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Contextual factors that enable forest users to engage in tree-planting for forest restoration

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ABSTRACT

Social, biophysical, and institutional contexts affect forest users' incentives to work together to restore forests. With renewed government commitments to support such activities, we argue that effective interventions need to consider several context-specific factors – such as the user groups' future discount rates, opportunity costs, and collective-action capabilities – because these factors will help determine the effectiveness of such interventions. To test the effects of a suite of contextual factors, we analyzed observations from 184 different groups in 133 forests across eight developing countries. We find that the combination of certain enabling factors increases the probability of users undertaking forest improvement activities, and that social contexts can condition the effect of institutional and biophysical contexts. Our findings carry implications for the design and implementation of future interventions to restore forests in developing countries.

1. Introduction

With the launch of the Bonn Challenge in 2011 and the New York Declaration of Forests at the 2014 UN Climate Summit, signatory countries have made significant political commitments to restore 150 million hectares of deforested and degraded land by 2020. Political leaders followed through with these commitments by implementing Initiative 20 × 20 of the Latin America and Caribbean countries and the African Forest Landscape Restoration Initiative (AFR100). Current initiatives advocate for participatory reforestation approaches, including community-based restoration initiatives, instead of top-down command and control approaches, arguing that such approaches result in better governance of restoration areas and greater social benefits (Demeo et al., 2015; Villaseñor et al., 2016; Derak et al., 2018). Local forest users are particularly important for the success of participatory governance of forest restoration activities because of their local knowledge, presence, and relatively large stake in the outcomes of such initiatives. However, successful forest restoration is a process that requires substantial time and financial commitments from a variety of actors. One fundamental challenge of participatory approaches to forest restoration is that many local users are hard-pressed to meet their short-term material needs, such as securing food, energy, and income for their households. As a result, users may not be in a position to prioritize activities such as sustained forest conservation or restoration activities, which typically yield benefits in the distant future. In many instances, the pursuit of short-term material needs is what has caused the ecological degradation of forest landscapes to the point that forest restoration has become necessary.

To respond to this problem, donors and practitioners advocate for interventions that can help forest users overcome the barriers created by short-term economic needs and short time horizons. These interventions frequently offer economic incentives to conserve and help restore forest ecosystems. Such programs often assume that external incentives are sufficient for users to commit to forest restoration activities. However, research shows mixed results from interventions offering external incentives, which suggest that the assumptions undergirding such interventions may not always hold (Wunder et al., 2008; Pagiola et al., 2007; Muñoz-Piña et al., 2008; De Koning et al., 2011). While overall enrollment in forest improvement is often high in these incentive schemes, many cases do not result in equitable distributions of long-term social and biophysical benefits, and the enrollment of the poorest segments of the target population can often be lower than other segments that are better off. This paper offers a possible explanation as to why these incentive schemes can fail to achieve their intended impact:

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adverse contextual factors. We theorize that contextual factors affect users' incentives to solve the collective action problem of sustained engagement in forest restoration. We analyze the role of several contextual factors in explaining variation in forest user decisions to engage in collective forest improvement activities across a wide variety of rural communities.

The central argument that we explore is that several contextual circumstances – related to the biophysical, social and institutional contexts –affect the likelihood of forest users to engage with collective forest restoration activities. Specifically, we hypothesize that users holding clear and secure property rights, using a relatively large forest, having low dependence on the forest to meet subsistence needs, and appreciating the forest for its sacred or commercial value will be more likely to engage in forest improvement activities. While some scholars view certain contexts, such as reduction in subsistence dependency and secure property rights, as social outcomes of successful reforestation efforts (Erbaugh and Oldekop, 2018), we argue that these contextual factors can also be important enablers of local forest improvement activities. To test this argument empirically, we employ original field data from 184 user groups and their use of forest products in 133 tropical forests across eight developing countries. We develop four specific hypotheses, which we test using multiple regression analysis.

