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Does secure land tenure save forests? A meta-analysis of the relationship between land tenure and tropical deforestation

Brian E. Robinson [a,d,*], Margaret B. Holland [b,d], Lisa Naughton-Treves [c,d]

[a] University of Minnesota, Institute on the Environment, 1954 Buford Avenue, St. Paul, MN 55108, United States
[b] University of Maryland-Baltimore County, Department of Geography & Environmental Systems, 211 Sondheim Hall, 1000 Hilltop Circle, Baltimore, MD 21250, United States
[c] University of Wisconsin-Madison, Department of Geography, 355 Science Hall, 550 North Park Street, Madison, WI 53706, United States
[d] University of Wisconsin-Madison, Land Tenure Center, 122 Science Hall, 550 North Park Street, Madison, WI 53706, United States

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ABSTRACT

Deforestation and degradation are tied to a complex array of socioeconomic and political factors. Many assume that among the most important of these are the particular bundles of rights regulating who can benefit from land (tenure form) and the overall assurance that those rights will be upheld (tenure security). This paper reviews literature that connects forest outcomes and land tenure to better understand broad interactions between tenure form, security and forest change. Papers from economic theory suggest tenure is embedded in a broader socioeconomic context, with the potential for either a positive or negative conservation impact on forested land. Empirically, we find 36 publications that link land cover change to tenure conditions while also controlling for other plausibly confounding variables. Publications often investigate more than one site and more than one form of tenure, so from these we derive 118 cases linking forest change with a specific tenure form in a particular location. From these cases, we find evidence that protected areas are associated with positive forest outcomes and that land tenure security is associated with less deforestation, regardless of the form of tenure. We conclude with a call for more robust identification of this relationship in future research, as well as set of recommendations for policymakers, particularly as forest carbon incentive programs such as REDD integrate further into national policies.

1. Introduction

Land tenure and forest property rights are critical issues for the new wave of incentive-based policy instruments that aim to safeguard ecosystem goods and services in tropical forests (such as carbon, water, and biodiversity) by paying people to protect them. One of the most recent and highest profile of these instruments, Reducing Emissions from Deforestation and Degradation (REDD), has attracted significant investment as well as critical scrutiny (Marino and Ribot, 2012). Property rights over forests directly determine who is eligible to receive protection incentives and who is responsible for meeting programs' contractual obligations. Clear and secure land tenure is crucial for an efficient REDD program and equitable distribution of benefits (Bruce et al., 2010). Yet the world's most carbon-rich forests are often found in regions where ownership is ill-defined, contested or insecure (Fig. 1). 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.

For these reasons, policymakers see land tenure and relatedly, carbon tenure, as key issues shaping the social and environmental impact of REDD and related programs (Sikor et al., 2010; Sunderlin et al., 2009; Unruh, 2008). Yet tenure and 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 and warrant a cautious approach, especially since titling programs show varied outcomes in improving landholders' livelihoods (Deininger and Feder, 2009). Moreover, 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,

Abbreviations: PES, payment for ecosystem services, payment for environmental services; REDD, Reducing Emissions from Deforestation and Degradation.

* Corresponding author at: University of Minnesota, Institute on the Environment, 1954 Buford Ave, St Paul, MN 55108, United States. Tel.: +1 612 625 7693; fax: +1 612 626 5555.
E-mail addresses: brobinson@umn.edu (B.E. Robinson), mholland@umbc.edu (M.B. Holland), lnaughto@wisc.edu (L. Naughton-Treves).

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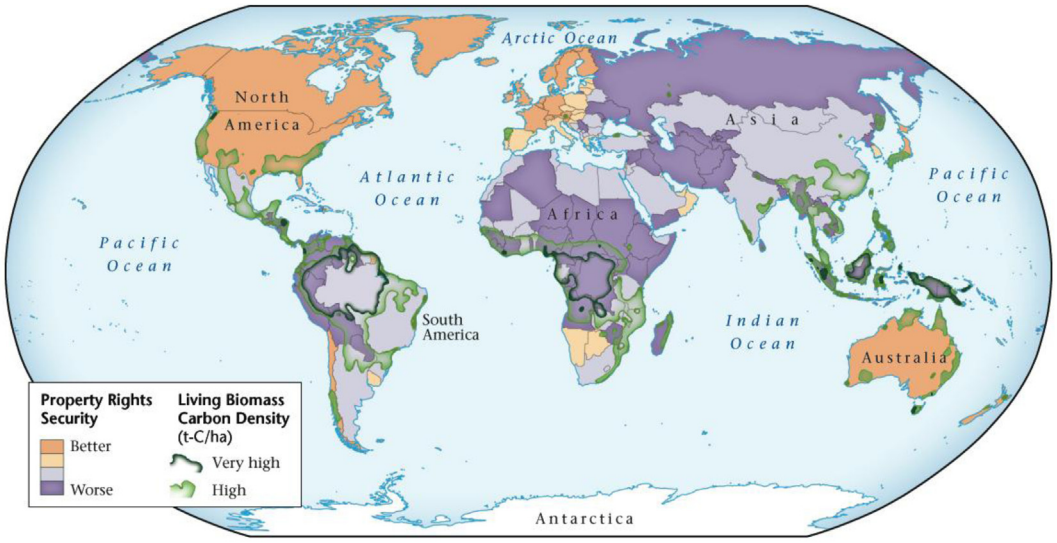

Source: Bruce et al. 2010.

Fig. 1. Tenure security and carbon biomass density.

2000) and ways of life that are not necessarily compatible with fixed land rights (Fox et al., 2013) (this issue).

