Do Common Property Rights Facilitate Local Adaptation to External Disturbance? Cross National Evidence in Forestry[☆]

Eric A. Coleman[a,b,1]

[a] *Florida State University, Department of Political Science, 543 Bellamy, P.O. Box 3062230, Tallahassee, FL 32303–2230*
[b] *Workshop in Political Theory and Policy Analysis, Indiana University, 513 N Park Ave, Bloomington, IN 47408-3895*

Abstract

Researchers remain uncertain about how forest users will adapt to the ecological and institutional disturbances of climate change. In this paper I analyze forest users' common property rights and assess adaptation strategies of different groups with different bundles of rights. I delineate common property rights in terms of rights of access, withdrawal, management, exclusion, and alienation. Then, using statistical analysis of 400 forest user groups from 15 countries in the International Forestry Resources and Institutions program, I show how forest users respond to disturbance in terms of their forest investments, their propensity to continue harvesting trees, and the overall conditions of the forest. I find that user groups with property rights enabling them to enact forest management rules and exclude others are significantly more likely to favorably respond to disturbance. Property rights are the strongest when there are rival groups that can threaten those rights. Rights of alienation, or full ownership, are shown to be ineffective at achieving sustainable forest outcomes in the face of disturbance.

Keywords: Property Rights, Adaptation, Forestry

1. Introduction

Forests play crucial roles both in the earth's climate system as well as in the rural livelihoods of many in less developed countries (Chhatre and Agrawal, 2009). In addition, those who depend most heavily upon forest resources are likely to be the most vulnerable to the effects of climate change (Mendelsohn et al., 2007). There is still much uncertainty as to how the rural poor will adapt to the challenges of climate change in the future, although in the past many forest users have been able to adapt to disturbances and continue to manage long-enduring resource systems (Ostrom, 1990). It is impossible to investigate the effects of climate change which have not yet happened; however, examining past responses to major disturbances may provide insight into how forest users will respond to climate change induced disturbances in the future.

Groups of forest users are likely to alter their responses to disturbance depending on the institutions which constrain or enhance the set of possible decisions. Thus, when considering local adaptation to disturbance one must carefully consider both ecological and institutional factors as well as their interplay (Young, 2002; Basurto and Coleman, Forthcoming). The nature and extent of the property rights which the forest user groups holds will provide incentives to adapt to disturbances in certain ways.

It is generally recognized that there are bundles of property rights associated with natural resources (Barzel, 1997; Schlager and Ostrom, 1992; McKean, 2000). These bundles of rights may be held in common, privately, by the state, or by nobody at all (open access) (McKean, 2000). In addition, different parties may hold different bundles of the property rights. For example, in many countries the residual claimant (the party to which all unspecified rights belong, see Coleman and Steed (2009)) of forest land is held by the state, while local communities may have property rights to appropriate timber or other forest products and outside tourists may hold rights of access to the forest. Thus, the property rights to the resource are dispersed over many different holders of those rights.

Despite the recognition that there are bundles of property rights associated with any given resource, there appears to still be a tendency for academics and policymakers to oversimplify resource ownership as wholly private, common, state, or open access (See McKean, 2000). Virulent debates have emerged to argue that one ownership type is superior to all others (See Ostrom, 1990; Ostrom, Janssen and Anderies, 2007), but little research has examined what stakeholders are best able to exercise which bundles of rights to achieve environmentally sustainable outcomes.[2]

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[1]Email: ecoleman@fsu.edu; Tel: 850–644–4540; Fax: 850–644–1367

[2]Although recent research has examined the relative effectiveness of vesting full ownership rights to private individuals, user groups, or states (Hayes and Ostrom, 2005; Ostrom and Nagendra, 2006; Coleman, 2009; Chhatre and Agrawal, 2009). This literature largely

Schlager and Ostrom (1992) identify and classify property rights and distinguish the diverse bundles of rights of natural resources. They classify property rights holders into four categories: authorized users who have rights of access and withdrawal; claimants who have rights to manage the resource; proprietors who have rights to exclude others from using the resource; and owners who have rights of alienation—they can divest themselves of the resource. The rights associated with the resource should not be confused with the type of rights holder. Individuals, national governments, or groups of forest users may be authorized users, claimants, proprietors, or owners. Schlager and Ostrom (1992) argue that the more property rights that are held by the holder the more likely they will be to invest in the resource. For example, owners of forest land will be more likely to invest in efforts to monitor the use of the forest than authorized users.