We treat tree-planting activities (both the planting of tree seedlings and tree saplings) as analogous to general forest restoration activities. It seems reasonable to assume that contextual factors that affect users' decisions to participate in collective tree planting activities for forest regeneration are very similar to those affecting users' decisions to participate in other collective forest restoration activities. Most forest-restoration initiatives involve the planting of tree seedlings or saplings (Gregorio et al., 2015; Hanson et al., 2015).

To preview our results, we find that a user group's (1) property rights, (2) dependence on forests to meet subsistence needs, (3) commercial interest in forests, and (4) the size of the forests they access help explain varied participation rates in collective tree planting activities across user groups. Not only is the individual effect of each of these factors statistically significant and substantively important, but several contextual factors also moderate the effect of one another.

1.1. Enabling contextual factors for user-initiated forest restoration

Most policy instruments developed to encourage user groups to undertake forest restoration activities are designed to lower immediate barriers to tree planting by offsetting local people's opportunity costs, hence supporting direct, grassroots participation in these initiatives. Instruments that incentivize users to undertake forest improvement activities include payments for environmental services (e.g. carbon storage, biodiversity) as well as the direct provision of tree seedlings and technical assistance (Erbaugh and Oldekop, 2018; Huang et al., 2009; Southgate and Wunder, 2009). We argue that aside from these direct incentives designed to compensate users for the costs of forest improvement activities, there are important contextual factors that, if in place, can enable user groups to work together to carry out costly forest restoration activities. These contextual factors influence users' future discount rates, perceived opportunity costs, and cooperation cost of restoration, which, in turn, affect the likelihood of initiating and sustaining improvement activities. These factors do so through enabling collective action among users to carry out long-term collective restoration initiatives. We focus on long-term engagement with planting in addition to one-time planting. Not only is the growth of tree seedlings and saplings into forests a long-term process, but the ability to sustain restoration initiatives ultimately may facilitate virtuous cycles of social-environmental interaction (Tidball et al., 2017). For example, Tidball et al. (2017) found that sustained tree replanting efforts by local residents in post-Hurricane Katrina New Orleans, for both practical and symbolic motives, helped create a social system and ecosystem improvements that then fed back into increased social connectivity and sustained ecosystem improvement activities.

We hypothesize that institutional arrangements, biophysical attributes of the forest, and social characteristics of user groups play an important role in creating an enabling environment for tree planting activities. Below, we discuss the influence of several possible institutional, biophysical, and socio-economic factors that shape the likelihood of local users engaging in these activities. We use Ostrom's (2009) framework for analysis of socio-ecological systems, specifically second-level variables in Resource units (RU), Users (U) and Governance systems (GS) categories, to guide our hypotheses (Ostrom, 2009). Nagendra (2007) used a similar framework to identify biophysical, social, institutional, and economic factors that influence reforestation in Nepal, testing their effect on reforestation using bivariate associations of social leadership, tenure regime, user-group to forest ratio, and monitoring of forest use with actual changes in forest density. She found that the latter three contextual factors are associated with increases in forest density, providing initial evidence that non-economic factors also influence the emergence of reforestation activities. Here we build on Nagendra (2007) to analyze how a wider array of contextual factors influence the likelihood of a user group carrying out forest improvement activities.

2. Theoretical arguments

Based on application of Ostrom's SES framework and our review of the literature on in-forest and on-farm tree planting, we advance four theoretical arguments about the specific contextual variables that can enable local forest users to engage in collective tree-planting activities in developing countries. Collective action problems are pervasive throughout all stages of forest improvement programs, from the aggregation of preferences for planting, the provision and production of forest improvement activities, equal or proportional sharing of benefits from forest improvement, to the biophysical maintenance of improvement areas. We consider local variations in biophysical, socioeconomic, and institutional contexts that affect the motivation and collective action capabilities of local forest users. Moreover, we also distinguish between any engagement with planting activities and sustained engagement with planting activities, because it takes sustained engagement over many years to develop a stable forest. We expect that the effect of the hypothesized contextual factors will be greater with sustained engagement because it is so costly.

