cases. The questionnaire includes questions about the effect of several key variables on deforestation such as: owner type, the form of tenure, tenure security (assurance), governance, collective action and other proximate causes (infrastructure, agriculture, demographics, technology, etc.). The survey contains mostly structured questions but includes open ended responses to capture nuance in findings.

Questionnaires were each completed by the co-authors or coders (graduate students) who are trained in the relevant issues and broadly familiar with the literature. After coding cases began, regular meetings were held with all coders to ensure consistency in interpretation, reporting and to address other conceptual issues as a team. Before compilation of findings, the lead author additionally reviewed all articles and responses for consistency.

7.2.3 Analysis methods and assumptions

All studies were input into a database by the number of sites analyzed within a study. Sites are further disaggregated into the forms of tenure present at each site, which were each labeled as a separate case. Cases are our fundamental units of analysis, each carrying equal weight. We

compile descriptive statistics by case and, when appropriate, we use statistical tests to infer confidence in observed differences.

7.2.4 Limitations

As with any review of literature, our inferences are inherently biased since the studies we review take place in settings where forests and tenure issues are particularly salient. Thus, there is inherent bias in our sample selection.

In some geographic areas, we found a limited amount of published literature. For example, we encountered relatively few studies in Asia and the south Pacific (Figure 2), where remote sensing analyses have been less frequent and tenure studies often focuses on communal or customary land managed by minority groups (e.g., see Pagdee et al. 2006), but forest cover change is less quantitative. Similarly, forest cover change in West Africa seems to have received limited attention (although Africa as a continent is well represented). There, studies are dominated with other explanatory factors such as migration, climate change and colonial inheritance (Ouedraogo et al. 2009, Ouedraogo et al. 2010, Paré et al. 2010, Wardell et al. 2003). Where land tenure is explicitly discussed it often comes in the context of complex community relations and resource-allocation norms but is not connected to forests (Reenberg 2001).

7.2.5 Case descriptions

The majority of our 43 sites are in tropical forest and the dominant land use activities are subsistence agriculture, livestock production, subsistence forest use and commercial agriculture (

Table 3). Twenty-nine of the sites are located in protected areas and 16 were on indigenous groups' land.

Table 3 Dominant vegetation and land uses at 43 sites

Dominant vegetation types		Dominant economic land use activity	
tropical forest	92	subsistence agriculture	122
wetlands	14	subsistence forest use	82
montane forest	27	commercial agriculture	63
grassland	7	livestock production/ranching	61
tropical dry forest	9	commercial NTFP collection	41

mangroves	3	commercial logging	24
		hunting	13
		tourism	7

While remote sensing data was used 28 sites, the remaining cases utilized previous remote sensing studies, plot-level analysis, or household and community surveys to examine land use change. Remote sensing utilized mostly Landsat imagery (24 of the 28 sites) and focused on change over time from forest to non-forest or the conversion of forest to agriculture. Many of these studies used hybrid approaches to match remote sensing analysis with household or community-based surveys (22 sites). The duration of analysis ranges from one to fifty years (Table 4), with an average of 14 years. The study area for each site varies considerably, from less than one square kilometer to approximately 5 million km² (the area of the nine Brazilian Amazonian states). Excluding the high outlier, the average size of area studied is 4,856 km².

Table 4 Case areas and duration of analysis

	Minimum	Mean	Median	Maximum	N (# reporting)
Study area (km ²)	0.06	4,856*	241	64,000*	99
Duration analyzed (# yrs)	1	14.2	12	50	121

*After excluding the high-end outlier (5million km² (Araujo et al.)).

We also gathered information on how forest outcomes were associated with other measures, such as the length of time over which forest cover change was analyzed, presence of violent conflict, infrastructure characteristics and other demographic factors. However, none of these factors showed a significant relationship with forest cover or their presence in our study set was limited. Since our focus is on tenure measures, we report these in the main text.

