ELSEVIER
www.elsevier.com/locate/worlddev
CrossMark
World Development Vol. 64, pp. S43–S55, 2014
0305-750X/© 2014 The Authors. Published by Elsevier Ltd.
This is an open access article under the CC BY-NC-ND license
(http://creativecommons.org/licenses/by-nc-nd/3.0/).
http://dx.doi.org/10.1016/j.worlddev.2014.03.004

Tenure and Forest Income: Observations from a Global Study on Forests and Poverty

PAMELA JAGGER
University of North Carolina at Chapel Hill, USA
Center for International Forestry Research (CIFOR), Bogor, Indonesia

MARTIN (MARTY) K. LUCKERT
University of Alberta, Edmonton, Canada

AMY E. DUCHELLE
Center for International Forestry Research (CIFOR), Rio de Janeiro, Brazil

JENS FRIIS LUND
University of Copenhagen, Denmark

and

WILLIAM D. SUNDERLIN *
Center for International Forestry Research (CIFOR), Bogor, Indonesia

Summary. — We explore the relationship between tenure and forest income in 271 villages throughout the tropics. We find that state-owned forests generate more forest income than private and community-owned forests both per household and per hectare. We explore whether forest income varies according to the extent of rule enforcement, and congruence (i.e., overlap of user rights between owners and users). We find negative associations between enforcement and smallholder forest income for state-owned and community forests, and positive associations for privately owned forests. Where user rights are limited to formal owners we find negative associations for state-owned forests. Overlapping user rights are positively associated with forest income for community forests. Our findings suggest that policy reforms emphasizing enforcement and reducing overlapping claims to forest resources should consider possible negative implications for smallholder forest income.

Key words — enforcement, forestry, livelihoods, Poverty and Environment Network (PEN), institutions

1. INTRODUCTION

The characteristics of tenure systems are thought to be an important mediating factor in pursuing development objectives focused on enhancing livelihoods and achieving sustainable environmental outcomes (Deininger, 2003; DFID, 2007; FAO, 2002; SIDA, 2007; Sunderlin *et al.*, 2005).[1] Among others, critical questions dominating the policy dialog on forests and tenure include questions of who should own forests, the influence of overlapping claims to forests, and the articulation, monitoring, and enforcement of property rights. Examples of contemporary tenure-related policy issues include: the devolution of property rights from centralized governments to communities and private entities (RRI, 2012; RRI/ITTO, 2009; Sunderlin, Hatcher, & Liddle, 2008); the decentralization of forest management to local governments (Jagger, 2010; Larson, 2005; Larson, Pacheco, Toni, & Vallejo, 2007; Ribot, 2004);[2] movements to formalize property rights throughout the developing world (Meinzen-Dick & Mwangi, 2008); and the emphasis of a wide range of stakeholders on the need to clarify rights to land, trees, and carbon in processes of developing and implementing reduced emissions from deforestation and forest degradation (REDD+) policies and projects (Sunderlin *et al.*, 2013; Corbera, Estrada, May, Navarro, & Pacheco, 2011; Larson, Corbera, *et al.*, 2010).

The focus of much of the research on forests and tenure is on the relationship between forest tenure and resource sustainability (Bowler, Buyung-Ali, Healey, Jones, Knight, & Pullin, 2012; Chhatre & Agrawal, 2008; Gibson, Ostrom, & Williams, 2005; Sayer, McNeely, Maginnis, Boedhihartono, Shepard, & Fisher, 2008). But there are considerable gaps in our understanding of how characteristics of forest tenure influence the ability of rural households to obtain income from forests. This paper uses data from the Center for International Forestry Research's (CIFOR) Poverty Environment Network (PEN) to test hypotheses about the influence of tenure characteristics on the amount and type of income that rural households obtain from forests. Specifically we explore the role of forest ownership (i.e., state, community, or private), the effect of varying levels of enforcement of rules,

* We thank the PEN partners and their teams for providing the data for this study. Financial support to the PEN project was provided by ESRC-DFID, DANIDA, USAID (BASIS-CRSP), IFS, and Centre for International Forestry Research (CIFOR), Bogor, Indonesia. Three anonymous reviewers provided useful suggestions to a draft version of this article.

and the degree of overlap between use by formal owners and other resource users (i.e., congruence) on forest incomes realized by rural households. Our analysis draws on a large and heterogeneous sample including data from 271 villages and over 6,000 rural households. The sample includes study sites in 20 countries in the three major tropical regions of Asia, Latin America, and Africa. We contribute to the limited literature on forest income and tenure, and place our findings in the broader discussion of the potential trade-offs and synergies between welfare and sustainable forest management outcomes. Our study is motivated by the desire to understand the role of forest tenure variables that can be influenced by national-level public policy interventions including, but not limited to, devolution of forest ownership, clarification of property rights, clarification of tenure systems with overlapping claims, and increased enforcement of rules.

2. RESEARCH QUESTIONS AND HYPOTHESES, DATA, AND APPROACH

(a) *Research questions and hypotheses*

The central topic of this study is how tenure characteristics influence the amount of income that rural households obtain from forests. Our study focuses on three fundamental aspects of forest tenure: formal ownership; level of enforcement of rules; and congruence, or the extent of overlap in use rights, between forest owners and the actual users of the resource.[3] Accordingly our analysis is centered on three research questions:

i. What forest ownership categories (i.e., state, community, or private) do rural households obtain forest income from?
ii. How does the degree of enforcement of rules at the village-level (i.e., none, moderate or high) influence the amount of forest income obtained by rural households?
iii. How does the extent of overlap between use by formal forest owners and actual forest users (i.e., congruence parsed as none, partial or full) at the village-level influence the amount of forest income obtained by rural households?

We define ownership as the *de jure* or legal holding of property rights to the forest, including rights of access, withdrawal, management, exclusion, and alienation (Schlager & Ostrom, 1992). Following previous studies of forest tenure (i.e., RRI, 2012; RRI/ITTO, 2009; Sunderlin *et al.*, 2008) we use the formal ownership categories of state, community, and privately owned forests.[4] Many studies on forest tenure in developing countries have focused on the relationship between forest ownership and sustainability, and generally find an ambiguous relationship (Dietz, Ostrom, & Stern, 2003; Ostrom & Nagendra, 2006). Other literature looks at the relative effectiveness of different types of forest ownership to understand which ownership categories lead to lower rates of deforestation and degradation (e.g., Bowler *et al.*, 2012; Porter-Bolland, Ellis, Guariguata, Ruiz-Mallen, Negrete-Yankelevich, & Reyes-Garcia, 2012; Andam, Ferraro, Pfaff, Sanchez-Azofeifa, & Robalino, 2008; Nepstad *et al.*, 2006). In this study, our focus is on tenure and forest income, though our results do suggest some implications for sustainable forest management.

Most studies examining the relationship between forest tenure and forest income focus on a specific ownership category or on single case studies (Adhikari, 2005; Chhetri, 2010). Some exceptions are Ferraro and Hanauer (2011) and Andam, Ferraro, Sims, Healy, and Holland (2010) who compare protected areas and reserves (e.g., state-owned lands) with ungazzeted areas in Costa Rica and Thailand, and Jagger, Pender, and Gebremedhin (2005) and Jagger and Luckert (2008) who compare household incomes from community and privately owned small-scale woodlots in Ethiopia and Zimbabwe respectively. To our knowledge, this is the first study to investigate relationships between tenure characteristics and forest income with a global dataset. We have no specific hypotheses regarding the types of formal forest ownership categories that rural households use most for forest income. These relationships are largely the result of historical settlement and land use patterns that are difficult to identify with cross-sectional behavioral data.

We define enforcement as the degree to which sanctions are applied in the event that rules are not followed. Several recent studies find that enforcement, and more specifically engagement of local resource users in enforcement, contributes to sustainable forest management and biodiversity conservation (Chhatre & Agrawal, 2008; Gibson *et al.*, 2005; Persha, Agrawal, & Chhatre, 2011). These studies are largely based on findings from community forests and, with the exception of Persha *et al.* (2011), are squarely focused on biophysical outcomes. Enforcement is hypothesized to be an important variable with respect to forest income as forests yield multiple benefits and products, and have multiple stakeholders with competing claims. We hypothesize that high levels of enforcement on state-owned forests will be associated with lower forest incomes. High enforcement in such settings implies that local forest users are being closely monitored and that use of forest resources may be limited or forbidden. Conversely, we hypothesize that high levels of enforcement will be associated with higher forest incomes for community- and privately owned forests. Findings from studies of community forests suggest that in the absence of enforcement of rules against those who would extract excess benefits (e.g., illegal harvesting), forest sustainability and the maintenance of forest-based livelihoods can be jeopardized (Chhatre & Agrawal, 2008). However, over the short term, an absence of rule enforcement can yield higher benefits for households that are not constrained in their forest collection activities. Therefore, there may be some situations where no or low enforcement may be associated with high forest incomes.