Addressing tenure issues is pivotal for the success of payments for ecosystem services (PES) or REDD programs, since landholders must have the authority to make land use decisions and defend land against outside claimants or other agents of land use change. In the context of these incentive-based approaches as well as more standard command-and-control type policies (Börner et al., 2013) (this issue), there seems little alternative to improving and supporting state-recognized land tenure rights. Yet drawing clear lessons from previous research is hindered by confused or ill-defined basic tenure and deforestation terminology. Further, it is unclear whether specific forms of tenure are more "sound" or how much tenure *security* matters. 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). Protected areas generally help avoid tropical deforestation over other land tenure forms (Andam et al., 2008; Joppa and Pfaff, 2011), but some may simply displace deforestation and extensive tracts of carbon-heavy, biodiverse forest lie outside of areas under strict protection (Agrawal, 2007; Soares-Filho et al., 2006; Sunderlin et al., 2008b). We need a better understanding of how the form of tenure and tenure security interact to affect forest outcomes.

Our aim with this review is to identify these relationships and, in doing so, outline the specific contexts in which land tenure interventions can help slow deforestation. We follow the U.S. Agency for International Development (USAID, 2008) in referring to *land tenure* as 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. To gain analytical traction 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 from tenure security (Section 2). Section 3 reviews the theoretical economic literature on tenure security and land use change to provide an underpinning for our discussion. Turning to the empirical literature, Section 4 discusses the methods for our review and empirical relationships 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., 2008a), we examine variation in the tenure–forest relationship between geographic regions as well as across them. Section 5 offers broad lessons from our review and Section 6 concludes with suggestions for future research and policy.

2. Basic terms

The debate regarding the impact of tenure on forest conservation is hindered by inconsistent use of terminology. *Property rights* and *land tenure* are often used interchangeably and, moreover, are often used to imply rights for individual landholders only. *Property rights* refer to a bundle of rights guiding the use, management and transfer of assets. *Land tenure*, as previously noted, 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.

Both *land tenure* and *property rights* may refer to any number of bundles of rights, only one of which is what we typically think of as individual private property rights. The *form* of land tenure then 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 ultimately attractive to PES and REDD initiatives, given the lower transaction costs of implementation and maintenance of ecosystem function. Public and communal landholdings are generally nontransferable, which also has special 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

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(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 that how local residents *perceive* land tenure often has a greater impact on their land use decision-making than whether that tenure is formal or legalized (Broegaard, 2005; Unruh et al., 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.

Finally, we recognize there is increasing interest in defining and managing rights to carbon specifically. Cotula and Mayers (2009) refer to "carbon rights" as a form of property rights separate from broader rights to forest and land that allows for commodification and trading of carbons stocks in the forest and soil. In our review here we do not deal with these more nuanced concepts since they are just now becoming widely understood and many countries have yet to develop practices for their adoption.

3. Lessons from economic theory

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-theoretic 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 a more attractive land use relative to forest. In a model of optimal investment and resource use, Bohn and Deacon (2000) find that increased insecurity also results in lower overall forest stocks, and they back this up with a cross-country regression analysis.

The fourth type of model, cost-benefit analyses that compare the net present value of alternative land uses, has more ambiguous implications. Mendelsohn (1994) sparked this literature showing that tenure insecurity has an ambiguous impact on forest conversion to agriculture. Barbier and Burgess (2001) extend Mendelsohn's model to show the potential rationality of "timber mining," but tenure insecurity still promotes or protects 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. This paper attempts to derive some general lessons, but the relevant point here is that better approximations of reality result in various outcomes with respect to tenure security, all conditional on initial parameterization or underlying assumptions.

As a whole, the theoretical economic literature shows that the relationship between tenure insecurity and forests depends on local context. One contextual factor is the way one frames the investment decision. If forest is assumed a productive investment (i.e. an industrial timber forest) then tenure insecurity promotes more deforestation (Bohn and Deacon, 2000). Alternatively, if agriculture is modeled as the productive investment relative to (unproductive) forest, insecure tenure results in protection of forest (Angelsen, 2007). Barbier and Tesfaw (2013) (this issue) allow for land tenure security and land management decisions to be endogenous which they show can, for instance, induce more tree planting. 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 socioeconomic conditions.

However, since these theoretical explorations must model the form of tenure and tenure security in relatively stylized ways for analytic tractability, they do not provide clear lessons about particular forms of tenure or the mechanisms through which tenure insecurity works. In most cases, models use a profit-maximizing framework that simulates form, and tenure security is cast as the probability of expropriation of property. But profit-maximizing agency is consistent with any number of tenure forms including freehold and leasehold land, and sometimes communal and customary arrangements. Complexity increases even further when one attempts to understand how the *security* of these various forms of tenure might affect land use decisions (Kaimowitz and Angelsen, 1998: p. 68).

The general lesson from this literature is that tenure security matters, but whether its effect is positive or negative on forests depends on the assumptions and assumed context of the model. This provides an underpinning for our look into the empirical literature to see whether there are particular forms of tenure associated with forest conservation, and how much tenure security seems to matter.

4. Lessons from empirical studies

4.1. Methods

We looked for studies in the peer-reviewed literature that specifically include aspects of land tenure related to form or security in assessing forest cover change over time in tropical and subtropical regions. We targeted publications that use remotely sensed data to measure changes in forest cover, but included some cases that use in-field inventories or discuss forest cover change from secondary sources in careful detail.