References

Empirical Studies Reviewed

- Alston L, Libecap G, Mueller, B. 2000. Land reform policies, the sources of violent conflict, and implications for deforestation in the Brazilian Amazon. *Journal of Environmental Economics and Management* 39(2): 162-188.
- Araujo C, Bonjean C, Combes J, Combes Motel P, Reis E. 2009. Property rights and deforestation in the Brazilian Amazon. *Ecological Economics* 68(8-9): 2461-2468.
- Carrero GC and Fearnside PM. 2011. Forest clearing dynamics and the expansion of landholdings in Apuí, a deforestation hotspot on Brazil's Transamazon Highway. *Ecology and Society* 16(2).
- Castillo-Santiago M, Hellier A, Tipper R, de Jong B. 2007. Carbon emissions from land-use change: an analysis of causal factors in Chiapas, Mexico. *Mitigation and Adaptation Strategies for Global Change* 12(6): 1213-1235.
- Chakraborty RN. 2001. Stability and outcomes of common property institutions in forestry: evidence from the Terai region of Nepal. *Ecological Economics* 36(2): 341-353.
- Chidumayo E. 2002. Changes in miombo woodland structure under different land tenure and use systems in central Zambia. *Journal of Biogeography* 29(12): 1619-1626.
- Collins J. 1986. Smallholder settlement of tropical South America: the social causes of ecological destruction. *Human Organization* 45(1): 1-10.
- Ekadinata A, Dewi S, Hadi D, Nugroho D. 2007. *Can Secure Tenure Help Reduce Deforestation?* World Agroforestry Centre South East Asia.
- Futemma C and Brondizio E. 2003. Land reform and land-use changes in the lower Amazon: Implications for agricultural intensification. *Human Ecology* 31(3): 369-402.
- Godoy R, Jacobson M, de Castro J, Aliaga V, Romero J, Davis A. 1998. The role of tenure security and private time preference in neotropical deforestation. *Land Economics* 74(2): 162-170.
- Hayes T. 2007. Does tenure matter? A comparative analysis of agricultural expansion in the mosquitia forest corridor. *Human Ecology* 35(6): 733-747.
- Hayes T and Murtinho F. 2008. Are indigenous forest reserves sustainable? An analysis of present and future land-use trends in Bosawas, Nicaragua. *International Journal of Sustainable Development & World Ecology* 15(6): 497-511.

- Jakobsen J, Rasmussen K, Leisz S, Folving R, Quang N. 2007. The effects of land tenure policy on rural livelihoods and food sufficiency in the upland village of Que, North Central Vietnam. *Agricultural Systems* 94(2): 309-319.
- Johnson K and Nelson K. 2004. Common property and conservation: The potential for effective communal forest management within a national park in Mexico. *Human Ecology* 32(6): 703-733.
- Kakembo V. 2001. Trends in vegetation degradation in relation to land tenure, rainfall, and population changes in Peddie district, Eastern Cape, South Africa. *Environmental Management* 28(1): 39-46.
- Kijima Y, Sakurai T, Otsuka K. 2000. Iriaichi: Collective versus Individualized Management of Community Forests in Postwar Japan. *Economic Development and Cultural Change* 48(4): 867-886.
- Klooster D. 2000. Institutional Choice, Community, and Struggle: A Case Study of Forest Co-Management in Mexico. *World Development* 28(1): 1-20.
- Kuri P. 2007. Extractions of Common Property Resources and its Implications to Environmental Degradation and Poverty in Arunachal Pradesh. *Environment and Ecology* 25(2): 265-269.
- Linkie M, Smith R, Zhu Y, Martyr D, Suedmeyer B, Pramono J, Leader-Williams N. 2008. Evaluating biodiversity conservation around a large Sumatran protected area. *Conservation Biology* 22(3): 683-690.
- Long C and Zhou Y. 2001. Indigenous community forest management of Jinuo people's swidden agroecosystems in southwest China. *Biodiversity and Conservation* 10: 753-767.
- Ludewigs T, D'antona A, Brondízio E, Hetrick S. 2009. Agrarian Structure and Land-cover Change along the Lifespan of Three Colonization Areas in the Brazilian Amazon. *World Development* 37(8): 1348-1359.
- Lund J and Treue T. 2008. Are We Getting There? Evidence of Decentralized Forest Management from the Tanzanian Miombo Woodlands. *World Development* 36(12): 2780-2800.
- Luoga E, Witkowski E, Balkwill K. 2005. Land cover and use changes in relation to the institutional framework and tenure of land and resources in eastern Tanzania miombo woodlands. *Environment, Development and Sustainability* 7(1): 71-93.
- Mena CF, Barbieri AF, Walsh S, Erlien C, Holt F, Bilsborrow R. 2006. Pressure on the Cuyabeno Wildlife Reserve: Development and Land Use/Cover Change in the Northern Ecuadorian Amazon. *World Development* 34(10): 1831-1849.