Congruence is the extent of overlap in use between the *de jure* formal owners and the *de facto* or actual users of the forest. The influence of this aspect of tenure has not been well explored empirically in the literature, though we note that several scholars have explored the connection between the well-being of rural households and contestation of ownership rights between the state and local users (RRI, 2012; Larson, Barry, Dahal, & Colfer, 2010; Ellsworth, 2004; Ellsworth & White, 2004; Larson *et al.*, 2007). We hypothesize that for state-owned forests a higher degree of congruence is associated with lower forest incomes for rural households. States with a vested interest in extracting resources from a particular forest may be less likely to allow other users to harvest products. Conversely, we hypothesize that for community- and privately owned forests, partial or full congruence between formal owners and actual users will be associated with higher forest incomes, as those holding the property rights are the local users. This hypothesis follows from findings from the community forestry literature suggesting that a high degree of engagement of local resource users in rule making and management decisions, including rules of use, may increase the likelihood of sustainable forest management and favorable rural livelihoods outcomes (McKean, 2000; Persha *et al.*, 2011).

(b) *Key variables and definitions*

Central to this study is the collection of data characterizing forest tenure. A broad tenure classification system suitable for use across the diversity of countries included in the PEN study was developed by a multi-disciplinary group of researchers that included anthropologists, economists, political scientists, and sociologists. Discussions among scholars in these disciplines resulted in three central questions: (1) Who are the formal (*de jure*) owners of the forest?; (2) Who are the actual (*de facto*) forest users?; and (3); If they exist, how well are rules of access, use, and management enforced? While it is not easy to classify diverse forest tenure systems with a parsimonious set of variables, we developed a three digit coding system which captures the possible combinations of three key dimensions of tenure: ownership; formal and informal use rights; and level of enforcement of rules. The system was used in village surveys to code tenure characteristics of forests accessed by village members, and in household surveys to describe the characteristics of forests where products were collected. The coding system is comprised of three levels as follows (CIFOR, 2007):

1. The first level represents the formal or legal (*de jure*) owner of the land, which is the entity with the *transfer* rights (rights to sell, lease or rent out the land), and can be: (1) the state (nationally or regionally); (2) communities (i.e., collective); (3) private (individuals or companies);
2. The second level represents the actual or *de facto* forest users, (who normally have no *de facto* or *de jure* transfer rights). One problem can be overlapping use rights on the same piece of land, e.g., individual agricultural rights combined with collective rights to collect fuel wood or wild fruits. Hence, we introduced mixed categories for *de facto* overlapping land rights, thus yielding seven categories: (1) state, (2) community, (3) private, (4) state–community, (5) state–private, (6) community–private, and (7) state–community–private. [5]
3. The third level indicates the degree of enforcement of rules, which regulates access of users, permissible uses, and possibly also the management of the land and its resources. Three categories are distinguished: (1) high, (2) moderate, and (3) no enforcement of rules. Note that the rules might be set by the *de facto* and/or the *de jure* owners, and may have the backing by either the state or customary institutions.

For example, code 122 is a state-owned forest, used/managed by the community, with a moderately low degree of rule enforcement. It could be a sustainable-use protected area in Brazil, such as an extractive reserve, or an agro-extractive community in Bolivia. A forest assigned code 221 is a community-owned and -managed forest with no rule enforcement, e.g., a community in Democratic Republic of Congo with the inability to exclude timber companies. The joint forest management program in India would have the code 142: the state is the official owner of the forest, but shares use rights with communities, and is managed with moderate enforcement of rules.

Employing a parsimonious classification system to describe forest tenures across a heterogeneous set of study sites is challenging. The PEN project undertook several measures to ensure data quality including: comprehensive training of PEN research partners on the tenure coding system; the provision of detailed technical guidelines to clarify the tenure classification system for use in training enumerators and for trouble shooting in the field; and training on how to conduct an effective focus group, which is how the majority of the village-level survey questions were answered.

The broader structure of the PEN dataset has been described in detail in Angelsen *et al.* (2014). In addition to village-level data that characterize the forest tenure types in the study villages, we use village-level data that indicate the size of forests, the extent of forest-centered collective action, (i.e., number of forest user groups), group heterogeneity (i.e., the number of ethnic groups in the village); and group size (i.e., the population of the village). Geographic Information Systems (GIS) data are used to characterize dominant ecosystem, forest cover, deforestation/degradation trends between 2006 and 2009, the time frame during which most of the PEN data were collected, market access, and population density for the villages in the PEN sample.

The dependent variables in our analysis are variants of forest income (total, subsistence and cash). For all three types, we define forest income as the gross value (quantity produced multiplied by price) minus the costs of purchased inputs (e.g., transportation and marketing costs, and hired labor). [6] The PEN guidelines (CIFOR, 2007) stress the importance of collecting data on households' extraction and production of forest products used for both subsistence and generating cash income. Forest income data were collected for each household on a quarterly basis using a detailed household income questionnaire. [7] Data were collected with a recall period of one month and multiplied by three to estimate the value for each quarter. Quarterly data were then aggregated and adjusted for adult equivalent units to provide annual per adult equivalent estimates for each household. Data across study countries were adjusted for purchasing power parity (PPP) and normalized to USD. Household-level data were then averaged for each village in our study to provide an estimate of the mean annual household total, subsistence, and cash forest income by tenure type for each village in the sample.

(c) *Sample and representativeness*

Country and site selection for the PEN project was purposive based upon a desire to cover all major forest regions across the tropics, and by the interests of selected research partners. Village selection included a variety of methods depending upon the research design of the PEN partner. Sampling methods range from national or regional random or stratified random samples of villages, to purposive sampling on the basis of site-level characteristics important to the individual PEN study. Households were randomly selected from village-level rosters. The average number of households sampled within a PEN village is 24.

Data on tenure for forests [8] accessed by households in the PEN sample are available for a subset of the total PEN sample. Of the 620 forests documented in the PEN dataset, we have a complete set of data for 487 forests in 271 villages. [9] Complete data include information on: tenure (i.e., formal ownership, enforcement, and congruence), forest size (i.e., estimated area in hectares), and the GIS data used for characterizing forest conditions, market access, and population density. [10] Missing data on the size of forests were by far the most significant limiting factor for our sample. In order to address potential bias in our sub-sample of PEN villages relative to the full PEN sample we provided a number of robustness checks which are elaborated in the following section.

We consider the representativeness of the PEN study sites by comparing the distribution of forests by formal or *de jure* owner identified in Sunderlin *et al.* (2008) and RRI/ITTO (2009) with the distribution of forest ownership in the villages included in the PEN sample (Table 1). [11] We note that the Sunderlin *et al.* (2008) and RRI/ITTO (2009) data (hereafter RRI) are not globally representative, but rather provide an overview of forest ownership in the most forested countries in each of the three major tropical regions using available secondary data. The PEN and RRI data are closely aligned with

Table 1. *Representativeness of PEN tenure data, share of forest by formal ownership category*[1,2]

	Number of villages (PEN)	State		Community		Private	
		RRI	PEN	RRI	PEN	RRI	PEN
Asia[3]	56	68.0	68.9	28.0	2.8	4.0	28.2
Latin America[4]	68	36.0	60.9	32.0	24.9	32.0	14.1
Africa[5]	147	97.9	72.7	2.0	11.7	0.1	15.5
All	271	65.0	69.0	22.0	13.2	13.0	17.8

[1] Area data missing for 63 villages in PEN sample.
[2] RRI data are drawn from Sunderlin *et al.* (2008) and RRI and IITO (2009).
[3] Includes PEN sites in Bangladesh, Cambodia, India, Indonesia, and Vietnam.
[4] Includes PEN sites in Bolivia, Brazil, Ecuador, and Guatemala.
[5] Includes PEN sites in Burkina Faso, Cameroon, Democratic Republic of Congo, Ethiopia, Ghana, Malawi, Mozambique, Nigeria, Senegal, Uganda, and Zambia.

respect to the share of forest owned by the state overall (69% and 65% respectively), and for state-owned forests in Asia (69% and 68% respectively). Relative to the RRI data, PEN has a smaller share of state-owned forests in the Africa region, and a larger share of state-owned forests in Latin America. We find considerable differences between the distribution of forest ownership in the RRI and PEN samples for community- and privately owned forests. Overall the PEN dataset has a smaller share of community forest than the RRI dataset (13% and 22% respectively), with very large differences in the Asia region. Relative to the RRI data, the PEN dataset has a larger share of private forests (18% *vs.* 13% for RRI), with large differences in all three regions, but particularly in Asia. The overall representativeness of the PEN study sites is addressed in more detail in Angelsen *et al.* (2014).