The investment decision of property rights holders with different bundles of rights has not been thoroughly investigated empirically. Some evidence suggests that full ownership is not necessary to achieve sustainable outcomes, but that some rights of access and withdrawal are important (Coleman, 2009). Other work shows that when groups of forest users are given rights to withdraw forest resources they are more likely to make investments to monitor and sanction other forest users, while government owners are less likely to do so (Coleman and Steed, 2009). This paper adds to this literature by investigating in finer detail the full range of property rights that might be given to local forest user groups and how forest users respond to ecological disturbances when they hold different bundles of property rights.

2. Forest Property Rights

2.1. Incentives of Property Rights

Forest property rights are given to user groups. "A user group is a group of people who harvest from, use, and/or maintain one or more forests and who share the same rights and duties to products from the forest(s), even though they may or may not be formally organized (International Forestry Resources and Institutions, 2008, p.III.A.5-1)." User groups hold common property rights; a group of people jointly hold some subset of the bundle of rights. Such arrangements are quite common in many parts of the world (Agrawal, Chhatre and Hardin, 2008) and are often effective institutional arrangements for the sustainable management of forests (Chhatre and Agrawal, 2009).

Schlager and Ostrom (1992) provide a typology of property rights which is presented in Table 1. In Table 1 we list four types of property rights associated with forests and the relative strength of incentives each right provides in the investments decisions of the rights holders. It is important to note here that investments here are broadly termed; an investment is any action which delays consumption of forest products. Examples of investments include the following: time spent creating, implementing, or enforcing rules (Coleman and Steed, 2009); physical investments in the forest such as fencing, planting seedlings, or other maintenance activities (Coleman, Fleischman and Bauer, 2009); and delaying harvesting so that greater harvests might be made in the future (Tietenberg, 2000).

Table 1: Bundles of Rights and Property Rights Holder Designation

Property Right	Property Right Holder	Incentives to Invest
Access and Withdrawal	Authorized User	Weak
Management	Claimant	Somewhat Weak
Exclusion	Proprietor	Somewhat Strong
Alienation	Owner	Strong

Source: Adapted from Schlager and Ostrom (1992).

The most prevalent property rights in forestry relate to rights of access (the right to enter a defined physical property) and withdrawal (the right to obtain forest products). Those who hold only rights of access and withdrawal are termed "authorized users" by Schlager and Ostrom, and are hypothesized to have weak incentives to invest in the forest or limit harvesting effort. They have no rights to make rules about forest use; authorized users who make forest investments are dependent on the rights that others may exercise to expropriate their investments.

Forest users with rights of management (to regulate internal forest use and choose priorities over uses) are termed claimants. Claimants have somewhat weak incentives to invest in the resource because without rights of alimentation they are not guaranteed to benefit from such investments. On the other hand claimants may still invest in the resource if no other groups are interested in these resources or if the resource is physically isolated from others.

Those with rights to exclude others from the forest (i.e. to decide who will have access and withdrawal rights) can realize the benefits of the investments they make in the forest. Such users are termed proprieties. Proprieties are hypothesized to have somewhat strong incentives to invest in the forest as they can realize the direct benefits from their investments and exclude others from them.

Many authors have argued that the right to alienation (the right to sell or lease any of the aforementioned rights) is the crucial characteristic of property rights (Schlager and Ostrom, 1992; Arnason, 2005; Scott, 2008). When owners are allowed to sell their rights and realize the benefits of long-term investments they can potentially realize the full benefits from those investments. While proprietors have the right to realize the direct investment themselves, owners have rights to sell those benefits to those that value them the most and receive the largest possible benefits

concludes that no single owner is significantly more likely to sustainably manage forests, although Chhatre and Agrawal (2009) find that local users with ownership rights are more likely to have more forest biomass than national governments or private individuals.

from investment. Thus, full ownership is hypothesized to give the largest incentive to invest in the resource.[3]

2.2. Adaptation to Disturbance

Climate change models suggest that the rural poor and those most dependent on forest resources are likely those to become extremely vulnerable to the adverse effects of climate change (Agrawal, 2008). Climate change is expected to increase the volatility of weather patterns and engender more frequent extreme weather events such as fires and floods (Stern, 2007). Forest dependent people that live just above subsistence are sensitive to such disturbances. This increased vulnerability to disturbance in turn raises the uncertainty of realizing the future gains from investment decisions. For example, if fires frequently destroy forest assets then risk averse forest users may be much less likely make investments in those assets.

Most research on climate change adaptation stresses the role of technology to respond to such disturbances and largely ignores the role of social institutions such as property rights (Agrawal, 2008). While technological interventions may benefit those producing and providing such technology, creating robust institutional conditions may simultaneously improve adaptive capacity as well as benefit the forest-dependent poor.

A user groups' property rights bundle endowment modifies their ability to respond to disturbance. There is a relative paucity of research on such intuitions, which is alarming given the central role of local institutions in adapting to climate change. Agrawal (2008, p.24) has remarked,

> "The relative absence of systematic, comparative work to enable targeted policy initiatives that can strengthen local institutions and enhance adaptive capacity is therefore all the more striking. Undertaking such an analysis would require significant empirically based research on a selected, comparable set of adaptation projects."