- Messina J, Walsh S, Mena C, Delamater P. 2006. Land tenure and deforestation patterns in the Ecuadorian Amazon: Conflicts in land conservation in frontier settings. *Applied Geography* 26(2): 113-128.
- Mwase W, Bjørnstad Å, Bokosi J, Kwapata M, Stedje B. 2007. The role of land tenure in conservation of tree and shrub species diversity in miombo woodlands of southern Malawi. *New Forests* 33(3): 297-307.
- Mwavu E and Witkowski E. 2008. Land-use and cover changes (1988-2002) around budongo forest reserve, NW Uganda: implications for forest and woodland sustainability. *Land Degradation & Development* 19(6): 606-622.
- Nabanoga G and Gombya-Sembajjwe W. 2001. The effect of household endowments and entitlements on sustainability of natural forests. *International Forestry Review* 3(1): 34-41.
- Naughton-Treves L, Alix-Garcia J, Chapman C. 2011. Lessons about parks and poverty from a decade of forest loss and economic growth around Kibale National Park, Uganda. *Proceedings of the National Academy of Sciences* 108(34): 13919-13924.
- Nelson G, Harris V, Stone S. 2001. Deforestation, land use, and property rights: empirical evidence from Darien, Panama. *Land Economics* 77(2): 187.
- Owubah CE, Le Master DC, Bowker J, Lee J. 2001. Forest tenure systems and sustainable forest management: the case of Ghana. *Forest Ecology and Management* 149(1-3): 253-264.
- Pichón F. 1997. Colonist land-allocation decisions, land use, and deforestation in the Ecuadorian Amazon frontier. *Economic Development and Cultural Change* 45(4): 707-744.
- Place F and Otsuka K. 2000. Population Pressure, Land Tenure, and Tree Resource Management in Uganda. *Land Economics* 76(2): 233-251.
- Rudel T. 1995. When do property rights matter? Open access, informal social controls, and deforestation in the Ecuadorian Amazon. *Human Organization* 54(2): 187-194.
- Sirén A. 2007. Population Growth and Land Use Intensification in a Subsistence-based Indigenous Community in the Amazon. *Human Ecology* 35(6): 669-680.
- Turyahabwe N, Geldenhuys C, Watts S, Tweheyo M. 2008. Linking forest tenure and anthropogenic factors with institutions and the effectiveness of management in Mpigi forests, central Uganda. *Southern Forests: a Journal of Forest Science* 70(3): 255-267.
- van Gils H. and Ugon A. 2006. What Drives Conversion of Tropical Forest in Carrasco Province, Bolivia? *AMBIO: A Journal of the Human Environment* 35(2): 81-85.
- Varughese G and Ostrom E. 2001. The Contested Role of Heterogeneity in Collective Action: Some Evidence from Community Forestry in Nepal. *World Development* 29(5): 747-765.

Wannasai N and Shrestha R. 2008. Role of land tenure security and farm household characteristics on land use change in the Prasae Watershed, Thailand. *Land Use Policy* 25(2): 214-224.

Cited in text

Agrawal A. 2001. Common Property Institutions and Sustainable Governance of Resources. *World Development* 29: 1649-1672.

Agrawal A. 2007. Forests, governance, and sustainability: Common property theory and its contributions. *International Journal of the Commons* 1: 111.

Amacher GS, Koskela E and Ollikainen M. 2009. Deforestation and land use under insecure property rights. *Environment and Development Economics* 14: 281-303.

Andam KS, Ferraro PJ, Pfaff A, Sanchez-Azofeifa GA and Robalino JA. 2008. Measuring the effectiveness of protected area networks in reducing deforestation. *Proceedings of the National Academy of Sciences* 105: 16089-16094.

Angelsen A. 2007. Forest Cover Change in Space and Time: Combining the Von Thunen and Forest Transition Theories. *World Bank Policy Research Working Paper*

Ankersen T and Barnes G. 2004. Inside the polygon: emerging community tenure systems and forest resource extraction. In: D. Zarin, J. Alavalapati, F. Putz and M. Schmink. *Working forests in the neotropics: conservation through sustainable management*. New York, USA: Columbia University Press.