(d) *Analytical approach*

Methods of analysis include: factor analysis to identify forest domains; descriptive statistics to identify general patterns of forest tenure classifications and forest income in the PEN study areas; and econometric analysis to investigate the relationship between enforcement of rules, congruence, and forest income. Our empirical model is based on the general specification:

$$FY_i^j = f\left(\boldsymbol{E}_i^j, \boldsymbol{C}_i^j, \boldsymbol{CT}_i^j\right)$$

where:

FY_i^j = annual total, subsistence or cash forest income per adult equivalent, averaged across each household in village i ($i = 1, \ldots, 271$ *villages*), for a given forest ownership type j ($j = 1, 3$ *forest ownership types*);
$\boldsymbol{E}_i^j$ = a vector of 2 enforcement of rules variables (c.f. none); =1 if moderate, =0 otherwise; =1 if high enforcement, =0 otherwise;
$\boldsymbol{C}_i^j$ = a vector of 2 congruence variables (c.f. none); =1 if partial congruence, =0 otherwise; =1 if full congruence = 0 otherwise;
$\boldsymbol{CT}_i^j$ = a vector of control variables that includes:
Forest area (in hectares);
Number of forest user groups in the village;
Number of people in the village;
Number of ethnic groups in the village
Forest Domain Factor Score (factors 1–5) (see definition below)
Presence of other forest ownership category (3 categories, c.f. state) = 1 if community, =0 otherwise; =1 if private, =0 otherwise OR
(3 categories, c.f. community) =1 if state, =0 otherwise; =1 if private, =0 otherwise OR
(3 categories, c.f. private) =1 if state, =0 otherwise; =1 if community, =0 otherwise
Regions (3 regions, c.f. Asia) =1 if Latin America, =0 otherwise; =1 if Africa, =0 otherwise.

We estimate a series of village-level ordinary least squares regression models to test hypotheses about the relationship between forest income and enforcement of rules and congruence for each ownership type. We parse our analysis by formal owner because we believe that there are systematic differences in state-, community-, and privately owned forests with respect to size, quality, and other factors.[12] Our regression models for each formal forest ownership category are further decomposed by the type of forest income: subsistence, cash, or total. We did no not use forest incomes per hectare as our dependent variable due to the challenges of obtaining reliable estimates of forest size, particularly in cases where the forest is very large, and due to the very wide and non-normal distribution of forest size, particularly for state forests. Our independent variables include the level of enforcement of property rights, and the extent of congruence between owners and users of the forest. We control for a number of variables known to influence forest income including forest size, presence of village level collective action, village population, and ethnic heterogeneity (Chhatre & Agrawal, 2008; Persha *et al.*, 2011).

We control for exogenous forest characteristics using the factor scores generated by our factor analysis (described below) and regional dummy variables. In our models we also include dummy variables that reflect whether other ownership categories of forests are present in the village. Due to limited degrees of freedom particularly for our models for community- and privately owned forests we use a relatively parsimonious model specification. We recognize the potential for endogeneity in our model because, for example, the level of enforcement could influence forest income (as per our model structure), and forest income could influence the level of enforcement. In the same way, the values that can be extracted from a forest may influence the institutional and ownership arrangements that come to dominate that forest. Therefore, we interpret the results that follow as associations rather than strict causal relationships.To address the issues of potential bias in our sub-sample of villages relative to the full PEN sample we undertook a number of robustness checks. First we replicated the principal components factor analysis using the complete set of GIS data.[13] We find that most of the factor scores and by extension our characterization of forest domains are robust (Table 2). We also run our full set of regression

Table 2. *Identification of forest domains (factor analysis results)*[1,2,3]

Variable	Rotated factor loadings				
Interpretation of factor	1 High quality moist broadleaf forest in remote regions	2 Dry broadleaf forest in populated regions	3 Low quality forest in populated regions	4 Montane grassland in populated regions	5 Coniferous forest in populated regions
Forest cover in 2006 (%)	0.667^{R}	−0.471	0.006	−0.272	0.069
Annual rate of deforestation between 2006 and 2009 (%)	−0.044	0.086	0.797^{R}	−0.013	−0.002
Annual rate of degradation between 2006 and 2009 (%)	0.132	−0.154	0.681^{R}	−0.079	−0.092
Dominant ecosystem (c.f. desert and shrubland)					
Montane grassland	−0.011	−0.065	−0.020	0.979^{R}	−0.040
Tropical and subtropical coniferous	0.013	−0.040	−0.020	−0.038	0.988^{R}
Tropical and subtropical dry broadleaf	0.012	0.950^{R}	−0.014	−0.117	−0.065
Tropical and subtropical grasslands/savannah	−0.862	−0.339	−0.005	−0.281	−0.152
Tropical and subtropical moist broadleaf	0.802^{R}	−0.308	0.051	−0.211	−0.176
Population density	−0.479	0.488^{R}	0.371^{R}	0.282^{R}	0.272^{R}
Distance to nearest road (km)	0.506^{R}	−0.078	−0.369	−0.158	−0.110

[1] Principal components factor method used. Factors rotated using varimax method. The five retained factors account for 77.4% of the variance, and represent factors with eigenvalues greater than 1.09.
[2] Unit of analysis is the village ($N = 271$). Included in this analysis are all villages with forest tenure data and area data available.
[3] Factor scores are robust (R) when compared with PEN sample of 308 villages with remote sensing, GIS and forest tenure data available. Remote sensing and GIS data were missing for six villages in China and seven villages in Nepal. Thirteen villages in one of the Brazilian sites had missing forest tenure data.

models with an alternative specification that does not include forest size, thereby allowing us to include a larger portion of sampled forests. We do not present these results, because they are similar to the models presented, but in Table 5 have only noted findings which are robust (i.e., same sign and significant at least at the 10% level) to the alternative specification. All models are estimated with robust standard errors clustered at the site level,[14] have been tested for multicollinearity using the variance inflation factor test, and heteroskedasticity using the Breusch-Pagan test.

3. RESULTS AND DISCUSSION

(a) *Forest domains*

The diversity of ecosystems, forest conditions, population density and market access in the villages included in the PEN dataset presents a challenge for identifying relationships between tenure and income. Our aim is to control for important exogenous factors that may affect both forest income and our policy variables of interest: enforcement and congruence. We use factor analysis to describe variability among a number of observed correlated variables obtained from remote sensing and GIS data with the aim of producing a lower number of unobserved variables (i.e., factors) (Table 2).[15] We identify five factors that can be clearly interpreted as “forest domains.”[16] The first principal component is strongly associated with tropical and sub-tropical moist broadleaf forest, high forest cover, and large distances to roads. For example, the factor loading on tropical and sub-tropical moist broadleaf forest is 0.802, and the factor loading on percent of forest cover in 2006 is 0.667, indicating that these variables are strongly correlated with this factor. The second component is strongly associated with dry broadleaf forest and high population density. The third component is strongly correlated with high rates of deforestation and degradation and high population density. The fourth and fifth components are strongly associated with high population densities and, respectively, with montane grassland and coniferous forest ecosystems. The factor scores from each of the five forest domains are used as control variables in our subsequent analysis. Our factor scores are robust when considering the full sample of PEN villages.