This paper seeks to fill this gap by providing a comparative empirical analysis of different property rights bundle endowments on the ability of forest user groups to adapt to external disturbance through changes in investment activities.

Agrawal (2008, p.27) defined three mechanisms through which different local institutions affect adaptation practices at the local level. Specifically, institutions,

1. "structure environmental risks and variability and thereby the nature of climate impacts and vulnerability";
2. "create the incentive framework within which outcomes of individual and collective action unfold"; and,
3. "are the media through which external interventions reinforce or undermine existing adaptation practices".

According to these mechanisms I hypothesize that as a user group has property rights closer to full ownership (i.e. alienation rights) they will be more adaptive to disturbance. Full ownership allows user groups to pool risks to a greater degree than proprietors, claimants, or authorized users. The right to alienation allows user groups to diversify their assets and become less reliable on forests; the income streams from some rights can be sold or leased to other groups and those profits invested in non-forest assets. Indeed, there are strong incentives for owners to search out the most valued use of the forest and transact with those who value the forest most highly. In addition, because ownership rights imply greater certainty in realizing resource benefits than other rights, there are strong incentives to act collectively and adapt to new conditions in order to increase the value of the resource.

The hypothesis can be expressed mathematically. If adaptation is a function of property rights, disturbance, and a set of control variables, x, such that,

$$\begin{aligned} Adaptation =& f(Authorized\ user,\ Claimant,\ Proprieter \\ & Owner,\ Disturbance,\ x), \end{aligned} \tag{1}$$

then the hypothesis is,

$$\frac{\partial Adaptation}{\partial Authorized\ user} < \frac{\partial Adaptation}{\partial Claimant} < \frac{\partial Adaptation}{\partial Proprieter} < \frac{\partial Adaptation}{\partial Owner}. \tag{2}$$

3. Results

To investigate adaptation practices of forest user groups to instances of disturbance, given the property rights institutions they hold, I analyze data from 469 user groups from forests in 15 countries around the world. Table 2 presents the distribution of user groups across countries for the data used in this analysis.[4] The data is collected from the International Forestry Resources and Institutions (IFRI) program (see Section 5 for details on the dataset and coded variables).[5]

The IFRI program is an effort by a worldwide network of colleagues to analyze forestry and the local user groups which access the forests. IFRI researchers use a standard instrument to collect data; this data is then compiled into

[3] It is important to note that if the rate of returns from investments are not sufficient or if owners have particularly high discount rates then even those with full ownership rights still may not invest in the resource.

[4] These data do not represent a random sample of all forests in the world or even in the given countries; it is difficult to imagine a process for such sampling. However, none of the sampled user groups were chosen on the basis of the outcomes analyzed in this paper, so the inferences here can be generalized to user groups with similar ranges of the independent variables (See Coleman, 2009)

[5] See International Forestry Resources and Institutions (2008) for a discussion of the data collection process and Gibson, McKean and Ostrom (2000) for an introduction to IFRI analysis.

Table 2: Distribution of User Groups by Country

	Frequency	Percent	Cumulative Percent
Bhutan	8	1.71	1.71
Bolivia	44	9.38	11.09
Brazil	4	0.85	11.94
Colombia	1	0.21	12.15
Ecuador	5	1.07	13.22
Guatemala	25	5.33	18.55
Honduras	5	1.07	19.62
India	62	13.22	32.84
Kenya	58	12.37	45.20
Madagascar	29	6.18	51.39
Mexico	30	6.40	57.78
Nepal	93	19.83	77.61
Tanzania	19	4.05	81.66
Thailand	3	0.64	82.30
Uganda	83	17.70	100.00
Total	469	100.00	

Notes: Data from (International Forestry Resources and Institutions, 2008).

a worldwide dataset. Data is collected both on forest biophysical characteristics (through forest mensuration techniques) and on the institutional and socioeconomic characteristics of forest users (through ethnographic techniques). Thus, the data represent a consistent way to analyze forest users management practices as well as the biophysical outcomes which result from such practices (Coleman, 2009). IFRI presents a unique opportunity to analyze forest commons with cross national data (Ostrom and Nagendra, 2006; Chhatre and Agrawal, 2009; Coleman, 2009; Coleman and Steed, 2009).