Araujo C, Bonjean C, Combes J, Combes Motel P and Reis E. 2009. Property rights and deforestation in the Brazilian Amazon. *Ecological Economics* 68: 2461-2468.

Arnot C, Luckert MK and Boxall PC. 2011. What is Tenure Security? Conceptual Implications for Empirical Analysis. *Land Economics* 87: 297-311.

Barbier EB and Burgess JC. 2001. Tropical Deforestation, Tenure Insecurity, and Unsustainability. *Forest Science* 47: 497-509.

Bohn H and Deacon R. 2000. Ownership risk, investment, and the use of natural resources. *American Economic Review* 90: 526-549.

Broegaard R. 2005. Land tenure insecurity and inequality in Nicaragua. *Development and Change* 36: 845-864.

Bromley D. 1992. *Making the commons work: Theory, practice, and policy*. San Francisco: ICS Press.

Bromley D. 2008. Resource degradation in the African commons: accounting for institutional decay. *Environment and Development Economics* 13: 539-563.

- Bromley DW. 1999. Deforestation - Institutional Causes and Solutions. In: M. Palo and J. Uusivuori. *World Forests, Society and Environment*. Dordrecht, The Netherlands:
- Bruce J, Wendland K and Naughton-Treves L. 2010. Whom to pay? Key Concepts and Terms regarding Tenure and Property Rights in Payment-based Forest Ecosystem Conservation. Madison, WI: Land Tenure Center.
- Cheung SN. 1970. Structure of a Contract and the Theory of a Non-Exclusive Resource, *The Journal of Law and Economics* 13: 49.
- Chidumayo E. 2002. Changes in miombo woodland structure under different land tenure and use systems in central Zambia. *Journal of biogeography* 29: 1619-1626.
- Clarke HR, Reed WJ and Shrestha RM. 1993. Optimal enforcement of property rights on developing country forests subject to illegal logging. *Resource and Energy Economics* 15: 271-293.
- Cotula L and Mayers J. 2009. *Tenure in REDD: start-point or afterthought?* London, UK: International Institute for Environment and Development.
- Dasgupta P and Heal G. 1979. *Economic Theory and Exhaustible Resources*. Cambridge University Press.
- Deacon RT and Mueller B. 2006. Political economy and natural resource use. *Economic development and environmental sustainability: new policy options* 122.
- Deininger K and Feder G. 2009. Land Registration, Governance, and Development: Evidence and Implications for Policy. *The World Bank Research Observer* 24: 233-266.
- FAO. 2008. Forests and poverty reduction. <http://www.fao.org/forestry/livelihoods/en/>.
- Feder G and Feeny D. 1991. Land tenure and property rights: Theory and implications for development policy. *the world bank economic review* 5: 135.
- Fitzpatrick D. 2006. Evolution and Chaos in Property Right Systems: The Third World Tragedy of Contested Access. *Yale Law Journal* 115: 996-1048.
- Futemma C and Brondizio E. 2003. Land reform and land-use changes in the lower Amazon: Implications for agricultural intensification. *Human Ecology* 31: 369-402.
- Garnett S, Sayer J and Du Toit J. 2007. Improving the effectiveness of interventions to balance conservation and development: a conceptual framework. *Ecology and Society* 12: 2.
- Gibson CC, Williams JT and Ostrom E. 2005. Local Enforcement and Better Forests. *World Development* 33: 273-284.
- Gordon HS. 1954. The Economic Theory of a Common-Property Resource: The Fishery. *The Journal of Political Economy* 62: 124.
- Hardin G. 1968. The Tragedy of the Commons. *Science* 162: 1243-1248.