Ideally we would only include studies that credibly control for counterfactual hypotheses, (that is, what forest outcome would we observe if a different form of land tenure were in place?), as is becoming standard in reviews that synthesize lessons from policy interventions (Blackman and Rivera, 2010; Bowler et al., 2012; International Initiative for Impact Evaluation, 2012; The Campbell Collaboration, 2012). Studies held to this "counterfactual standard" control for the endogeneity of tenure choice and deforestation activities, aiming to identify tenure's causal impact on land use. However, few choices of land tenure are interventions per se, except for the establishment of protected areas, which is indeed the subject of most counterfactual analyses in this area thus far (see Joppa and Pfaff, 2010 for a review). We found only seven studies that construct a credible counterfactual with respect to tenure form, five of which are focused on protected area impacts. These counterfactual studies are a subset of a larger set of literature that attempts to address or control for *confounding* variables (e.g., distance to roads, soil type, etc.). Although such 'confounding studies' are not as strict as counterfactual assessments, comparisons between the two methods can yield similar results (e.g., Andam et al., 2008; Pfaff et al., 2013). Therefore, we explored the broader set of 36 studies that control for confounding variables

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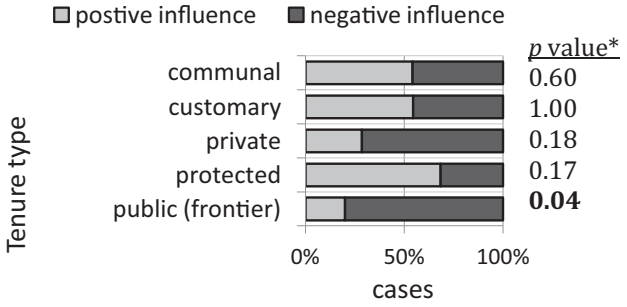
below, mindful that we can only generalize correlational lessons from this review.

Some publications reviewed looked at deforestation conditions in multiple locations, including across national boundaries, therefore we split each study into "sites" that were investigated. Multiple forms of tenure could be present in any given site, so we further differentiated our units of observation into the forms of tenure present at each site. Our fundamental unit of analysis is a "case" – a particular form of tenure at a specific site in a given study.

We first categorized land tenure form into one of five categories: *public* (unmanaged public frontier or open access), *protected* (managed public land with restrictions on forest clearing), *private*, *communal* and *customary/traditional*. Categorizing such broad range of literature into these four forms is admittedly simplistic. For example, there is a large category of landowners who delineate and manage their land individually within a broader community landholding. Although their individual rights are locally recognized, they do not hold legal titles due to prohibitively high costs. Here we categorized such cases based on the authors' descriptions, which could plausibly be either as private or communal land tenure. Additionally, much literature conflates communal and customary forms of tenure, often referring to land held by indigenous communities as "communal" even though the bundle of rights associated with those communities are often much more complex than simple common ownership. When these cases were described clearly, we attempted to differentiate them in this review, but our "communal" category may contain situations that we would otherwise identify as customary given more information.

Second, we recorded whether each case represents a positive (1) or negative (0) forest outcome according to each set of authors. Positive outcomes referred to slowed deforestation rates (relative to other local sites), maintained forest cover or regenerated forest cover. Negative outcomes included increased deforestation rates or overall forest loss. This categorization is obviously influenced by authors' site selection, but it allows for a meaningful comparison across studies and keeps in line with the spirit of the authors' conclusions. Our results focus on tenure's broadly positive or negative impact on forests.

Finally, we used the study's context or explicit recognition to record a measure of tenure security for each case. Many of the papers do not engage tenure security directly, so this is inherently subjective to our interpretation of the papers. This subjectivity limits the strength of conclusions we can draw about security in the quantitative analysis. However, authors often discuss contextual relationships such as local conflict, policy enforcement, incidence of squatting or agencies' monitoring capabilities, and we used these to infer whether a case broadly exhibits secure (1) or insecure (0) tenure. A continuous measure of a case's "true" security would be ideal, but we used this dichotomous value to limit any undue judgment we drew from the literature (this coarse measure also introduces greater measurement error over a "true" continuous measure, and thus attenuation bias suggests our statistical results are conservative). If there is no indication of insecurity, we did not assume any.



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

Fig. 2. Forest outcomes and type of tenure.

We reviewed over 150 peer-reviewed publications as candidate studies, from which we ultimately find 36 that fit the minimum topical and methodological requirements of our selection criteria and were published between 1997 and 2013. From these, we identified 79 different sites where forest cover was analyzed within the 36 publications, and end up with 118 cases of a specific tenure condition tied to a specific site. We aimed to stratify our sample by region, but found a relative lack of studies in Asia and the South Pacific. Cases with positive and negative forest outcomes are distributed evenly throughout our regions (Table A.1). See Appendix A for a more detailed description of our coding protocol and our rationale applied to a sample study.

4.2. Form of tenure

The study set reveals both positive and negative outcomes for forest cover across all the most common tenure forms (Fig. 2). However, public land (unmanaged) is associated with negative forest outcomes and protected land has more positive than negative outcomes.