3.1. Description of Data

A subset of the data collected through IFRI is used in this paper. Table 3 reports the data, divided into three categories of variables: variables which measure forest user group adaptation strategies, variables which measure the bundle of property rights with which a particular forest user groups has been endowed, a measure of disturbance, and a set of control variables. Adaptation strategies include the propensity of user groups investments such as cooperatively harvesting forest products, cooperatively monitoring and sanctioning the use of the forest, and cooperatively engaging in forest maintenance activities. Each investment activity is dichotomized to indicate if a user group regularly engages in such investments (=1) or not (=0). A variable indicating how the user group ranks the resulting forest conditions is also included for analysis (=1 if the condition is average or better for similar forests; =0 otherwise) as well as a variable indicating whether the user group continues to harvest trees (=1 if they do not harvest trees; =0 otherwise).

Also included in Table 3 are various measures of the bundle of property rights which the user group enjoys. Rights of access and withdrawal are not included as all user groups have such rights. As part of the coding process for IFRI forms, user groups must be able to at least access the forest. Rights of management indicate that the user group has relative autonomy to make and enforce rules within the forest, and about 40% of user groups have such rights. Exclusion right indicate that only one user group can make rules and thus exclude others from some rights and about 27% of user groups have these rights. Alienation right refer to user groups right to sell or lease the aforementioned rights. Only 5% of user groups possess alienation rights; these are private forest owners or indigenous groups that have exclusive rights to a forest.

According to the theoretical arguments in Schlager and Ostrom (1992) these rights are nested; that is, those with alienation rights are assumed to possess exclusion and management rights. The variables in this analysis are coded as such. The effects of alienation rights, for example, should be interpreted as the effects of having rights to alienation in addition to the rights of management and exclusion.

The affects of property rights are attenuated by the number of potential rival claimants to those rights. For example, one would expect exclusion rights to be the most vital in situations where there are other user groups that threaten management rights. In places where there are few rival user groups, the effects of exclusion should be smaller. A variable is included in the property rights section to indicate the number of rival groups. The maximum number of other groups is 5 in any given forest.[6]

The measure of disturbance is an indicator if there was a significant decrease in tree density in the past 5 years. The reasons for such a decrease ranged from exogenous natural disturbances (such as fire, flooding, or wind damage), to exogenous institutional change (encroachment on the forest from other groups, roads, or market access for forest products), to endogenous user group behavior (overharvesting) or some combination of all three. The majority (56%) of the cases where tree density decreases was attributed solely by exogenous change. While it would be helpful to separate purely exogenous change from endogenous change this is difficult because both processes often act simultaneously; thus for this analysis we look at all disturbances that decrease tree density.

A number of other control variables are also included in the analysis. Scarcity is measured by (the natural logarithm of) the number of households per forest hectare. If there is much pressure on the forest then forest users may be less able to act collectively to respond to disturbance (See Coleman, Fleischman and Bauer, 2009). Forest size is measured by the (natural logarithm of) forested hectares and presents a scale effect. Those in large forests may have more valuable assets and thus more incentive to adapt to changes (Chhatre and Agrawal, 2009). Forest subsistence

[6]Table 6 in the Appendix shows the distribution of other user groups. The most frequent number of other user groups is 0 (about 41% of user groups in the sample are the sole user group in the forest). However, for more than 50% of the user groups there is at least one other user group in the forest.

is measured by the proportion of households in the user group that rely on the forest for subsistence and ranges 0 to 1. This is an especially important control because it severely limits the types of adaptation that users might employ. High subsistence user groups may not be able to limit harvesting in the forest if doing so would endanger many of its households from subsiding. On the other hand low subsistence groups may be able to delay harvesting while the forest recovers from the disturbance event. A control variable is also included to indicate the type of forest. If the forest is a nature preserve or sacred forest it may be explicitly acknowledged that certain types of adaptations are more likely, such as more careful monitoring of the forest to ensure that sacred elements are not removed. Finally, a variable is included to indicate ease of monitoring—whether or not there are easily accessible places where harvesting can be observed. Forests where others behavior can be easily observed decreases the likelihood of illegal harvesting and increases the incentives to monitor forest use (Coleman and Steed, 2009).[7]

3.2. Estimation and Inference

To investigate the effects of property rights institutions on adaptation strategies, logit regressions were run according to Equation 1. The suite of adaptation strategies in the top panel of Table 3 was regressed on the institutional, disturbance, and control variables. These results are reported in Table 4. Estimated logit coefficients and robust standard errors are reported.

Table 4 shows three important findings among the different property rights regimes. First, as expected, there is a strong negative correlation between disturbance and the propensity to invest in adaptation strategies. When there is a decrease in trees it is much less likely that the user groups will engage in any kind of forest investment, that they will be less likely to not harvest trees, and that forest conditions are less likely to improve.