- Hayes TM. 2006. Parks, People, and Forest Protection: An Institutional Assessment of the Effectiveness of Protected Areas. *World Development* 34: 2064-2075.
- Ho P and Spoor M. 2006. Whose land? The political economy of land titling in transitional economies. *Land Use Policy* 23: 580-587.
- Hotte L. 2005. Natural-resource exploitation with costly enforcement of property rights. *Oxford Economic Papers* 57: 497-521.
- Hyde WF, Belcher BM and Xu J. 2003. *China's forests: global lessons from market reforms*. Washington, DC: RFF Press.
- Johnson K and Nelson K. 2004. Common property and conservation: The potential for effective communal forest management within a national park in Mexico. *Human Ecology* 32: 703-733.
- Joppa LN and Pfaff A. 2010. Reassessing the forest impacts of protection: The challenge of nonrandom location and a corrective method. *Annals of the New York Academy of Sciences* 1185: 135-149.
- Joppa LN and Pfaff A. 2011. Global protected area impacts. *Proceedings of the Royal Society: Biological Sciences* 278: 1633.
- Kaimowitz D and Angelsen A. 1998. *Economic models of tropical deforestation: a review*. Bogor, Indonesia: Center for International Forestry Research (CIFOR).
- Kakembo V. 2001. Trends in vegetation degradation in relation to land tenure, rainfall, and population changes in Peddie district, Eastern Cape, South Africa. *Environmental Management* 28: 39-46.
- Liverman D and Cuesta R. 2008. Human interactions with the Earth system: people and pixels revisited. *Earth Surface Processes and Landforms* 33: 1458-1471.
- Long C and Zhou Y. 2001. Indigenous community forest management of Jinuo people's swidden agroecosystems in southwest China. *Biodiversity and Conservation* 10: 753-767.
- Mena CF, Barbieri AF, Walsh SJ, Erlien CM, Holt FL and Bilsborrow RE. 2006. Pressure on the Cuyabeno Wildlife Reserve: Development and Land Use/Cover Change in the Northern Ecuadorian Amazon. *World Development* 34: 1831-1849.
- Mendelsohn R. 1994. Property Rights and Tropical Deforestation. *Oxford Economic Papers* 46: 750-756.
- Mwavu E and Witkowski E. 2008. Land-use and cover changes(1988-2002) around budongo forest reserve, NW Uganda: implications for forest and woodland sustainability. *Land Degradation & Development* 19: 606-622.

- Nepstad D, Schwartzman S, Bamberger B, Santilli M, Ray D, Schlesinger P, Lefebvre P, Alencar A, Prinz E and Fiske G. 2006. Inhibition of Amazon deforestation and fire by parks and indigenous lands. *Conservation Biology* 20: 65-73.
- Ostrom E. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge: Cambridge University Press.
- Ostrom E and Nagendra H. 2006. Insights on linking forests, trees, and people from the air, on the ground, and in the laboratory. *Proceedings of the National Academy of Sciences* 103: 19224-19231.
- Ouedraogo I, Savadogo P, Tigabu M, Cole R, Odén PC and Ouadba JM. 2009. Is rural migration a threat to environmental sustainability in Southern Burkina Faso? *Land Degradation & Development* 20: 217-230.
- Ouedraogo I, Tigabu M, Savadogo P, Compaoré H, Odén PC and Ouadba JM. 2010. Land cover change and its relation with population dynamics in Burkina Faso, West Africa. *Land Degradation & Development* 21: 453-462.
- Pagdee A, Kim Y-s and Daugherty PJ. 2006. What Makes Community Forest Management Successful: A Meta-Study From Community Forests Throughout the World. *Society & Natural Resources: An International Journal* 19: 33 - 52.
- Paré S, Savadogo P, Tigabu M, Ouadba J and Odén P. 2010. Consumptive values and local perception of dry forest decline in Burkina Faso, West Africa. *Environment, Development and Sustainability* 12: 277-295.
- Persha L, Agrawal A and Chhatre A. 2011. Social and Ecological Synergy: Local Rulemaking, Forest Livelihoods, and Biodiversity Conservation. *Science* 331: 1606.
- Pichón F. 1997. Colonist land-allocation decisions, land use, and deforestation in the Ecuadorian Amazon frontier. *Economic Development and Cultural Change* 45: 707-744.
- Platteau JP. 2000. Allocating and Enforcing Property Rights in Land: Informal versus Formal Mechanisms in Sub-Saharan Africa. *Nordic Journal of Political Economy* 26: 55-81.
- Reed WJ. 1984. The effects of the risk of fire on the optimal rotation of a forest. *Journal of Environmental Economics and Management* 11: 180-190.
- Reenberg A. 2001. Agricultural land use pattern dynamics in the Sudan-Sahel--towards an event-driven framework. *Land Use Policy* 18: 309-319.
- Rudel T. 1995. When do property rights matter? Open access, informal social controls, and deforestation in the Ecuadorian Amazon. *Human Organization* 54: 187-194.
- Rudel T, Coomes O, Moran E, Achard F, Angelsen A, Xu J and Lambin E. 2005. Forest transitions: towards a global understanding of land use change. *Global Environmental Change Part A* 15: 23-31.