2.1. Hypothesis 1a: user groups are more likely to undertake planting activities if they value the forest economically. Hypothesis 1b: user groups are more likely to undertake planting activities if they value the forest spiritually

Users can have non-economic or economic motivations for undertaking forest improvement activities (Rahman et al., 2017; Beedell and Rehman, 2000, 1999; Zubair and Garforth, 2006). Social characteristics of user groups often influence the extent to which cultural or commercial values are associated with the forest, and thus influence users' perceived intrinsic and extrinsic incentives to plant. Valuing ecosystem services may also be motivated by economic interests. In fact, the existing literature suggests that users often plant trees for the instrumental reasons related to the provision of ecosystem services (Beedell and Rehman, 2000, 1999; Meijer et al., 2015; Zubair and Garforth, 2006; Sood and Mitchell, 2004; McGinty et al., 2008; Etongo et al., 2015). For example, landowners around the Australian rainforest planted trees for creek bank stabilization and wind breaking; In the Australian wheat belt, wheat farmers plant trees for the purpose of conservation and salinity mitigation (Harrison et al., 2003; Smith, 2008). In Pakistan, some smallholder farmers plant trees to control erosion, pollution, and provide shade for animals (Zubair and Garforth, 2006). In Brazil and Panama, farmers who plant trees are motivated by the amenity value of trees and desire to sustain the amenity to future generations (Simmons et al., 2002).

However, most studies about forest use in less-developed countries also indicate that the primary driver of user-initiated tree planting is a more direct motivation of pursuing of economic income from forest products. Farmers often use tree planting as a strategy for livelihood change or diversification when the commercial conditions favor tree products over other agricultural products. The market conditions for wood products and fruits, perceived stability of the market, and access to market are the most often mentioned motivations and discouragements to tree planting in developing nations (Zubair and Garforth, 2006; Managabat et al., 2009; Ndayambaje et al., 2012; Jagger and Pender, 2003; Etongo et al., 2015; Simmons et al., 2002; Brancalion et al., 2016). Therefore, we assume that farmers who are more reliant on the forest for commercial reasons, or farmers who have access to forests of higher commercial values, perceive stronger economic incentives to engage in forest-improvement activities. Such economic motivation captures both the value of forest products and well as the instrumental value of ecosystem services.

The existing literature also suggests that spiritual and other noneconomic values drive farmers' tree planting. In India, one study found that farmers who are more religious are more likely to plant trees (Sood et al., 2008). In the UK, farmers with greater environmental awareness are more likely to adopt agroforestry practices (Beedell and Rehman, 1999, 2000). These findings suggests that farmers and forest users in both low-income and high-income countries are often motivated to plant trees based on their values related to conservation and spirituality.

2.2. *Hypothesis 2: user groups with more secure de jure and de facto property rights over local forest resources are more likely to undertake planting activities*

Having secure property rights over forest resources and products influences users' confidence in receiving an economic payoff from tree planting. Without perceived secure property rights, users will not be able to ensure that future benefits will be theirs to keep (Rahman et al., 2017; Schuren and Snelder, 2008; Managabat et al., 2009; Etongo et al., 2015; Simmons et al., 2002; Insaidoo et al., 2013). Complete ownership of forest resources by users are rare in the developing world since most forest resources are owned by national governments, even where the land upon which forests grow are owned by communities or private individuals (FAO, 2014; RRI, 2014). The implication of such property-rights regimes is that even if the land is titled and owned privately by the local users, such rights do not necessarily grant them the right to manage, harvest, or sell the products from the forest. Recognizing these distinct dimensions of property rights, as first conceptualized by Schlager and Ostrom (1992), what ultimately influences tree planting in forested landscapes may be the long-term security of the withdrawal rights for forest products, rather than general access and exclusion rights to the forest land. Having both *de jure* and *de facto* withdrawal rights over forest products means more secure property rights than only de facto rights, and we predict that enjoying such rights will increase the likelihood of user engagement in planting activities.