(b) *Forest tenure decomposed*

Our first research question is focused on the formal forest ownership categories from which rural households obtain income. As already summarized in Table 1, state tenure dominates the PEN dataset with 69% of the total forest area in study villages formally owned by the state. Privately owned forests represent the second most common ownership category at 18%, and community forests comprise 13%. We decompose the distribution of forests by enforcement and congruence characteristics (Table 3). We find that only 16% of state forests are characterized as having no enforcement. The remainder of state-owned forest is split evenly between moderate and high enforcement (approximately 40% for each category). The most straight forward interpretation of moderate *vs.* high enforcement relates to whether sanctions for rule breaking are sometimes applied (moderate) or always applied (high), but the severity of sanctions was also a consideration for village-level focus groups asked to explain the degree of enforcement. The majority of state forests are characterized as having no congruence (68%). That means that although the state is the formal owner of the forest, the state does not use the forest. An example is a central forest reserve that is accessed by village members, but where the state does not actively harvest any products from the forest. A second example is the case of the Amazon where smallholders are living on state-owned land, but due to lack of transfer rights are not forest owners under the PEN definition. It is important to note that the tenure data are based upon perceptions of village focus groups. Their views reflect their observations of whether or not the state is an actual forest user, and is limited to observations within the geographic sphere of the village and surrounding areas. The second largest category is cases of full congruence (23.7%) where the state is both the owner and the sole user

Table 3. *Distribution of forest area by tenure characteristics at village-level, percent*[1,2]

	State		Community		Private	
	Share of total	Share of state-owned forest	Share of total	Share of community-owned forest	Share of total	Share of privately owned forest
All forests	68.9	100	13.2	100	17.8	100
	(44.1)	(0)	(32.5)	(0)	(35.5)	(0)
Level of enforcement						
No enforcement	11.8	16.4	1.5	9.3	2.6	11.4
	(31.6)	(36.6)	(11.4)	(28.9)	(15.1)	(30.7)
Moderate enforcement	25.6	39.7	8.5	65.1	12.9	71.4
	(41.6)	(43.4)	(26.8)	(47.7)	(31.1)	(42.9)
High enforcement	31.5	43.8	3.2	25.6	2.2	17.1
	(45.6)	(49.4)	(16.9)	(43.8)	(12.7)	(34.4)
Congruence between formal owners and actual users						
No congruence	46.7	68.4	4.5	25.3	1.0	3.4
	(47.7)	(45.4)	(19.9)	(42.5)	(9.7)	(17.8)
Partial congruence	5.8	7.9	1.2	24.1	7.7	37.6
	(23.1)	(27.0)	(9.2)	(42.5)	(25.4)	(45.1)
Complete congruence	16.5	23.7	7.5	50.6	9.0	58.9
	(35.4)	(41.3)	(24.6)	(48.7)	(24.9)	(45.7)
N[3]	271	199	271	63	271	80

[1] Standard deviations in parentheses.
[2] Shares are based upon village focus group reports of ownership, enforcement and congruence, and estimates of total area of each forest. Forest-level data are aggregated to the village-level. State forest area was truncated at 50,000 ha for 16 villages in the sample.
[3] Sample sizes for within ownership category indicate number of villages that have forest ownership category present.

of the forest. We would expect very low smallholder forest incomes in cases where village-level focus groups indicated complete congruence for state-owned forests.

A small share of community forest is characterized as having no enforcement (9%). The most common situation is moderate enforcement. This is the case for 65% of community forests, suggesting that sanctions for rule breaking in community forests are not always applied, variably applied, or not very severe. We observe high levels of full congruence for community forests (51%), suggesting that the property rights surrounding the use of community forests are limited to community members or community groups only. However, there is also a relatively large share of community forest for which there is no congruence. This means that although the formal owner of the forest is the community, those forests are not utilized as community resources. A potential explanation for this is that the forest has been set aside for regeneration, meaning that community members do not have *de facto* use rights. Or alternatively, as is the case in several of the Latin American sites, a formal community forest has been *de facto* divided up for private use among community members.

The majority of privately owned forests has moderate enforcement (71.4%), and a relatively small share of private forest has no enforcement (11.4%). While one might expect private forests to be predominantly characterized as having high enforcement, the dominance of moderate enforcement might reflect that the rules surrounding use of private forests are clearer and power to exclude is greater, meaning that more severe or frequent sanctions are not necessary in many settings. However, we speculate that enforcement may vary depending upon whether subsistence forest products such as fuel wood and wild foods are being sought as compared with cash generating forest products such as timber. We find that the majority of private forests (59%) are characterized as having complete congruence, which means that forest owners are perceived to be the sole users of their forests. It is noteworthy that 38% of forests are characterized as having partial congruence, meaning that other households within the village, community groups, and even state actors may be accessing privately owned forests to extract resources. This finding is borne out in the household-level data, which show that many households that do not own forests harvest products from private forests owned by others.

(c) *Tenure and forest income*

Total, subsistence, and cash forest income are the dependent variables in our regression models. We present village-level averages of adult equivalent adjusted incomes for state, community- and privately owned forests in Table 4. We find that state-owned forests have by far the largest average incomes associated with them at approximately US$358 /year. This value is almost an order of magnitude larger than average incomes derived from community forests (US$44/year). Average income from privately owned forest is US$88/year. These figures are averages for all villages having this particular forest tenure system. Given that state forests are more common, and community forest the least common, the differences in average forest income for the full PEN sample are even larger (see note 4 in Table 4). We also present per hectare estimates of average household incomes for each formal ownership category. We find approximately the same pattern of forest income as for the household-level estimates, although the differences are smaller (indicating that state forest areas per household are larger than for the other tenure categories). Households in our sample obtain most forest income on a per hectare basis from state forests (US$ 4.55/ha), followed by private forests (US$ 3.11/ha) and community forests (US$ 1.32/ha).

We observe some trends in subsistence *vs.* cash income for each of the three formal ownership categories. On a per

Table 4. *Village-level averages of household absolute and relative forest income*[1,2,3,4]

	State-owned forest	Community-owned forest	Privately owned forest	All forests[6]
Absolute income, USD/adult equivalent				
Total forest income	357.89	44.09	87.73	270.55
	(772.29)	(126.70)	(112.82)	(632.29)
Subsistence forest income	142.65	22.09	52.62	113.65
	(270.29)	(54.28)	(59.46)	(213.07)
Cash forest income	215.16	22.00	35.11	156.84
	(580.81)	(85.90)	(65.57)	(447.03)
Absolute income, USD/adult equivalent/ha				
Total forest income	4.55	1.32	3.11	2.67
	(36.05)	(2.76)	(5.41)	(15.75)
Subsistence forest income	2.49	1.06	1.83	1.56
	(24.0)	(2.34)	(2.80)	(10.55)
Cash forest income	2.06	0.25	1.28	1.11
	(16.19)	(0.84)	(3.51)	(7.08)
N[5]	199	63	80	271

[1] Standard deviations in parentheses.
[2] Represents share of total income from unprocessed forest products and harvested inputs (*vs.* purchased inputs) to processed forest products.
[3] All between ownership category means (i.e., total forest income from state *vs.* community; state *vs.* private; community *vs.* private) are statistically significantly different at the 1% level.
[4] Figures are for the subset of villages for which forest area data are available ($N = 271$). For the full set of villages ($N = 333$) in the PEN dataset we estimate forest incomes per adult equivalent of US$302 from state forest, US$17 from community forest and US$67 from private forest. Estimated total forest income (US$386) is lower than US$440 as calculated in Angelsen *et al.* (2014). Our calculations include income from unprocessed forest products from natural forests and woodlots/plantations and the value of collected forest products used as inputs to processed products. They do not include forest income from processed forest products produced with purchased inputs because the tenure status of the forest where purchased inputs were derived is unknown. Our estimates also exclude income from forest services.
[5] Some villages have forests from more than one ownership category. Total number of villages in the sub-sample is 271.
[6] Average per household and per household/hectare adult equivalent forest income irrespective of formal ownership category.

household basis, we estimate larger amounts of cash forest income derived from state forests (US$215/year *vs.* US$142/year for subsistence income), whereas most income from privately owned forests is based on subsistence products (US$53/year *vs.* US$35/year for cash products). The proximity of private forests relative to state forests may be at play here. In many cases privately owned forests are nearer to settlements, suggesting that the collection and transport of generally lower value subsistence products is more efficient. Higher value products, including many that are sold for cash income, may be more prevalent in state-owned forests, and higher returns may justify traveling longer distances to collect them. Average incomes from community forests are almost equally split between subsistence and cash, suggesting that community forests are used for more than simply providing subsistence products for marginalized households. When we consider the split between subsistence and cash income on a per household per hectare basis, for both state and private forests the split between subsistence and cash income is roughly 55% and 45% respectively. This is quite different than community forests where 80% of household forest income on a per hectare basis is for subsistence use. Due to the large standard deviations observed for state forests, we chose to model the relationship between forest income and tenure on a per household, rather than a per hectare basis.