The second finding is that the effects of property rights are not as straightforward as hypothesized in Equation 2. Looking at the first three columns of Table 4 one can see that those with management rights do not appear to be more likely to make investments in cooperative harvesting or maintenance than those with access and withdrawal rights (the base category). However, they are more likely to engage in monitoring and sanctioning, which in past literature has been shown to play an important role for the sustainable management of forest commons (Hayes and Ostrom, 2005; Ostrom and Nagendra, 2006; Coleman, 2009). The possession of exclusion rights is measured to have a large impact on the propensity to engage in cooperative harvesting and maintenance, but not monitoring and sanctioning. The coefficient on exclusion right is large, positive, and statistically significant at the 0.05 level for both measures.

The effects of alienation rights are surprisingly weak. Those with alienation rights are not more likely to engage in investment activities than those with only access and withdrawal rights. While the estimated coefficients is large for cooperative maintenance, the standard error is large. The estimated coefficients for cooperative harvesting and monitoring and sanctioning, however, appear quite small. This finding runs counter to the *a priori* hypothesis of Schlager and Ostrom (1992) that is outlined in Equation 2.

The third important finding is that despite the large effects of property rights on forest investment decisions, they do not seem important in explaining the condition of the forest. The fourth column of Table 4 shows that none of the estimated property rights have a significant effect on the user groups ranking of forest conditions. This is puzzling given many of the large, positive effects measured on forest investments. To investigate the cause of this finding a separate logit model is included in the fifth column of Table 4.[8] Here the harvesting activities of the user group are modeled as a function of the same set of property rights bundles. These estimates show that user groups with different bundles of property rights are no more or less likely to not harvest trees. Thus, it appears that property rights bundles effect not how much will be harvested, but rather to increase the value of that which is harvested and to ensure that the value is captured by the user group and not others.

To further investigate the role of rival user groups on the effects of property rights, separate logit regressions were conducted and interactions between property rights and the number of other user groups were included. These results are reported in Table 5. In this table the coefficients on the interactions should be interpreted at the level where the given property right is present and there is one other user group in the forest. The coefficient on the property rights terms where there is no interaction is a measure of the effects of the property rights when there is no other rival user group.

Table 5 brings out a number of important dependencies not apparent in Table 4. It appears that the effects of cooperative harvesting a largely independent on the number of other user groups. No interaction is significant and tests of model fit (BIC, AIC, Likelihood-Ratio tests) confirm that not much analytical traction is gained from including the interactions for cooperative harvesting. However, for cooperative monitoring and sanctioning it appears that management rights have the greatest impact on user groups

[7]A number of other control variables were included at various stages of the analysis such as: the commercial value of the forest, distance to market, and whether or not there was disruptive conflict in the past. These controls were generally insignificant and the results reported here are robust to their inclusion. These results are available from the author upon request.

[8]There is not an estimated effect of alienation rights on tree harvesting because all user groups with alienation rights engaged in tree harvesting; the variable perfectly predicts tree harvesting.

Table 3: Summary Statistics

	N	Mean	Std.Dev.	Min	Max
Adaptation Strategies					
Cooperative Harvesting	442	0.29	0.45	0.00	1.00
Cooperative Monitoring and Sanctioning	442	0.35	0.48	0.00	1.00
Cooperative Maintenance	434	0.26	0.44	0.00	1.00
Forest Conditions	409	0.55	0.50	0.00	1.00
No Tree Harvesting	394	0.12	0.32	0.00	1.00
Property Rights					
Management Rights	412	0.40	0.49	0.00	1.00
Exclusion Rights	412	0.27	0.45	0.00	1.00
Alienation Rights	469	0.05	0.22	0.00	1.00
Number of Other User Groups	469	1.41	1.53	0.00	5.00
Control Variables					
Tree Density Decrease	444	0.55	0.50	0.00	1.00
ln(Scarcity)	408	−1.78	2.44	−8.77	4.22
ln(Forest Size)	438	5.97	1.98	−0.11	10.71
Forest Subsistence	469	0.76	0.37	0.00	1.00
Conservation/Aesthetic Objectives	469	0.04	0.20	0.00	1.00
Disruptive Conflict	469	0.15	0.36	0.00	1.00

Notes: Data from (International Forestry Resources and Institutions, 2008).