Our data suggest some regional patterns among tenure forms and deforestation (we do not present results for South Asia since the publications included from this region focus almost exclusively on communal lands). Though we cannot make strong conclusions due to limited sample sizes within regions, communal and customary tenure seem to perform somewhat poorly in Africa (Fig. 3a), fairly well in Central America (Fig. 3b) and have more mixed effects in South America (Fig. 3c) (communal land is further

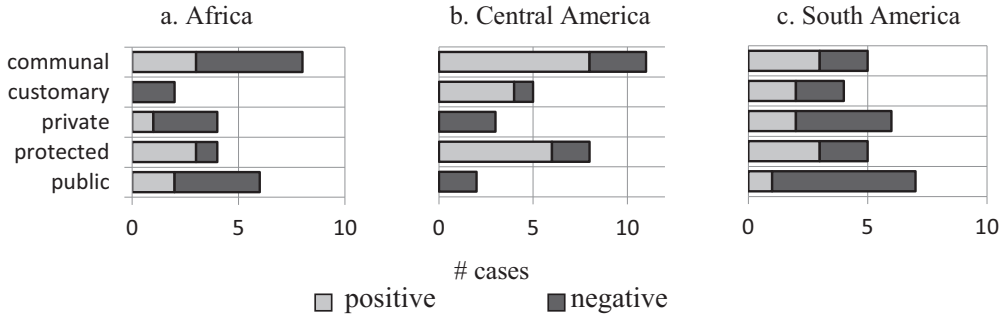


Fig. 3. Regional forest outcomes by tenure.

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discussed in Section 6.2 below). Overall, private land also leads to mixed outcomes, but is associated with higher deforestation in Central America. Protected areas have more positive than negative results in all regions, and the opposite is true for unmanaged public land. This latter result 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. Taken together, these results give us reason to question our first null hypothesis, that the form of tenure has no relationship with forest outcomes, especially when we look at protected land versus unmanaged public land.

4.3. Tenure security

Table 1 shows not only significant heterogeneity in forest outcomes across all forms of tenure, but also for secure and insecure tenure conditions. Notably, government-controlled lands (protected land and unmanaged public land) seem particularly prone to insecure conditions. This is potentially due to publication bias, since these areas are often studied *because* they are insecure (e.g. encroachment into the forest–farm interface via occupation of public land). For communal land, insecurity is tightly linked to negative forest outcomes and secure tenure with positive outcomes ($\chi^2 = 21.57$; $p = 0.00$). This relationship holds even in aggregate ($\chi^2 = 18.38$; $p = 0.00$), and we do not find any discernable regional differences in this interaction.

Using a probit regression model, Table 2 presents the marginal effects for the common factors we observed in this review on positive (1) or negative (0) forest outcomes, including dummy variables for the form of tenure and our binary measure of tenure security. The four models are reduced-form estimations of the association between tenure form, security and forest change.

Table 1
Tenure form, security and forest outcomes.

		Total cases	Positive outcome	Negative outcome	Probability of correlation*	
					χ^2	p
Public	Total	15	3	12		
	Insecure	15	3	12	n/a	n/a
	Secure	0	0	0		
Protected	Total	19	13	6		
	Insecure	11	7	4	0.28	0.60
	Secure	8	6	2		
Private	Total	14	4	10		
	Insecure	3	1	2	0.04	0.84
	Secure	11	3	8		
Customary	Total	11	6	5		
	Insecure	4	1	3	1.04	0.31
	Secure	7	5	2		
Communal	Total	59	32	27		
	Insecure	19	2	17	21.57	0.00
	Secure	40	30	10		
Total	Total	118	58	60		
	Insecure	52	14	38	18.38	0.00
	Secure	66	44	22		

* The null hypothesis of the χ^2 test is that there is no correlation between tenure security and positive or negative forest outcomes. A significant result suggests the distribution between these factors is not likely random.

Table 2
Marginal effects for the predictors of the probability of observing negative (0) or positive (1) forest outcomes.

	I		II		III		IV	
Communal	0.24	(0.14)*	0.27	(0.15)*	0.23	(0.17)	0.31	(0.22)
Customary	0.25	(0.20)	0.29	(0.20)	0.25	(0.20)	0.43	(0.26)
Protected	0.39	(0.19)**	0.51	(0.19)**	0.51	(0.20)***	0.61	(0.23)**
Public	−0.10	(0.17)	0.23	(0.19)	0.25	(0.20)	0.28	(0.19)
Tenure security			0.40	(0.08)***	0.40	(0.08)***	0.43	(0.13)***
Central America					0.11	(0.08)	0.08	(0.12)
South America					0.01	(0.11)	0.02	(0.14)
South Asia					0.09	(0.08)	0.23	(0.16)
South East Asia					−0.16	(0.20)	−0.02	(0.20)
Public*South America							−0.05	(0.21)
Length of analysis (yrs)							0.01	(0.00)*
n	118		118		118		103	
Log psuedolikelihood	−76.0		−66.6		−65.3		−51.9	
Pseudo-R^2	0.07		0.19		0.20		0.27	
% Correctly predicted	62%		76%		75%		69%	

Robust standard errors are in parentheses, clustered by publication.
For land tenure categories, private land is the reference group.
For regional categories, Africa is the reference group. East Asia and South Pacific dummy variables were not included due to small samples in those categories.
The constant, whose marginal effects are not calculated, represents the reference group of private property (I, II) or private property in Africa (III, IV). The constant was −0.6, −1.6, −1.7 and −2.3 in models I through IV, respectively, and conventionally significant in all but model I.
* $p<0.05$
** $p<0.01$
*** $p<0.001$.

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Model I takes into account only tenure form. Model II controls for tenure security and form, model III includes regional controls and model IV adds interaction terms the descriptive results above suggest might be important. We attempted to use instrumental variables techniques to control the endogeneity of tenure security and deforestation using the World Bank's country-level governance indicators (Kaufmann et al., 2010) as instruments. However, none proved valid instruments since there was not a strong correlation with tenure security in our sample. Thus the results may indicate cases where deforestation occurs with the *intent* of impacting tenure security (e.g. "clearing to claim", see Unruh et al., 2005) as well as cases where tenure security influences the decision to deforest. These models performed relatively well, correctly predicting 62–76% of the observations in our sample and are qualitatively consistent with equivalently specified linear probability (ordinary least-squares) and logit models.