To understand the relationship between tenure and forest income we investigate enforcement and congruence for each ownership category for the sub-sample of PEN villages that have complete data on forest tenure, forest size, and forest domain ($N = 271$) (Table 5). Our dependent variable is the village mean of household forest income per adult equivalent. The policy variables of interest are a series of binary variables that indicate the level of enforcement and congruence associated with the forests in each village. We control for forest size, forest centered collective action (i.e., number of forest user groups in village), group characteristics (i.e., village population and number of ethnic groups), forest domains, whether the village has either or both of the other two types of forests (i.e., for state forests we consider the effect of the presence of community and privately owned forests), and region. Regression results are presented by ownership category, and for total, subsistence and cash income. In general, the models explain between 38% and 78% of the variation, with the highest R^2 for the models focused on privately owned forests.

For state-owned forests, we find a negative and significant relationship between forest income and moderate enforcement relative to the base case of no enforcement. This relationship holds for subsistence income, but is only weakly significant for cash income. These findings suggest that moderate enforcement, characterized by irregular or moderate sanctions, is associated with reduced access to forest resources on state forests. The lower level of statistical significance for cash income is surprising. We would expect enforcement efforts to be targeted toward smallholders seeking to utilize state forests for commercial purposes. However, it may be the case that enforcement is targeted toward both subsistence and cash income and is more effective for subsistence users, or that users generating cash income may have better social networks, or have greater means for paying bribes that persuade enforcers to look the other way. We note that in the Amazon context enforcement is not necessarily from state actors, but rather from the smallholders that occupy state land who assume enforcement responsibilities. As hypothesized, we find

Table 5. *OLS results for village-level regressions, dependent variable is village mean of per adult equivalent forest income*[1,2]

	State-owned forests			Community-owned forests			Privately owned forests		
	Total forest income	Subsistence	Cash	Total forest income	Subsistence	Cash	Total forest income	Subsistence	Cash
Level of enforcement (c.f. none)									
Moderate enforcement	−0.726**R	−0.690**R	−0.624*R	−1.335***R	−1.081***R	−1.273	0.777**	0.637*	0.809
	(0.300)	(0.307)	(0.355)	(0.432)	(0.345)	(0.742)	(0.327)	(0.302)	(0.711)
High enforcement	−0.576	−0.365	−0.754	0.44	0.551	−0.088	0.783**	0.801***	0.701
	(0.348)	(0.350)	(0.590)	(0.736)	(0.548)	(0.845)	(0.315)	(0.228)	(0.693)
Congruence between formal owners and actual users (c.f. none)									
Partial Congruence	−0.608*R	−0.703*R	−0.755	1.485*R	1.486**	0.944	0.153	0.354	−0.423
	(0.319)	(0.356)	(0.491)	(0.707)	(0.561)	(0.791)	(0.935)	(0.722)	(1.455)
Full congruence	−0.934***R	−1.018***R	−0.632	−0.153	−0.041	−0.352	−0.688	−0.669	−0.607
	(0.312)	(0.333)	(0.414)	(0.559)	(0.441)	(0.606)	(0.951)	(0.732)	(1.457)
(Ln) Forest size	0.007	0.002	0.123*	−0.132	−0.156*	−0.109	0.316***	0.288***	0.308***
	(0.067)	(0.061)	(0.090)	(0.108)	(0.082)	(0.158)	(0.076)	(0.069)	(0.067)
Forest user groups (number of groups)	−0.098	−0.008	−0.328*	0.275	0.259*R	0.247	0.037	0.037	0.018
	(0.110)	(0.101)	(0.165)	(0.164)	(0.137)	(0.173)	(0.156)	(0.141)	(0.210)
(Ln) Number of people in village	−0.038	−0.05	−0.107	−0.11	−0.094	−0.08	−0.384	−0.365	−0.464
	(0.091)	(0.089)	(0.140)	(0.158)	(0.149)	(0.195)	(0.256)	(0.218)	(0.325)
Ethnic diversity (number of groups in village)	0.015	0.022	−0.013	0.124*R	0.089*R	0.152**R	0.037	0.025	0.078***R
	(0.035)	(0.028)	(0.042)	(0.067)	(0.046)	(0.069)	(0.036)	(0.039)	(0.020)
Forest domain (factor score)									
Factor 1: High quality moist broadleaf forest in remote regions	0.667***R	0.530***R	0.927***R	1.095**R	1.045***R	0.629	−0.109	−0.07	−0.086
	(0.165)	(0.169)	(0.235)	(0.389)	(0.324)	(0.380)	(0.256)	(0.258)	(0.255)
Factor 2: Dry broadleaf forest in populated regions[3]	0.081	0.131	0.061	−1.232***R	−1.133***R	−0.927**R	–	–	–
	(0.155)	(0.172)	(0.173)	(0.387)	(0.275)	(0.394)			
Factor 3: Low quality forest in populated regions	−0.161	−0.226**	−0.123	−0.306	−0.518***R	−0.038	−0.252	−0.175	−0.213
	(0.111)	(0.106)	(0.154)	(0.201)	(0.134)	(0.211)	(0.252)	(0.242)	(0.270)
Factor 4: Montane grassland in populated regions	−0.016	−0.123	0.156	−0.468	−0.155	−0.739	−0.104	0.158	−0.897
	(0.134)	(0.116)	(0.211)	(1.07)	(0.904)	(0.947)	(1.224)	(1.141)	(1.30)
Factor 5: Coniferous forest in populated regions	−0.082	0.067	−0.360**R	−0.007	0.06	−0.047	4.429*	3.239	6.524**R
	(0.107)	(0.106)	(0.164)	(0.185)	(0.140)	(0.172)	(2.383)	(2.510)	(2.445)
Presence state forest (0/1)	–	–	–	−0.806	−0.656	−0.875	0.241	0.175	0.219
				(0.506)	(0.449)	(0.558)	(0.285)	(0.247)	(0.303)
Presence community forest (0/1)	−0.186	−0.174	−0.063	–	–	–	−0.058	−0.029	−0.205
	(0.385)	(0.343)	(0.421)				(0.276)	(0.251)	(0.299)
Presence private forest (0/1)	−0.745**R	−0.867***R	−0.573	−0.343	−0.255	−0.496	–	–	–
	(0.294)	(0.293)	(0.423)	(0.323)	(0.278)	(0.362)			
Region (c.f. Asia)									
Latin America	0.131	−0.229	−0.43	−3.743***R	−3.458***R	−1.814	−4.931***	−4.198***	−4.194***
	(0.786)	(0.821)	(1.10)	(0.969)	(0.591)	(1.217)	(0.304)	(0.299)	(0.360)
Africa	−0.56	−0.316	−0.719	−1.279	−0.931	−1.356	−1.001*	−0.479	−2.369***R
	(0.576)	(0.617)	(0.579)	(0.891)	(0.732)	(0.912)	(0.532)	(0.516)	(0.577)
Constant	6.243***R	5.575***R	5.027***R	4.728**R	4.252***R	3.149*R	5.877***R	5.184***R	5.686**R
	(0.595)	(0.568)	(1.00)	(1.64)	(1.29)	(1.661)	(1.450)	(1.040)	(2.550)
N	199	199	199	63	63	63	80	80	80
R^2	0.435	0.377	0.410	0.673	0.707	0.521	0.793	0.786	0.691
Log-likelihood (full model)	−320.02	−299.34	−379.33	−92.30	−81.19	−95.42	−102.27	−95.09	−116.40

[1] Standard errors in parentheses. Standard errors are clustered at the site-level.
[2] Coefficient is robust (R) to alternative specification that omits forest area data (i.e., same sign and significant at 10% level or higher) that includes full sample of villages with tenure data ($N = 226$ state forests; $N = 63$ community forests; $N = 88$ private forests).
[3] Omitted from private ownership models due to multicollinearity.
* Statistically significant at the 10% level.
** Statistically significant at the 5% level.
*** Statistically significant at the 1% level.

a negative and significant relationship between total income from state forests and congruence, with the strongest effects for full congruence. It appears as though use of forests by the state crowds out use by local forest users, particularly for subsistence purposes. Congruence has a negative but not significant effect on cash income from state forests.