However, future discount rates and opportunity cost of using the reforested area for other purposes also affects the value that users assign to long-term payoffs associated with restoration activities. Users may value future payoffs less because of immediate and unmet subsistence needs. Several case studies directly mention a lack of food security as a major reason for not planting trees in agroforestry initiatives (e.g. Rahman et al., 2017; Meijer et al., 2015; Managabat et al., 2009). Users with unmet short-term needs may be unable to afford the opportunity costs associated with the nonagricultural use of a land area that would be set aside for forest reforestation activities. The size of the forest or land available to users can enhance or reduce this opportunity cost. For on-farm planting, farmers with larger plots of land can afford to use a larger portion of the land for planting trees without compromising the amount of land needed for short-term crops that can satisfy the household's subsistence needs (Schuren and Snelder, 2008; Sood and Mitchell, 2009; Frayer et al., 2014; Etongo et al., 2015). The same mechanism should also apply to planting in collective forests and short-term subsistence needs from the forest. Users who are less dependent on the forest for subsistence needs, as well as users who have access to larger forests, have lower future discount rates and lower opportunity costs. It follows, then, that groups with secure harvesting rights to important products are much more likely to engage in tree planting activities when they are less reliant on the forest for subsistence needs and harvest from relatively large forests.

Table 1
Data overview: Number of forests, user groups, and user group-forest pairs by country.

Country	# of forests	# of user groups	# of user group-forest pairings
Bolivia	16	21	23
Guatemala	4	5	9
India	18	18	18
Kenya	13	34	37
Madagascar	6	18	18
Nepal	41	35	41
Tanzania	5	10	10
Uganda	30	53	57
TOTAL	133	184	213

2.3. *Hypothesis 3: socially and economically homogenous user groups are more likely to undertake collective planting activities*

To realize the long-run benefit of tree planting, user groups also need to establish effective reforestation governance capabilities (Cernea, 1989). The provision and production of forest improvement activities to the user group is similar to that of other public goods such as infrastructure (Ostrom et al., 1993). Case studies most often point out the lack of collective maintenance arrangements as contributors to failed reforestation efforts. For example, uncontained fires or pest infestation across individual farm plots can destroy planted tree seedlings in shared forest areas (Simmons et al., 2002). One study observed that "nearly 30% of farmers experience fire contagion from neighbors" (Simmons et al., 2002: 91; Meadows et al., 2014).

Previous studies have shown that groups with users who are more socially and economically homogeneous are more likely to solve collective-action dilemmas without special institutional arrangements because of higher degrees of common interests and trust (Poteete and Ostrom, 2004; Alesina et al., 1999; Habyarimana et al., 2007; Miguel and Gugerty, 2005). Collective action is easier to achieve when individuals in the group have similar preferences (Heckathorn, 1993; Vedeld, 2000) and when the transaction costs of communication and cooperative strategies are low (Habyarimana et al., 2007, 2009). Group heterogeneity can refer to heterogeneity in economic or political power (Persha and Andersson, 2014; Vedeld, 2000) or in social values associated with heterogenous ethnic groups (Alesina et al., 1999), although the two types are often correlated. In the forest governance literature especially, studies have found that both intra-user group and inter-user group economic inequality are associated with worse forest outcomes (Andersson and Agrawal, 2011; Torpey-Saboe et al., 2015). A study in Nepal found that ethnic homogeneity to be linked to better forest outcomes in terms of higher carbon and more biodiversity in community forests (Newton et al., 2016).

2.4. Hypothesis 4: user groups are much more likely to undertake forest improvement activities when a combination of favorable contextual factors are in place

While we expect of the socioeconomic, biophysical and institutional contextual factors to have a direct and independent effect on the likelihood of users undertaking forest improvement activities, we also expect that this likelihood to increase the most when a combination of these factors is present simultaneously. We use our regression estimates to model "ideal types" scenarios through which we explore what is likely to happen to collective planting activities when a combination of enabling contractual factors are in place.

3. Data and methods

To test the hypothesized effect of the contextual factors, we employ original field data from 184 user groups and their use of forest products in 133 forests in eight different developing countries. Table 1 summarizes the sample by displaying the number of user groups, forests and user group-forest pairings for each county. Our dataset includes observations from sites in Bolivia (n = 23), Guatemala (n = 9), India (n = 18), Kenya (n = 38), Madagascar (n = 18), Nepal (n = 41), Tanzania (n = 10) and Uganda (n = 57)[1] . The data come from a coordinated data collection effort by the International Forestry Resources and Institutions (IFRI) program, collected using common protocols across countries and sites, and purposively sampled[2] .