Accounting only for the form of tenure, Model I shows protected areas and possibly communal lands are positively associated with forest outcomes. Models II–IV include our measure of tenure security and show that, irrespective of controls regional effects, tenure security has a consistent positive association with forest outcomes, improving the probability of an associated positive forest outcome by about 40%. With respect to the form of tenure, in these models forests under active protection (parks and forest reserves) are also about 40–60% more likely to be linked with positive forest outcomes relative to private lands (the reference group). The effects of communal, customary, private, and unmanaged public land are not consistently different from one another. Regional dummy variables and a hypothesized interaction term (for public land in South America) show little influence on our forest outcome measure. The duration of land use change analyzed is associated with a very small but statistically significant positive impact.

Another way to evaluate the relationship between deforestation and tenure security while accounting for other variables is through qualitative comparative analysis (QCA) (Ragin, 1987; Rudel, 2008). As opposed to regression analysis, which uses the variation in the independent variables to explain the variation in the dependent variable, QCA uses Boolean logic and set theory to determine which *combinations* of characteristics are most closely associated with the outcome in question. QCA is readily adaptable to meta-analyses that aim to "scale-up" lessons from local and regional studies (Rudel, 2008) and has some history of being applied to forest-related studies (e.g. Rudel, 2005; Hellstrom, 1998). However, the assumptions involved in QCA are not trivial to the interpretation of the results, and attempting to correct some types of bias can result in a regression-like analysis with multiple interaction terms (Seawright, 2005). Most critically for this study, we worry about omitted variable bias, typically a much more detrimental to the assumptions of QCA than regression. Still, for completeness we present results from a crisp-set QCA with the full set of tenure form, tenure security and regional variables that were included in the regression analysis described above.

The results of a QCA analysis on our dataset are presented in Table 3. We present both complex and parsimonious solutions to show the range of outcomes one might expect from the data depending on the rules chosen to guide the Quine–McCluskey reduction algorithm used in QCA (Ragin, 2000). The most striking feature of the results is that tenure security is consistently present in all solutions as associated with positive forest outcomes. Several combinations of regions and tenure forms also show up as associated with positive forest outcomes, most notably communal forest in Latin America and South Asia. However, the variables representing Southeast Asia, Africa, private and unmanaged public land do not appear in any solutions as consistently associated with positive forest outcomes.

Table 3
Results from a qualitative comparative analysis (QCA) on factors associated (CAPS) or not associated (lower case) with positive forest outcomes.

Complex solution	Coverage	
SECURITY*CUSTOMARY*CENTRAL AMERICA	0.05	
SECURITY*PROTECTED*CENTRAL AMERICA	0.05	
SECURITY*COMMUNAL*SOUTH AMERICA	0.05	
SECURITY*COMMUNAL*CENTRAL AMERICA	0.12	
SECURITY*COMMUNAL*SOUTH ASIA	0.28	
Solution coverage:		0.55
Solution consistency:		0.82
Parsimonious solution	**Coverage**	
SECURITY*private*africa*south america	0.52	
SECURITY*customary*private*africa	0.53	
Solution coverage:		0.59
Solution consistency:		0.76

The presence of a variable with a cluster is denoted with all capital letters, its absence is denoted with all lower case letters.
The complex solutions were all full sets of all the variables, so we present only the variables associated with positive forest outcomes.
Coverage is defined as the proportion of cases that exhibit a cluster of outcomes. Results were obtained with a frequency cutoff of three cases and a consistency cutoff of 0.75 in the fs/QCA software package (Ragin et al., 2009).

With regard to our first null hypothesis that the form of tenure does not matter for forest outcomes, our results present a mixed message. When controlling for other factors in the regression analysis, namely tenure security, protected areas have a consistent positive association with forest outcomes over all other forms of tenure, which are not consistently distinguishable from one another. This is expected since protected land is the only form that manages for forest conservation. All other forms of tenure give varying degrees of use-rights and decision-making ability 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 consistent evidence across specifications of the data and methodologies (regression and QCA) to reject the notion that tenure security is not important. However, even though tenure security is associated with positive forest outcomes, it by no means prevents changes in forest cover in all situations. Payments or policies that aim to do so must take into account the suite of other conditions that determine the value of alternative land uses relative to forest to local landholders.

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, the literature also revealed that land tenure security is often mistakenly linked with particular forms of land tenure (for example, see Table 1 in Deininger and Minten, 2002). Perhaps born out of concepts 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, with common property resource systems as middle ground (Cheung, 1970; Dasgupta and Heal, 1979). Private property rights are conceptualized as "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 narrative conflates the form of tenure with

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security, and we find little evidence that these two concepts are consistently correlated.

Decades of common property research shows that informal social controls and local collective action can mitigate the "tragedy" that results from competition over common-pool resources (Agrawal, 2001; Bromley, 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 (Robinson et al., 2013). A literature review of community-managed forests (Porter-Bolland et al., 2011) finds lower and less variable deforestation rates relative to protected forest. Therefore, when properly recognized by national and/or local legal systems, many forms of tenure are legitimate and secure (Bruce et al., 2010).