Our models for income from state-owned forests control for a number of other variables hypothesized to influence forest income. The sign on the forest size variable is positive, but is weakly significant only for our regression focused on cash income from state forests, suggesting that larger state-owned forests have more potential for cash income generation than smaller ones. Larger forests are also more remote with large areas often out of reach from enforcement authorities. We find that the number of forest user groups present in a village is negatively associated with cash income from forest products, suggesting that where groups are present, they may not be focused on activities in state-owned forests, or may not have a relationship with the state that favors securing benefits for local resource users. As expected, we find strong positive associations between forest domains that reflect high quality forests and low population density environments (e.g., forest domain 1) and forest income, and the inverse relationship for degraded forests with higher population densities (e.g., forest domain 3). Finally, the presence of privately owned forest is strongly associated with negative incomes from state forests for total and subsistence forest income. This result suggests that private forests may provide a substitute source of forest income. This finding may be related to the proximity of state *vs.* privately owned forests in cases where both ownership categories are present, but may also be related to the relative influence of enforcement.

Community forests yield a somewhat different picture of how tenure characteristics influence forest income. As with state-owned forests, and relative to the base case of no enforcement, moderate enforcement is strongly negatively associated with total and subsistence income from community forests. High enforcement is positively, but not statistically significantly associated with total and subsistence income from community forests. Relative to the base case of no congruence, there is a positive and significant relationship between forest income from community forests and partial congruence. This means that community forests with *de facto* users that include private users, the state, and others that do not belong to the *de jure* ownership group yield higher incomes those using them. We find that community-owned forests with full congruence (i.e., community owners are the sole users) have a negative but not significant relationship between full congruence and forest income.

As with several studies on community forestry and sustainable forest management outcomes (Chhatre & Agrawal, 2008; Gibson *et al.*, 2005; Persha *et al.*, 2011), we find a positive association between forest income and the presence of forest user groups for subsistence forest income. Forest user groups are often responsible for negotiating very specific use rights frequently related to fuel, foods, thatch, and other products that make up part of the subsistence portfolio of goods from the forest. We do not identify clear patterns between other commonly observed indicators of sustainable forest management for community forests (i.e., forest size, group size), but do observe a positive and statistically significant relationship between ethnic diversity and income from community forests. As was the case for state forests, we find positive and significant relationships between high quality forests and forest income (factor 1); and also find the expected negative and significant relationship between forest income and forests with a high population pressure, especially for dry broadleaf forests (factor 2). The presence of state or private forest in a village does not have implications for income from community forests, suggesting that community forests are not substitutes or complements to other forest ownership categories. Finally, we find that relative to community forests in Asia, community forests in Latin America have lower incomes.[17]

Our results for private forests illustrate that relative to the base case of no enforcement, both moderate and high enforcement have a positive influence on forest income, but only for total forest income and for subsistence income. These findings are opposite (with respect to direction of signs on coefficients) to what we found for moderate enforcement of state-owned and community forests. There are at least two possible explanations for this. One is that privately owned forests that have no enforcement are of very low quality and thus have limited potential for generating income. The second and related explanation is that owners of forests with income generating potential are managing their forests to maximize income for themselves and for other members of the community, particularly for subsistence products. Interestingly, we find similar effects of moderate and high enforcement for privately owned forests, suggesting that for this ownership category moderate and high enforcement are not substantively different. We find positive signs for total and subsistence income and from privately-owned forests and partial congruence, but negative and non-significant signs on all coefficients related to full congruence (i.e., relative to the base case of none). This may be explained by the fact that it is common for subsistence products to be collected from private forests owned by others, for example, a private forest owner may allow other households in the village to collect fuel wood, wild foods, etc. from her forest. In such cases full congruence would have a negative rather than positive influence on income.

The other covariates in our models focused on privately owned forests provide further insights. We find positive and significant relationships between income from private forests and forest size, indicating the importance of scale in our models for private forest. Cash income from privately owned forests is positively associated with a higher number of ethnic groups in a village. This finding echoes our finding for community forests. We do not have a clear explanation for why this would be the case for privately owned forests. Unlike our models for state- and community-owned forests, we do not find strong effects of forest domain other than a positive and significant relationship between coniferous forests in populated regions and cash income from private forests, perhaps reflecting the presence of plantations.

4. CONCLUSIONS AND POLICY IMPLICATIONS

We set out to describe and analyze the relationship between forest income and forest tenure characteristics. This is an important policy question as many contemporary development projects and developing country policy reforms are focused on tenure-related issues including who should own forests, how strictly property rights should be enforced, and to what extent use rights should be clarified and limited. We aimed to fill a perceived knowledge gap by focusing on the relationship between forest tenure characteristics and forest based livelihoods rather than forest sustainability, which is the focus of much of the existing literature on forests and tenure. We are also able to leverage the heterogeneity in our data which includes state-, community- and privately owned forests in a diversity of research sites throughout the tropics. Using a common set of variables to operationalize concepts of enforcement and congruence across study sites and forest ownership categories provides potentially unique insights into the differential effects of tenure characteristics, and guidance for future policy reforms.

Our study has three main findings. First we find that state-owned forests account for the majority of forest areas (69%) accessed by rural smallholders in our study sites, with high forest incomes obtained from state-owned forests relative to privately owned and community forests. State-owned forests generate more cash than subsistence income. While privately owned forests account for slightly more of total forest area than community forests (18% *vs.* 13%), they generate more than twice the income of community forests, with particular emphasis on subsistence forest products. The lower ratio of cash to subsistence income from privately owned forests relative to state-owned and community forests could be due to distance. Many regularly used subsistence products may be collected from forests closer to homesteads, which would seem to favor privately owned forest over the two other ownership categories. With regard to the differences in the overall level of forest income, the low relative income from community forests could be a reflection of the fact that processes of devolving rights from state-owned forests to communities frequently target low-value and/or degraded forest areas (Mustalahti & Lund, 2010; Ribot, 2004).

A second finding is that enforcement matters for forest incomes. Yet, in what way depends on the formal ownership categories and the degree of enforcement. Moderate and high enforcement are both positively associated with income from privately owned forests. Conversely, for state-owned and community forests we find a negative association of moderate enforcement with the local smallholder forest incomes that we are registering. These findings coincide with our expectations for state-owned forests, where enforcement of rules can prevent access by local people, thereby reducing forest incomes. However, we note that in some cases (e.g., PEN sites in the Amazon), enforcement on state-owned forests is the purview of individuals or community groups protecting their use rights, meaning that enforcement of rules is not always a top-down action. Our findings also support our expectations for privately owned forests, where we expected enforcement to combat the degradation of the resource and thereby protect household benefit streams over time. Our results for community forests are somewhat surprising. Though we expected enforcement to relate to community forests and privately owned forests in a similar way, the results indicate instead that the enforcement of rules on community forests yields results more similar to state-owned forests. That is, enforcement of rules for community forests appears to restrict access to forests, thereby reducing incomes. However, community forests may also be set aside for regeneration, suggesting that some communities may take a medium-term perspective of forest management.

Our third main finding is that systems of overlapping users (i.e., no or partial congruence) are important for maintaining forest income for smallholders, at least when they are not the forest owners. Congruence has hence a negative association with forest incomes from state forests, and a positive association with incomes from community forests. We find, as expected, that state-owned forests with complete congruence are associated with lower smallholder forest incomes, suggesting that tenure reforms that seek to eliminate overlapping claims to forests, or to limit resource use to the state as formal title holder to forests, likely will have negative implications for local people. Resolving contested claims is obviously important, but overlapping systems of forest rights may alleviate poverty in some settings. We find different patterns between congruence on community forests and forest income. Relative to no congruence, systems with partial congruence (i.e., owners and users are partially overlapping sets) are associated with higher incomes. This finding supports our earlier assertion that limiting use rights to formal owners (i.e., full congruence) may have negative implications for forest income from community forests.