The dataset includes forest user characteristics, user group's relationships with specific forests, and biophysical characteristics of each forests, where each forest user group could have access to multiple forests. Where a site was visited more than once, we only used the data collected from the first visit. IFRI defines a user group as "a group of people who harvest from, use, and/or maintain a forest or forests […] who share the same rights and duties to products from the forest(s), even though they may or may not be formally organized "(IFRI field manual, 2011, II-3). The definition of a forest is "a surface area with woody vegetation of at least 0.5 ha, exploited by at least three households, and governed overall by the same legal structure" (IFRI field manual, 2011, II-1). A forest can be used by multiple users, and a user group can use multiple forests. IFRI collected information on user group-to- forest relationships, characterizing the relationship between each user group and each of the forests that it accesses. Our dependent variable of interest is the user group's planting activities in a specific forest (each with particular biophysical characteristics), thus our unit of analysis is the forest-to-user-group relationship. For example, if a user group has access to two forest as defined by IFRI, the user group's relation to each forest is considered as two separate units of analysis.

3.1. Dependent variables

To investigate how contextual factors affect the likelihood of forest users deciding to undertake forest restoration activities, we treat observational data on users' tree-planting activities (both the planting of tree seedlings and tree saplings) for regeneration purposes as analogous to general forest restoration activities. The question asked in the data collection protocol was "Have individuals in this user group undertaken any of the following management or regeneration activities, and if so, how frequently? a) Planted seedlings? b) Planted trees?". Because effective forest regeneration is a long-term commitment with many actions repeated over a long period of time, investigating the enabling contextual factors of sustained improvement activities is particularly important. Therefore, we constructed separate measurements for any planting activities at all and repeated planting activities. If the user group had done any (**occasional to repeated**) seedlings or saplings planting, (including "Rarely done", "Done about every ten years", "Done about every five years", "Done every several years" and "Done once a year"), we constructed a dummy variable called "any seedling planting" or "any sapling planting" respectively. If the user group had **regularly and repeatedly** planted seedlings or saplings in the past (ranging from "Done once every ten years" to "Done once a year"), we constructed a dummy variable called "sustained seedling planting" or "sustained sapling planting" respectively. The histogram of sampled user groups' seedling and sapling planting frequency (from which our dependent variables are constructed from) are displayed in Fig. A1 in the Appendix.

We chose to analyze the associations between contextual factors and the planting of *seedlings* and *saplings* separately because this distinction is important for our theoretical argument about the varying economic costs of different planting activities. Although users may consider environmental or species concerns when choosing between seedlings and saplings, the cost difference between these two alternatives is often substantial (saplings usually cost at least twice as much as seedlings). The purchase, transport, and planting costs for saplings are much higher than for seedlings, making its immediate cost barrier higher for most users.[3]

3.2. Independent variables

Our key explanatory variables include user groups' sacred and economic values of the forest, security of property rights over forest products, dependence on forest for subsistence needs, forest size, as well as social and wealth homogeneity within user groups. We measure *sacred value* of the forest with a dummy variable indicating whether most individuals in the user group sees the forest as sacred, including cases where user group sees the forest both as sacred and as an economic resource. We measure *economic value* that the user group places on the

[1] The dataset used for analysis excluded sites in Brazil, Thailand, and USA because these sites were used for training purposes rather than comparative research about community forests and therefore used a different set of criteria for selecting local sites. Sites in Ethiopia, Bhutan, and Honduras were also excluded because of the very small numbers of sites in each of these countries (<4).