- Sandbrook C, Nelson F, Adams WM and Agrawal A. 2010. Carbon, forests and the REDD paradox. *Oryx* 44: 330-334.
- Sikor T, Stahl J, Enters T, Ribot JC, Singh N, Sunderlin WD and Wollenberg L. 2010. REDD-plus, forest people's rights and nested climate governance. *Global Environmental Change* 20: 423-425.
- Sjaastad E and Bromley D. 2000. The prejudices of property rights: On individualism, specificity, and security in property regimes. *Development Policy Review* 18: 365-389.
- Soares-Filho BS, Nepstad DC, Curran LM, Cerqueira GC, Garcia RA, Ramos CA, Voll E, McDonald A, Lefebvre P and Schlesinger P. 2006. Modelling conservation in the Amazon basin. *Nature* 440: 520-523.
- Sunderlin WD, Dewi S, Puntodewo A, Müller D, Angelsen A and Epprecht M. 2008. Why forests are important for global poverty alleviation: a spatial explanation. *Ecology and Society* 13: 24.
- Sunderlin WD, Hatcher J and Liddle M. 2008. From exclusion to ownership? Challenges and opportunities in advancing forest tenure reform. Washington D.C.: Rights and Resources.
- Sunderlin WD, Larson AM and Cronkleton P. 2009. Forest tenure rights and REDD+: From inertia to policy solutions. In: M. Brockhaus. *Realising REDD+: national strategy and policy options*. Center for International Forestry Research (CIFOR). 139.
- Unruh JD. 2008. Carbon sequestration in Africa: The land tenure problem. *Global Environmental Change* 18: 700-707.
- USAID. 2008. Land Tenure and Property Rights: Tools for Transformational Development. Washington, D.C.:
- van den Brink R, Thomas G, Binswanger H, Bruce J and Byamugisha F. 2006. *Consensus, confusion, and controversy: selected land reform issues in Sub-Saharan Africa*. Washington, D.C.: World Bank Publications.
- van Gils H and Ugon A. 2006. What Drives Conversion of Tropical Forest in Carrasco Province, Bolivia? *AMBIO: A Journal of the Human Environment* 35: 81-85.
- Van Laerhoven F. 2010. Governing community forests and the challenge of solving two-level collective action dilemmas--A large-N perspective. *Global Environmental Change* 20: 539-546.
- Wainwright J. 2009. The first duties of persons living in a civilized community': the Maya, the Church, and the colonial state in southern Belize. *Journal of Historical Geography* 35: 428-450.
- Wardell DA, Reenberg A and Tøttrup C. 2003. Historical footprints in contemporary land use systems: forest cover changes in savannah woodlands in the Sudano-Sahelian zone. *Global Environmental Change* 13: 235-254.

- Wendland K. 2008. Rewards for Ecosystem Services and Collective Land Tenure: Lessons from Ecuador and Indonesia. Madison, WI: Land Tenure Center.
- Wynberg R and Laird S. 2007. Less is often more: governance of a non-timber forest product, marula (*Sclerocarya birrea* subsp. *caffra*) in southern Africa. *International Forestry Review* 9: 475-490.
- Zhang D. 2001. Faustmann in an uncertain policy environment. *Forest Policy and Economics* 2: 203-210.



The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) is a strategic initiative of the Consultative Group on International Agricultural Research (CGIAR) and the Earth System Science Partnership (ESSP), led by the International Center for Tropical Agriculture (CIAT). CCAFS is the world's most comprehensive global research program to examine and address the critical interactions between climate change, agriculture and food security.

For more information, visit www.ccafs.cgiar.org

Titles in this Working Paper series aim to disseminate interim climate change, agriculture and food security research and practices and stimulate feedback from the scientific community.