Yet scholars constrained by time and available data may simply use 'title' as a basis to infer the effect of tenure security. In our view this is an oversimplification 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. Tenure security can sometimes have negative consequences for environmental public goods since it promotes land use investments with private returns, such as agricultural intensification and development of built capital (Garnett et al., 2007). In another case Pinel (2009) discusses how efforts to bolster local communal tenure hastened deforestation by inducing competitive forest clearing. Clarifying tenure is often a slow and highly political process, but ignoring tenure issues potentially presents greater risks for forests and forest-dependent people (Naughton-Treves and Wendland, 2013).

5.2. Communal and customary land

More than one billion people depend on forests for their livelihoods (FAO, 2008), a large and increasing fraction of which live in communities with communal or customary rights to forest (Agrawal, 2007; Sunderlin et al., 2008b), making these lands a special category of interest. Further, development agencies are exploring targeting large communal landholders for REDD programs to secure large tracts of forest while minimizing transaction costs associated with identifying, contracting with and monitoring landholders. This targeting threatens to undermine communal forest management (Phelps et al., 2010) particularly given ambiguous or contradictory legal status of communal lands (Beymer-Farris and Bassett, 2011; Veit et al., 2011).

As noted above, communal and customary land tenure have mixed effects on forest outcomes (Fig. 2), but patterns may exist regionally (Fig. 3). The initial negative association seen in African communities falls out when we control for multiple variables in the regression analysis. Regardless, the simple association may have several explanations. Customary tenure is widespread in tropical Africa including regions where forest has best persevered. In recent decades enforcement of traditional rules has been difficult due to general crisis in governance compounded by population growth, inequality and emerging market and political forces (e.g. Kakembo, 2001; Mwavu and Witkowski, 2008). Africa has also been especially wrought with civil conflict and related changes in governance, which also impacts natural resource use. "Access," as defined by Ribot and Peluso (2003), may play a role in this setting. But deforestation is not inevitable on communal lands, rather, forest is at special risk if communal lands are not legitimately supported by governments. Our review suggests that communities may be simply managing communal lands to maximize livelihood gains, which may or may not prioritize forest cover.

An emerging body of "large-*N*" research projects documents how communities engage in collective action to prevent degradation of common-pool resources, particularly when a community has externally recognized property rights. Rules (Hayes, 2006), enforcement of rules (Gibson et al., 2005), monitoring and maintenance (Van Laerhoven, 2010) and metrics of governance (Hyde et al., 2003; Persha et al., 2011) have all emerged as important factors for positive forest outcomes. All these studies point toward increasing the security of tenure in communal systems (see also Pagdee et al., 2006).

Our review shows a mix of outcomes in forest commons, 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 issues of inter-community institutional incoherence (Bromley, 2008).

5.3. Tenure data and measurement

Over the past 20 years, data on forest cover and forest conditions has increased dramatically in both quantity and quality. The same is not necessarily true of land tenure data, which requires physical delineation and demarcation of social relations, which are sometimes contested, and requires field-based knowledge of intangible relationships or agreements between communities (Turner, 2003). Analysis of forest cover change is evolving to explore both temporal and spatial relationships, yet the investigation of the drivers of forest cover change is lagging due to relatively poor spatially delineated land tenure data over multiple points in time. For example, we sometimes know the location of community or plot-level boundaries, but the way that those boundaries may have shifted over time, or the rights associated with them often remain unclear. In forested areas of developing regions, even the location of community boundaries is often purely documented.

When such spatial land tenure data are not available, researchers may attempt to create maps from proxies or from scratch. 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 the local scale, household surveys and participatory mapping are useful techniques for deriving spatial definitions of land tenure and defining tenure security, but when aggregated, can result in definitions that are consistent with community perceptions but may not, in fact, be externally valid (recognized by the state and/or surrounding communities). Thus, it can be difficult to find locally derived tenure data that matches regional- or nationally defined land tenure systems.

As a specific example we note our difficulties parsing communal and customary land tenure for this review. 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 highly diverse forms of tenure (Ankersen and Barnes, 2004).

Key challenges remain in conceptually linking and spatially modeling human dimensions that influence or drive tropical deforestation (Rindfuss et al., 2004), despite "tenure" being widely recognized as a deforestation risk factor or driver (Rudel et al., 2005). "People and pixels" issues are of particular concern for studies attempting to match forest cover change results based on

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remotely sensed imagery with locally derived forest tenure and governance variables (Liverman and Cuesta, 2008; Ostrom and Nagendra, 2006).

Finally, although correctly documenting the form of tenure is challenging, measuring tenure *security* is even more difficult. Tenure security can be legitimate or perceived, and is largely determined by intangible characteristics that influence decision-making, so few empirical articles explicitly aim to measure and map it (Arnot et al., 2011). Further, the form of land tenure is a relatively static concept while land tenure security is inherently forward-looking, expressing an 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, for which data are especially scarce.

6. Conclusion

6.1. How does tenure matter?

The main goal of this article is to better understand when tenure form and security are likely to be important factors in deforestation. 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 drivers 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 or publication bias given our relatively small sample of case studies in each region, but these outcomes emphasize the importance of local factors. Overall, protected land is associated with positive outcomes in all regions, and public land seems to be particularly vulnerable to negative forest outcomes in South America. Communal land performs well in our Central American cases but worse in Africa, possibly due to the effects of regional conflict and/or weak governance. However, in poor areas, common property can be advantageous in other ways, for instance, by allowing community members access to common land for farming when external shocks would otherwise induce crises (van den Brink et al., 2006).