Table 4: Base Model Logit Regressions

	Cooperative Harvesting	Cooperative Monitoring and Sanctioning	Cooperative Maintenance	Forest Conditions	No tree Harvesting
Management Rights	0.065	1.547***	−0.111	−0.327	−1.375
	(0.49)	(0.47)	(0.47)	(0.39)	(1.07)
Exclusion Rights	1.350***	0.160	1.290**	0.571	0.542
	(0.52)	(0.52)	(0.54)	(0.47)	(1.19)
Alienation Rights	0.048	−0.097	0.707	0.064	
	(0.63)	(0.63)	(0.65)	(0.57)	
Number of Other User Groups	−0.071	−0.587***	−0.149	−0.131	0.023
	(0.12)	(0.18)	(0.13)	(0.10)	(0.17)
Tree Density Decrease	−0.877***	−0.762***	−1.026***	−1.119***	−0.808*
	(0.29)	(0.27)	(0.30)	(0.26)	(0.47)
ln(Scarcity)	0.246**	−0.014	0.224**	−0.152*	−0.098
	(0.11)	(0.10)	(0.11)	(0.09)	(0.15)
ln(Forest Size)	0.165	−0.093	0.163	−0.229**	−0.195
	(0.14)	(0.12)	(0.13)	(0.11)	(0.19)
Forest Subsistence	1.138***	0.517	0.668*	0.200	−0.721
	(0.42)	(0.34)	(0.37)	(0.34)	(0.49)
Conservation/Aesthetic Objectives	−0.232	0.309	−1.855*	−0.419	0.715
	(0.62)	(0.58)	(1.11)	(0.53)	(0.59)
Disruptive Conflict	−0.944**	−0.183	−0.259	−0.294	−0.776
	(0.40)	(0.42)	(0.38)	(0.32)	(0.63)
Constant	−2.178***	−0.160	−1.837**	2.031***	−0.031
	(0.75)	(0.66)	(0.76)	(0.65)	(0.99)
Log–Likelihood	−176.762	−175.207	−166.882	−207.864	−92.208
χ^2	51.068***	57.730***	59.165***	38.073***	13.019
AIC	375.524	372.414	355.765	437.727	204.416
BIC	418.024	414.945	398.107	479.683	241.685
N	352	353	347	335	307

Notes: Robust standard errors in parentheses. Two-tailed hypothesis tests: * p <0.10, ** p <0.05, *** p <0.01.

Table 5: Interaction Model Logit Regressions

	Cooperative Harvesting	Cooperative Monitoring and Sanctioning	Cooperative Maintenance	Forest Conditions	No tree Harvesting
Management Rights	0.213	3.651***	−0.530	0.739	−0.830
	(0.99)	(1.03)	(0.85)	(0.87)	(1.17)
Exclusion Rights	1.437	−1.640	1.212	−0.644	−0.713
	(0.98)	(1.02)	(0.85)	(0.88)	(1.29)
Alienation Rights	0.706	−1.137	0.892	0.575	
	(0.94)	(0.76)	(0.89)	(0.93)	
Management Rights × Number of Other User Groups	−0.103	−1.081**	0.279	−0.465	−0.210
	(0.37)	(0.52)	(0.35)	(0.33)	(0.25)
Exclusion Rights × Number of Other User Groups	−0.409	0.492	0.976**	0.904**	1.409***
	(0.52)	(0.69)	(0.47)	(0.45)	(0.43)
Alienation Rights × Number of Other User Groups	−0.561	1.491**	−0.795	−0.745	
	(1.06)	(0.73)	(0.77)	(0.73)	
Number of Other User Groups	0.017	−0.398**	−0.347*	−0.099	−0.087
	(0.12)	(0.20)	(0.20)	(0.11)	(0.16)
Tree Density Decrease	−0.876***	−0.804***	−1.147***	−1.210***	−0.908*
	(0.29)	(0.28)	(0.31)	(0.27)	(0.47)
ln(Scarcity)	0.268**	−0.030	0.243**	−0.124	−0.092
	(0.11)	(0.11)	(0.12)	(0.09)	(0.16)
ln(Forest Size)	0.188	−0.159	0.193	−0.222*	−0.180
	(0.14)	(0.13)	(0.14)	(0.11)	(0.20)
Forest Subsistence	1.173***	0.588	0.708*	0.317	−0.641
	(0.44)	(0.37)	(0.37)	(0.35)	(0.50)
Conservation/Aesthetic Objectives	−0.260	0.209	−1.778*	−0.439	0.759
	(0.64)	(0.59)	(1.06)	(0.54)	(0.60)
Disruptive Conflict	−0.966**	−0.149	−0.207	−0.249	−0.699
	(0.41)	(0.43)	(0.38)	(0.32)	(0.64)
Constant	−2.422***	−0.011	−1.778**	1.947***	0.001
	(0.79)	(0.72)	(0.79)	(0.66)	(1.04)
Log–Likelihood	−174.638	−169.177	−161.627	−205.907	−88.579
χ^2	54.735***	73.190***	59.353***	44.552***	25.888***
AIC	377.275	366.353	351.254	439.815	201.158
BIC	431.366	420.484	405.144	493.213	245.880
N	352	353	347	335	307

Notes: Robust standard errors in parentheses. Two-tailed hypothesis tests: * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

where there are few other rival groups. The effects of management rights are largest when there are no other groups and they diminish as more groups are present in the forest. In addition, it appears that alienation rights appear highly correlated with the propensity to monitor and sanction only when there are other user groups present.