Our analysis has several limitations. First, our three digit coding system necessarily simplifies the diversity of forest tenure characteristics, which in reality are nuanced property rights bundles, rules, and sanctions. Second, cross-section nature of our data provides only a snapshot of forest tenures and income relationships at a given point in time, so we are unable to capitalize on the dynamic nature of tenure transitions and reforms. Finally, our analysis includes only smallholder incomes. There may be considerable forest rents extracted by resident large-scale land holders, absentee large or small scale land owners, and migrant extractivists. Our congruence variable describes the relationship between formal owners and local smallholders, but does not quantify for the benefits that other groups with overlapping claims can derive.

This article sets the stage for further research on forest tenure and livelihoods. Our analysis has presented a pan-tropical overview of the relationship between forest tenure and incomes. We propose three directions for future research. First, more site-level comparative research can zoom in on settings where state-, community- and privately owned forests exist in tandem. We find evidence of substitution effects between state and privately owned forests, which could be further explored to illuminate implications of the global shift in forest ownership away from the state. At present, much of our understanding remains based upon studies of community forests and their sustainability. Second, regarding trade-offs and synergies between forest sustainability and income, we found that overlapping tenure systems and lower levels of enforcement may benefit rural smallholder. Yet, without longitudinal data we cannot measure whether over time these higher incomes trigger forest resource depletion and sharp reductions in livelihood contributions Third, our aggregation of data to village-level averages precluded an examination of the differential effect of tenure on female-headed households, ethnic minorities, and other marginalized groups. Past research on elite capture of forest resources in the wake of a diversity of forest policy reforms suggests that the role of tenure in facilitating or negating capture also needs to be explored.

NOTES

1. We define tenure as being synonymous with property rights, where a property right is an enforceable claim to a benefit stream (Bromley & Feeny, 1992). In the context of this paper we are concerned with the assignment of economic property rights over forest resources and benefit streams associated with those rights.

2. The relationship between tenure and decentralization is that many natural resource management decentralization reforms involve the changing of ownership or changing of property rights structures.

3. The literature on forest tenure generally refers to overlap in rights and responsibilities. Our data are limited to use rights and should be interpreted as such.

4. There are no forests identified as pure open access in our dataset. Instead, there are three types of formal ownership categories that influence who can have access to forested lands: state-, community-, and privately owned forests. State forests include lands owned and administered exclusively by governments, and forests that are designated for use by communities and indigenous people. For example, lands may be set aside on a semi-permanent but conditional basis as is common in Latin America. In this context governments retain ownership and entitlement to extinguish local groups' rights over entire areas. Community-owned forests are those where rights to land cannot be unilaterally terminated by the government without some form of due process or compensation. Private forests are forests owned by individuals or firms. In this case, rights cannot be unilaterally terminated by a government without due process or compensation. Note that these three categories coincide with the classifications used by Sunderlin *et al.* (2008) and RRI/ITTO (2009), which allows us to make comparisons to that study.

5. A distinction is made between community and private *de facto* use rights. Private use rights refer to situations where only *one* individual, household or lineage has the rights to use the resource, while community rights refer to situations where a more or less well-defined *group* of people have the rights.

6. Our analysis includes income from unprocessed and processed forest products. In cases where inputs to processed forest products were supplied by the household, such values were included. However, for cases where inputs were purchased, we do not have data on the type of forests where these inputs originated. Therefore, such values cannot be included in our analysis. Our data on source of forests allow us to include approximately 65% of total forest income.

7. Forest income is inclusive of income from fishing that was undertaken in rivers, lakes, or streams located in forests. Our analysis of forest income does not disaggregate income from forest plantations. Forest income from plantation accounts for roughly 4.7% of total forest income.

8. The PEN study uses the FAO definition of a forest. Forests are contiguous areas of greater than 0.5 hectares, with a tree canopy of greater than 10%, which are not primarily under agricultural or urban land use, and where trees can reach a minimum height of 1.5 meters (FAO, 2000).

9. Several villages have more than one spatially distinct forest, and/or multiple forests that all under different ownership categories.

10. All data used for the factor analysis are at the provincial-scale.

11. Twelve of 20 PEN countries are the same as the 39 RRI/ITTO (2009) cases. PEN countries cases that are not the same are: Bangladesh; Ethiopia; Ghana; Guatemala; Malawi; Uganda; Vietnam.

12. Descriptive statistics for the variables used in the regression models are presented in Appendix A.

13. Our remote sensing and GIS data are missing for China, one PEN site in Nepal.

14. A site is a geographic grouping of villages within an individual PEN study. For example, the Uganda PEN study includes three sites that are geographically distinct from one another.

15. We used the principal component factor method, and rotated the first 5 five factors using the orthogonal varimax method.

16. Following Kaiser (1960) we retain all factors that have a loading of greater than 1.00.

17. We note that we have classified some of the Latin American sites with very high forest incomes (e.g., Pando, Bolivia) as state-owned according to our definition of ownership (i.e., who has the right to sell land). However, these forests under a less strict definition of ownership (i.e., a definition that excludes alienation, but includes access, withdraw, management and exclusion) would be classified as community forests.

REFERENCES

Adhikari, B. (2005). Poverty, property rights and collective action: Understanding the distributive aspects of common property resource management. *Environment and Development Economics, 10*, 7–31.

Andam, K. S., Ferraro, P. J., Pfaff, A., Sanchez-Azofeifa, G. A., & Robalino, J. (2008). Measuring the effectiveness of protected area networks in reducing deforestation. *Proceedings of the National Academy of Sciences, 105*(42), 16089–16094.

Andam, K. S., Ferraro, P. J., Sims, K. E., Healy, A., & Holland, M. B. (2010). Protected areas reduced poverty in Costa Rica and Thailand. *Proceedings of the National Academy of Sciences, 107*(22), 9996–10001.

Angelsen, A., Jagger, P., Babigumira, R., Belcher, B., Hogarth, N., Bauch, S., *et al.* (2014). Environmental income and rural livelihoods: A global comparative analysis. *World Development, 64*(S1), S12–S28.

Bowler, D. E., Buyung-Ali, L. M., Healey, J. R., Jones, J. P. G., Knight, T. M., & Pullin, A. S. (2012). Does community forest management provide global environmental benefits and improve local welfare? *Frontiers in Ecology and the Environment, 10*(1), 29–36.

Bromley, D. W., & Feeny, D. (1992). *Making the commons work: Theory, practice, and policy*.

Chhatre, A., & Agrawal, A. (2008). Forest commons and local enforcement. *Proceedings of the National Academy of Sciences, 105*(36), 13286–13291.

Chhetri, B. B. K. (2010). *Livelihoods, forests, and poverty in the Nepal Himalaya* (unpublished doctoral dissertation). Division of Economics, Policy and Management Planning, Danish Centre for Forests, Landscape and Planning, University of Copenhagen, Denmark.

CIFOR (2007). *PEN Technical Guidelines, Version 4*. Bogor, Indonesia: Center for International Forestry Research.

Corbera, E., Estrada, M., May, P., Navarro, G., & Pacheco, P. (2011). Rights to forests and carbon: Insights from Mexico, Brazil and Costa Rica. *Forests, 2*, 301–342.

Deininger, K. (2003). *Land policies for growth and poverty reduction*. Washington DC, USA: World Bank and Oxford University Press.

DFID (2007). *Land: Better access and secure tenure for poor people*. London, UK: Department for International Development.

Dietz, T., Ostrom, E., & Stern, P. (2003). The struggle to govern the commons. *Science, 302*, 1907–1912.

Ellsworth, L. (2004). *A place in the world: A review of the global debate on tenure security*. New York, USA: Ford Foundation.

Ellsworth, L., & White, A. (2004). *Deeper roots: Strengthening community tenure security and community livelihoods*. New York, USA: Ford Foundation.

FAO. (2000). *Definitions of forest and forest change*. Forest resource assessment, working paper 33. Rome, Italy: Food and Agriculture Organization of the United Nations.

FAO. (2002*). Land tenure and rural development.* FAO land tenure studies 3. Rome, Italy: Food and Agriculture Organization of the United Nations.

Ferraro, P. J., & Hanauer, M. H. (2011). Protecting ecosystems and alleviating poverty with parks and reserves: 'Win-win' or 'tradeoffs'? *Environmental and Resource Economics, 48*, 269–286.