Further, we have argued that when designing policies to influence forest outcomes the form of tenure can take many shapes, but ensuring tenure is *secure* is far more critical. Theoretical economic models demonstrate that when tenure is less secure, the expected net present value of all land uses decreases, but can impact forested land uses proportionally more than agriculture. This is not always the case, as land use decisions are determined by the value of various land use options, which are a function of local geographic and economic characteristics. Strengthening tenure security alone will not stop deforestation. Empirically, however, it seems possible that security increases the probability of positive forest outcomes after controlling for the form of tenure and regional factors. Table 4 gives example explanations for how some of the authors we reviewed above explain the relationship between tenure (security) and deforestation. Some claim tenure is of the utmost importance, while others find it marginal or insignificant.

In sum, land tenure form and security are not, in and of themselves, perfect safeguards for forests. Tenure form and security enable landholders, whether individuals or communities, to take into account future values incurrent 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 outcomes (e.g. maintain forest), the security of tenure is crucial to influence landholders' decision-making. Tenure security enables communities some control over whether REDD will be implemented in their community and, if so, how it will affect their livelihoods (Sunderlin et al., 2013). Therefore, security is necessary to prevent deforestation through market-based conservation mechanisms, but alone does not necessarily protect forests.

6.2. Future research

Future empirical studies should clearly describe how they conceptualize issues around tenure form and security. What forms of tenure exist in the study area and how are these defined? What is the respective security of each land tenure form as perceived by landholders? To simply use land title, especially individualized 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 and account for co-varying land qualities across tenure types as well as counterfactual scenarios. Joppa and Pfaff (2010) describe the advantages of statistical "matching" techniques for land cover datasets that addresses the latter concern and Blackman and

Table 4
Does tenure security slow deforestation? Sample explanations from the literature.

Yes (clearly important)	Helps, but inadequate	Insignificant
"The main outcome of this paper is that insecure property rights in land drive deforestation in the Brazilian Amazon." - (Araujo et al., 2009)	"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)	Threats from outsiders – colonists, Shining Path guerrillas, road crews – continued to plague the Yanesha, even after they had official title to their land - (Morrow and Hull, 1996)
"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)	"It is unclear whether, alone, the common property institutions of Tziscao would be sufficient to prevent overuse of the common-pool forest resource; the needs of the growing population of Tziscao 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)	"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)

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Rivera (2010) discusses counterfactual study design in general. Most empirical studies in our review compared forest cover trends for two or more areas with different tenure regimes, but it is crucial to remember this ignores the potential endogeneity of tenure choice that may be based, at least in part, on existing characteristics of the land. For example, protected forests far from urban centers might be under protection because the deforestation threat to that area is low, and thus the costs of protection are too. Communal holdings may be in rural areas simply because competition is weaker and enforcement of borders is not as costly. Additionally, studies of time series data should increasingly be able to use techniques to control for time-varying factors through analysis of deforestation rates over time (e.g. Holland et al., 2013), difference-in-difference methods or a combination of these and counterfactual methods that better capture the *ceretis paribus* effect of a change in tenure form or security.

A better understanding of how the larger suite of economic and social pressures impact forest users is needed. 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, 2008).

Finally, a better understanding of how to strengthen tenure security is needed. Insecure land tenure is often a symptom of more broad political and economic systemic incoherence. We must often look beyond forests themselves to find the final causes of deforestation in a region (Bromley, 1999). With regard to the implementation of REDD, communities need assurance that protecting forests will result in future benefits. What are ways to strengthen landholders' current tenure security? The most important efforts likely entail the hard work of strengthening legal and social institutions, but interim steps may include promotional campaigns, prosecuting more cases against land claims and promoting dialog among communities and government officials to ensure claims will be upheld.

6.3. Addressing tenure issues at the forest–farm interface

Policies that aim to limit conversion of forest to agriculture must first understand the incentives for conversion. Policymakers should first assess whether there policies exist that favor conversion to agriculture, like subsidies or incentives to clear land to show "beneficial use" (i.e., not native forest vegetation, 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)). Further, recent changes in relative agricultural or forest-product prices, access to markets or the arrival of new technologies that shape incentives for greater conversion may have just as much or more short-term impact on forest clearing than tenure security. One challenge for policies that aim to preserve forests is to provide *enough* incentive to reverse the attractiveness of the alternative land use option. So to determine an appropriate quantity of compensation, we must understand the context in which land use decisions are made. Security in such payments is also needed. For policies to have any lasting effect, clarifying tenure and developing a supporting institutional environment to back tenure claims is crucial.

Additionally, where tenure security is currently lacking, transitions to clearer rights can be difficult (Ho and Spoor, 2006). In some cases, the process of clarifying tenure can hasten deforestation by increasing access to credit, which can positively or negatively impact forests. In another example, Deacon and Mueller (2004) argue that strengthening property rights can encourage competition for land acquisition, resulting in rent-seeking behavior with the potential for violent conflict. In Côte d'Ivoire an intervention aimed to fully describe the rights tied to communal access to resources for legitimization by the government, but this proved to be complex and ended in a simplification of rights that ultimately strengthened the rights of individuals over the rights of the collective (van den Brink et al., 2006). Finally, resolving tenure issues can amount to a conflict resolution process, so working both at local- and policy-levels is vital to ensure smooth social and statutory transitions (Garnett et al., 2007).

These anecdotes caution us that efforts to clarify tenure can be risky for forests and for people, at least in the short term. And while clarifying and strengthening tenure is costly and slow, investment is needed for both social equity and long-term environmental sustainability. 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).