In general it appears that the effects of exclusion rights are highly dependent upon the existence of other user groups. That is, when there are more rivals user groups with exclusion rights are more likely to engage in cooperative maintenance, have good forest conditions, and cease to harvest trees. These effects are not present for user groups with few rivals.

In addition to the main results from Tables 4 and 5 many of the control variables are significant predictors of adaptation. Fore example, when a user group has a higher percentage of their households as subsistence users they are more likely to engage in cooperative harvesting and maintenance, but no more likely to have good forest conditions or stop harvesting trees. Subsistence has been linked to adaptive strategies in the past by a number of authors (Agrawal, Chhatre and Hardin, 2008), but there is still little empirical research examining subsistence households responses to disturbance.

3.3. Analysis

The specific research question of this paper relates to how user groups respond to disturbance. That is, inferences should be made conditional on there being a disturbance in the forest. The estimation results outlined in the previous section need to be analyzed conditional on disturbance. This can be best done by a visual inspection of the predicted probabilities from the interaction model estimated and reported in Table 5.

Figure 1 reports the estimated effects of property rights conditioning on there being a disturbance in the past five year (Tree Density Decrease=1). Predicted probabilities are examined based upon the estimated effects of property rights, number of other user groups, and their interaction.

The figures reinforce the interpretation of Table 5 from the previous section. The number of other user groups does not appear important in determining the propensity to engage in cooperative harvesting. However, property right structure is significant as to the adaptive strategies on the other measures.

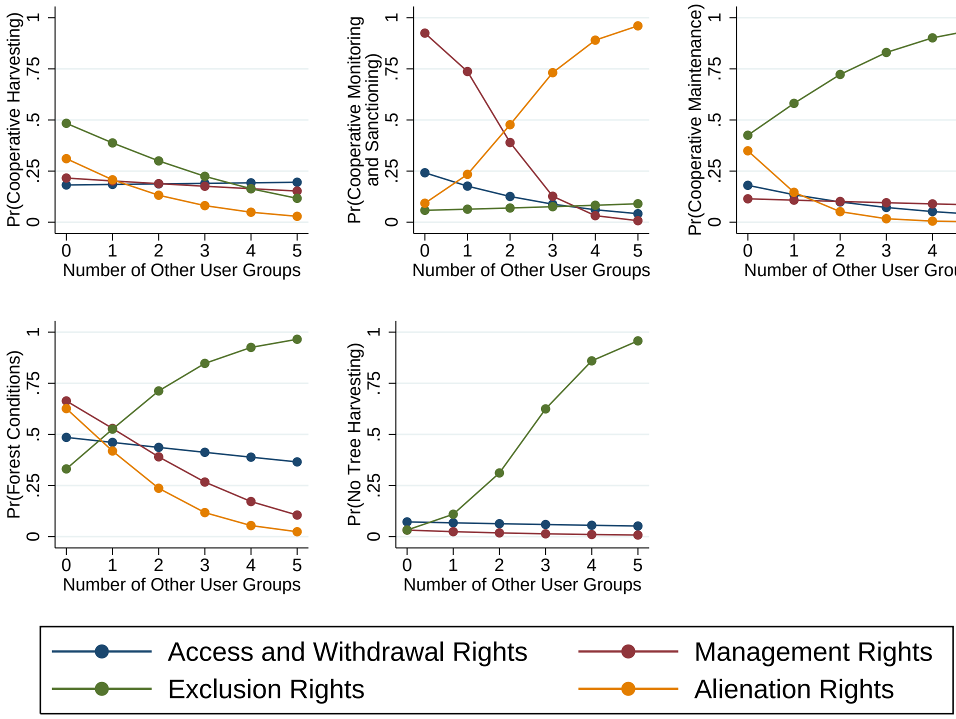

Figure 1: Predicted Probabilities of Various Property Rights Schemes. The five panels show the predicted probability of achieving the given outcome, dependent upon the number of other user groups in the forest and the property rights held by the user group. Predicted probabilities are calculated by conditioning on a disturbance (Tree Density Decrease=1) and holding all other variables at their median. *Note:* There are no predicted probabilities for no tree harvesting for user groups with alienation rights, because all user groups with alienation rights in the data predict the outcome perfectly; they all continue to harvest trees.

The middle panel of the top row shows the probability of cooperative monitoring and sanctioning. Note that the effects of management rights seem quite important when there are few other user groups; however, as the number of other user groups increase the effectiveness of management rights diminishes. Management rights are only effective at inducing investments when there is little chance that other users will appropriate rents from those investments.