Gibson, C. C., Ostrom, E., & Williams, J. (2005). Local enforcement and better forests. *World Development, 33*(2), 273–284.

Jagger, P. (2010). Forest sector reform, livelihoods and sustainability in Western Uganda. In L. German, A. Karsenty, & A. M. Tiani (Eds.), *Governing Africa's forests in a globalized world* (pp. 103–125). London, UK: Earthscan Publications Ltd. and Center for International Forestry Research.

Jagger, P., & Luckert, M. K. (2008). Investments and returns from cooperative and household managed woodlots in Zimbabwe: Implications for rural afforestation policy. *Land Use Policy, 25*(1), 139–152.

Jagger, P., Pender, J., & Gebremedhin, B. (2005). Trading-off environmental sustainability for empowerment and income: Woodlot devolution in Northern Ethiopia. *World Development, 33*(9), 1491–1510.

Kaiser, H. F. (1960). The application of electronic computers to factor analysis. *Educational and Psychological Measurement, 20*, 141–151.

Larson, A. M., Barry, D., Dahal, G. R., & Colfer, C. J. P. (2010c). *Forests for people: Community rights and forest tenure reform*. London, UK: Earthscan Publications Ltd.

Larson, A. M., Corbera, E., Cronkleton, P., van Dam, C., Bray, D., Estrada, M., et al. (2010). *Rights to forests and carbon under REDD+ initiatives in Latin America*. CIFOR Infobrief 33. Bogor, Indonesia: Center for International Forestry Research.

Larson, A. M., Pacheco, P., Toni, F., & Vallejo, M. (2007). Trends in Latin American forestry decentralisations: Legal frameworks, municipal governments and forest dependent groups. *International Forestry Review, 9*(3), 734–747.

Larson, A. M. (2005). Democratic decentralization in the forestry sector: Lessons learned from Africa, Asia and Latin America. In C. J. Pierce Colfer, & D. Capistrano (Eds.), *The politics of decentralization: Forests, power and people* (pp. 32–62). London, UK and Sterling, Virginia: Earthscan Publications Ltd.

McKean, M. A. (2000). Common property: What is it, what is it good for, and what makes it work? In C. Gibson, M. A. McKean, & E. Ostrom (Eds.), *People and forests: Communities, institutions and governance* (pp. 27–55). Boston, USA: Massachusetts Institute of Technology.

Meinzen-Dick, R., & Mwangi, E. (2008). Cutting the web of interests: Pitfalls of formalizing property rights. *Land Use Policy, 26*, 36–43.

Mustalahti, I., & Lund, J. F. (2010). Where and how can participatory forest management succeed? Learning from Tanzania, Mozambique and Laos. *Society and Natural Resources, 23*(1), 31–44.

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

Ostrom, E., & Nagendra, H. (2006). Insights on linking forests, trees and people from the air, on the ground, and in the laboratory. *Proceedings from the National Academy of Sciences, 103*, 19224–19231.

Persha, L., Agrawal, A., & Chhatre, A. (2011). Social and ecological synergy: Local rule-making, forest livelihoods, and biodiversity conservation. *Science, 331*, 1606–1608.

Porter-Bolland, L., Ellis, E. A., Guariguata, M. R., Ruiz-Mallen, I., Negrete-Yankelevich, S., & Reyes-Garcia, V. (2012). Community managed forests and forest protected areas: An assessment of their conservation effectiveness across the tropics. *Forest Ecology and Management, 286*, 6–17.

Ribot, J. C. (2004). *Waiting for democracy: The politics of choice in natural resource decentralization*. Washington, DC, USA: World Resources Institute.

RRI (2012). *What rights? A comparative analysis of developing countries' national legislation on community and indigenous peoples' forest tenure rights*. Washington, DC, USA: Rights and Resources Initiative.

RRI/ITTO (2009). *Tropical forest tenure assessment: Trends, challenges and opportunities*. Washington, DC, USA and Yokohama, Japan: Rights and Resources Initiative and International Tropical Timber Organization.

Sayer, J., McNeely, J., Maginnis, S., Boedhihartono, I., Shepard, G., & Fisher, B. (2008). *Local rights and tenure for forests: Opportunity or threat for conservation?* Washington, DC, USA: Rights and Resources Initiative and IUCN.

Schlager, E., & Ostrom, E. (1992). Property rights regimes and natural resources: A conceptual analysis. *Land Economics, 68*(3), 249–262.

SIDA (2007). *Natural resource tenure. A position paper for SIDA*. Stockholm, Sweden: Swedish International Development Cooperation Agency.

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

Sunderlin, W. D., Hatcher, J., & Liddle, M. (2008). *From exclusion to ownership?: Challenges and opportunities in advancing forest tenure reform*. Washington, DC: Rights and Resources Initiative.

Sunderlin, W. D., Larson, A., Duchelle, A. E., Resosudarmo, I. A. P., Huynh, T. B., Awono, A., *et al.* (2013). How are REDD+ proponents addressing tenure problems? Evidence from Brazil, Cameroon, Tanzania, Indonesia, and Vietnam. *World Development*. http://dx.doi.org/10.1016/j.worlddev.2013.01.013.

APPENDIX A. SUUMMARY STATISTICS FOR VARIABLES USED IN REGRESSION MODELS[1,2]

Independent variables	State-owned forest		Community forest		Privately owned forest	
	Mean	Range	Mean	Range	Mean	Range
Moderate enforcement (c.f. none) (0/1)	0.40 (0.49)	0–1	0.63 (0.49)	0–1	0.73 (0.45)	0–1
High enforcement (c.f. none) (0/1)	0.45 (0.50)	0–1	0.29 (0.46)	0–1	0.21 (0.41)	0–1
Partial congruence (c.f. none)	0.14 (0.35)	0–1	0.32 (0.47)	0–1	0.25 (0.44)	0–1
Full congruence (c.f. none)	0.20 (0.40)	0–1	0.44 (0.50)	0–1	0.73 (0.45)	0–1
Area (hectares)	6,457 (13,825)	0.49–50,000	1,533 (4,021)	0.25–24,585	191.2 (441.7)	0.50–2,967
Forest user groups in village (number)	0.73 (0.83)	0–5	1.08 (1.15)	0–5	0.69 (1.03)	0–5
Group size (number of people in village)	1079.61 (1554.50)	55–9,000	1,050.35 (1,885.83)	56–9,132	1,047.52 (1,703.42)	96–9,000
Ethnic groups (number in village)	3.87 (4.38)	1–30	4.30 (4.58)	1–20	5.58 (6.13)	1–30
Domain 1: High quality moist broadleaf forest in remote regions (factor score)	−0.09 (0.98)	−1.71 to 1.91	−0.16 (−1.16)	1.62–2.22	−0.20 (0.92)	−1.62 to 1.40
Domain 2: Dry broadleaf forest in populated regions (factor score)	0.05 (0.99)	−1.06 to 2.68	−0.19 (−0.71)	1.13–2.64	–	–
Domain 3: Low quality forest in populated regions (factor score)	0.03 (1.13)	−1.61 to 5.12	0.25 (−1.19)	1.86–5.12	0.39 (0.79)	−0.88 to 1.93
Domain 4: Montane grassland in populated regions (factor score)	0.07 (1.06)	−1.09 to 2.92	−0.39 (−0.22)	1.24–0.15	−0.30 (0.19)	−0.66 to 0.13
Domain 5: Coniferous forest in populated regions (factor score)	0.07 (1.19)	−0.66 to 5.35	−0.10 (−0.71)	0.54–5.35	−0.13 (0.10)	−0.36 to 0.14
State forest in village (0/1)	–	–	0.37 (0.49)	0–1	0.53 (0.50)	0–1
Community forest in village (0/1)	0.11 (0.32)	0–1	–	–	0.29 (0.46)	0–1
Private forest in village (0/1)	0.21 (0.41)	0–1	0.37 (0.49)	0–1	–	–
Latin America (c.f. Asia) (0/1)	0.24 (0.43)	0–1	0.32 (0.47)	0–1	0.16 (0.37)	0–1
Africa (c.f. Asia (0/1)	0.55 (0.50)	0–1	0.57 0.50)	0–1	0.56 (0.50)	0–1
N	199		63		80	

[1] Standard deviations in parentheses.
[2] Summary statistics for dependent variables are found in Table 4.