Tenure insecurity is often cited as a cause for resource degradation, but inferring a causal relationship between tenure security, 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 form and security matter, but primarily as the 'rules of the game' when landholders interpret how other social, policy, economic and infrastructural changes will impact benefits they derive from any particular land use. We stress the need for secure and clear land rights, but policy makers and practitioners must be mindful of the larger context within which communities are embedded.

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Appendix A. Case review methods

A.1. Framework for assessing empirical studies

Our conceptual framework aims to measure whether there is a correlation between tenure or tenure security and forest outcomes

using prior published empirical studies. For each case we first record the form of tenure being discussed. Second, we record studies' recognition of tenure security for each case or use the context of the discussion in the paper to make an assessment of the extent to which tenure arrangements are secure. 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. This Appendix describes these decision rules below, and gives 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 are clearly differentiated within a study, we use the *de facto* arrangement for analysis since *de facto* tenure is the primary driver for landholders' decisions (Broegaard, 2005; Unruh et al., 2005). 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 public land, using the context of the paper to determine the best fit. The literature sometimes conflates customary and communal tenure; it may be that in some cases land labeled "communal" would be better described as "customary" for our purposes.

Many empirical studies mention the importance of tenure security, but few explicitly discuss this with respect to a particular parcel of land. 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 different, communities are in the process of adjusting to new tenure arrangements, or enforcement and monitoring of tenure arrangements are stated as particularly weak. We recognize our measure of security may be biased toward "secure" since the more traditional remote sensing analyses included do not generally discuss the politics or conflicts involved in making sure tenure is secure.

At the third level we record forest outcomes. 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 still report any loss of forest negatively. Relatively few studies analyze how forest outcomes change with a change in tenure on the same piece of land, rather most report forest outcomes associated with spatially different (but temporally static) tenure forms.

We categorize these forest outcomes as reported by each study. For relative studies we record whether deforestation accelerated, slowed or if forest regeneration accelerated relative to comparative areas in the study. When the magnitude of the change in forest stock was reported, we recorded whether forests were maintained, lost or regenerated. We ultimately focus on relative measures since here we stress the relative performance of secure tenure (and relative measures contain the absolute information – i.e., if deforestation is slowed or accelerated, we know there was forest lost in either case). Relative measures imply a clear normative relationship: accelerated deforestation is negative while slowed deforestation or forest regeneration is positive. So we simplify outcomes into a binary "positive" or "negative" measure. However, when studies only report absolute measures, we generally classified forest loss as negative and forest maintained or regenerated as positive, looking to the study for contextual interpretation.

As an example of study coding, Futemma and Brondizio (2003) describe a case in which land users have had *de facto* rights to the land for centuries, but prior to the study the forest was delineated and households were granted usufruct rights 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 was not yet formal and the system is in flux. Futemma and Brondizio show usufruct rights were associated with forest loss in this case, which we categorize as negative.

A.2. 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. We also asked several leaders in the land tenure–deforestation field to offer suggestions for other studies. We narrow our selection to 41 publications and drop studies that do not meet our criteria.

A.3. 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.

A.4. 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. A case is our units of analysis, with each case carrying equal weight. We compile descriptive statistics by case and, when appropriate, use statistical tests to infer confidence in observed differences.

A.5. Limitations

As with any review of literature, our inferences are inherently biased since the studies we review take place in settings where forests

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Table A.1
Frequency of cases by region.

	Total cases	Positive outcome	Negative outcome
South Asia	30	13	17
Central America	29	11	18
South America	27	16	11
Africa	24	15	9
South East Asia	5	3	2
East Asia	2	1	1
South Pacific	1	1	0

Table A.2
Vegetation and land uses with the 118 cases.

Vegetation types		Economic land use activity	
Tropical forest	102	Subsistence agriculture	107
Montane forest	29	Subsistence forest use	74
Wetlands	14	Commercial agriculture	65
Tropical dry forest	3	Livestock production/ranching	49
Grassland	7	Commercial NTFP collection	40
Mangroves	3	Commercial logging	22
		Hunting	14
		Tourism	5

and tenure issues are particularly salient. In some geographic areas, we found a limited amount of published literature. For example, we encountered relatively few studies in East Asia and the South Pacific, where remote sensing analyses seem to be less frequent and tenure studies often focuses on communal or customary land managed by minority groups (e.g., see Pagdee et al., 2006), but studies of forest cover change is have been 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, 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 often not connected to forests (Reenberg, 2001) (Table A.1).

A.6. Case descriptions

The majority of our 79 sites are in tropical forest and the dominant land use activities are subsistence and commercial agriculture, livestock production and subsistence forest use (Table A.2). Remote sensing data was used 79 of the 118 cases, with the remaining cases utilizing aerial photographs, plot-level analysis, or surveys to examine land use change. Remote sensing studies used mostly Landsat imagery (70 of the 118 cases) and focused on change over time from forest to non-forest or the conversion of forest to agriculture. The duration of analysis ranges from one to fifty year, with an average of 12.5 years. The study area for each site varies considerably, from less than 1 km^2 to approximately 440,000 km^2. The median size of area studied is 548 km^2 (Table A.3).

Table A.3
Case areas and duration of analysis.

	Minimum	Mean	Median	Maximum	*N* (# reporting)
Study area (km^2)	0.06	17,504	548	440,000	96
Duration analyzed (# yrs)	1	12.5	10	50	105

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, their presence in our study set was limited and, therefore, none of these factors showed a significant relationship with forest cover.

Appendix B. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi: 10.1016/j.gloenvcha.2013.05.012.

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