One expects that as the number of other user groups increases the more important will be exclusion rights. However, this does not appear to be the case. It appears that exclusion rights alone will not motivate user groups to engage in monitoring and sanctioning. If user groups are given alienation rights in addition to management and exclusion rights, then they are much more likely to engage in cooperative monitoring and sanctioning as the number of rival groups increases.

The results for cooperative maintenance, forest conditions, and tree harvesting are relatively similar. The key property right in ensuring adaptive responses, especially if there are other user groups, appears to be exclusion rights. User groups with alienation rights are less likely to favorably respond to disturbance than those with just exclusion rights in situations where there are other rival user groups. In such instances, those with alienation rights are less likely to engage in cooperative maintenance of the forest, have good forest conditions, or cease tree harvesting (not shown in the bottom middle panel of Figure 1 because not a single user groups with alienation rights stopped harvesting trees).

The strong effects of exclusion may be because absent alienation rights the user group is "tied to the forest." With no prospects of divesting itself from the resource it is forced to adapt to the disturbance rather than let another entity do so. After disturbance a user group with alieantion rights, however can decide it is better off selling the asset to provide short-term income rather than reinvest.

Another reason for the strong effects of exclusion rights rather than pure alienation rights is the role of liability. Suppose that the state or a private entity is the owner of the forest and leases exclusion rights to the user group. They may be liable for any damages done to the forest and thus have an incentive to invest resources in the face of disturbance. However, if the user group is the owner of the forest (i.e. it holds alienation rights) then it may be disinclined to make investments in the face of disturbance if the group has other priorities.

Exclusion rights are the most powerful when there are more rival user groups. If there are multiple user groups in a forest and one of the user groups has rights of alienation, then other groups may decide to risk harvesting resources (perhaps contrary to established rules) before the asset is sold. If the user groups with rights of alienation anticipates this they will be hesitant to invest in the resource. However, if the user group only has exclusion rights there is no prospect to divest itself of the resource; thus, other user groups do not have an incentive for risky harvesting because the asset cannot be sold.

4. Discussion

Following the theoretical framework of (Schlager and Ostrom, 1992), we have explored the effects of different property rights bundles on the propensity of forest user groups to make investments when faced with disturbance. A number of important findings have emerged. First, it appears that full ownership rights need not be given to user groups in order to ensure most adaptive responses to disturbance. Full ownership rights are specifically not necessary to ensure that forests remain in good condition and that tree harvesting is stopped in response. Second, exclusion rights appear to be the property right most associated with adaptive responses to continue investing in the resource. Third, the effects of property rights are the most pronounced in situations where there are rival users who might challenge those property rights.

These results also suggest that forest conditions are likely to deteriorate with an external disturbance and that user groups are less likely to stop harvesting trees in the following a disturbance. This finding suggests a positive feedback loop between deforestation and disturbance. Once a disturbance is felt local forest users may fail to adapt to these circumstances by harvesting less; this in turn will increase carbon emissions and increase the probability of future disturbances from climate change. This should be particularly troubling to climate change modelers and policy analysts of climate change. However, we have also identified a potential tool for addressing this problem: giving exclusion rights to forest users can engender adaptation in the face of disturbance when there are other rival groups. However, giving full alienation rights to user groups may speed the rate of deforestation and exacerbate the positive feedback loop. Thus, in the short term local communities with inadequate property rights may be relatively unaffected by climate change disturbances if their investments adequately ensure they receive the same benefits as before the disturbance. However, these strategies may have very negative long term impacts if current rates of harvesting are beyond levels that might be supported by the prevailing forest ecology or a changed forest ecology due to climate change.

In the face of disturbance, it appears that user groups adapt strategies in forest commons to help ensure the user group will continue to harvest forest resources and exclude other from those resources. Absent any property rights, adaptation strategies are not intended to harvest fewer resources but simply to take measures to ensure that those resources are captured by users with rights to the resources. Management rights appear to help with investments in forests with few user groups but are not effective in communities with many rival groups. Exclusion rights, on the other hand, appear to be most effect in situations where there are many rival groups. Alienation rights help ensure some kinds of investments, but appear to have strong negative impacts on the propensity to stop tree harvesting and the overall conditions of forests after disturbance.

5. Materials and Methods

The data for the analysis is taken from the IFRI training manual (International Forestry Resources and Institutions, 2008). Statistical analysis was conducted in Stata 11. Data files and Stata do file code is available from the author upon request.

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Appendix

Table 6: Distribution of Other User Groups

	Frequency	Percent	Cumulative Percent
0	194	41.36	41.36
1	90	19.19	60.55
2	69	14.71	75.27
3	44	9.38	84.65
4	60	12.79	97.44
5	12	2.56	100.00
Total	469	100.00	

Notes: Data from (International Forestry Resources and Institutions, 2008).