[2] IFRI sites are broadly representative of forests in human-dominated landscapes throughout the tropics which are outside of the three large contiguous tropical forest areas (Congo Basin forests in Central Africa, the Amazon Basin across nine Latin American countries, and Borneo across Indonesia and Malaysia). IFRI sites are selected to be representative of the range of forest management regimes that exist in a given country, to ensure variation on hypothesized causal variables, and with a clear knowledge that sites must not be selected on the basis of the primary outcome of interest-sustainable management of forests (e.g. the condition of the forests, successful collective action for forest management and restoration). What this means is that rather than a random sample, IFRI relies on a purposive sampling strategy that seeks to create meaningful variation on the variables related to local institutional variables, including property rights, norms, rules, and strategies related to interactions with forest resources, without any regard to outcomes. Because our sample is a purposive sample, care should be taken before generalizing the results beyond the range of independent variable values in the sample (See Persha et al. (2011) for a detailed discussion on IFRI sampling and implications for analysis).

[3] As a robustness check, we also ran the models with a collapsed measure of any planting of seedling or saplings as the dependent variable. The results are similar, except that the collapsed measure resulted in a much wider confidence interval for the moderating effect of subsistence dependency.

Table 2
Logistic regression results for main models without and with interaction terms, with exponentiated coefficients. (* $p < 0.05$ ** $p < 0.01$).

	(1) Any seedling planting	(2) Any seedling planting (with interactions)	(3) Sustained seedling planting	(4) Sustained seedling planting (with interactions)	(5) Any sapling planting	(6) Any sapling planting (with interactions)	(7) Sustained sapling planting	(8) Sustained sapling planting (with interactions)
Biophysical contexts								
Forest size	1.01*	1.01	1.01*	1.01	1.01	1.01	1.01	1.02
	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Forest commercial value	1.19	1.28	0.83	0.81	1.07	1.17	0.68	0.75
	(0.27)	(0.30)	(0.25)	(0.26)	(0.28)	(0.33)	(0.28)	(0.36)
Social context								
Sacred value for forest	1.47	1.44	1.85	2.24	2.93*	2.95	2.45	3.46
	(0.72)	(0.72)	(1.09)	(1.40)	(1.60)	(1.67)	(1.96)	(3.29)
Commercial dependency	1.23	1.22	3.35	5.43	6.59**	6.04**	11.98*	33.58**
	(0.86)	(0.86)	(2.95)	(5.44)	(4.44)	(4.14)	(12.81)	(45.41)
Subsistence non-dependency	1.44	1.67	1.10	11.93	4.16*	2.57	1.15	21.03
	(0.85)	(1.30)	(0.87)	(15.24)	(2.79)	(2.35)	(1.20)	(35.89)
Social homogeneity	0.13*	0.13*	0.62	0.56	2.21	3.26	2.74	7.57
	(0.13)	(0.12)	(0.73)	(0.71)	(2.29)	(3.65)	(4.33)	(14.59)
Wealth equality	0.83	0.80	0.88	0.96	1.07	0.81	1.65	1.52
	(0.38)	(0.38)	(0.54)	(0.63)	(0.53)	(0.44)	(1.25)	(1.28)
Institutional context								
Secure property rights	1.25	1.06	2.51**	4.06**	1.84*	0.77	2.76*	1.08
	(0.25)	(0.27)	(0.82)	(2.15)	(0.52)	(0.37)	(1.37)	(1.04)
Interaction terms								
Secure property rights x Forest size		1.01		1.01		1.02		1.03
		(0.01)		(0.01)		(0.01)		(0.02)
Secure property rights x Subsistence non-dependency		1.00		0.16*		3.55		1.36
		(0.51)		(0.12)		(2.36)		(1.67)
Forest size x Subsistence non-dependency		0.99		0.98		0.97		0.79
		(0.01)		(0.01)		(0.01)		(0.12)
Controls								
External support in planting governance	1.47	1.77	2.37*	3.52**	2.14*	2.26*	3.86**	4.43*
	(0.41)	(0.56)	(0.86)	(1.55)	(0.74)	(0.83)	(1.99)	(2.76)
External support in planting operations	0.93	0.84	0.58	0.48	0.77	0.69	0.82	1.01
	(0.29)	(0.28)	(0.25)	(0.23)	(0.32)	(0.30)	(0.47)	(0.69)
N	208	208	208	208	208	208	208	208
AIC	206.46	208.47	150.21	147.42	171.21	167.01	106.48	97.77
BIC	246.51	258.54	190.26	197.48	211.27	217.07	146.53	147.84

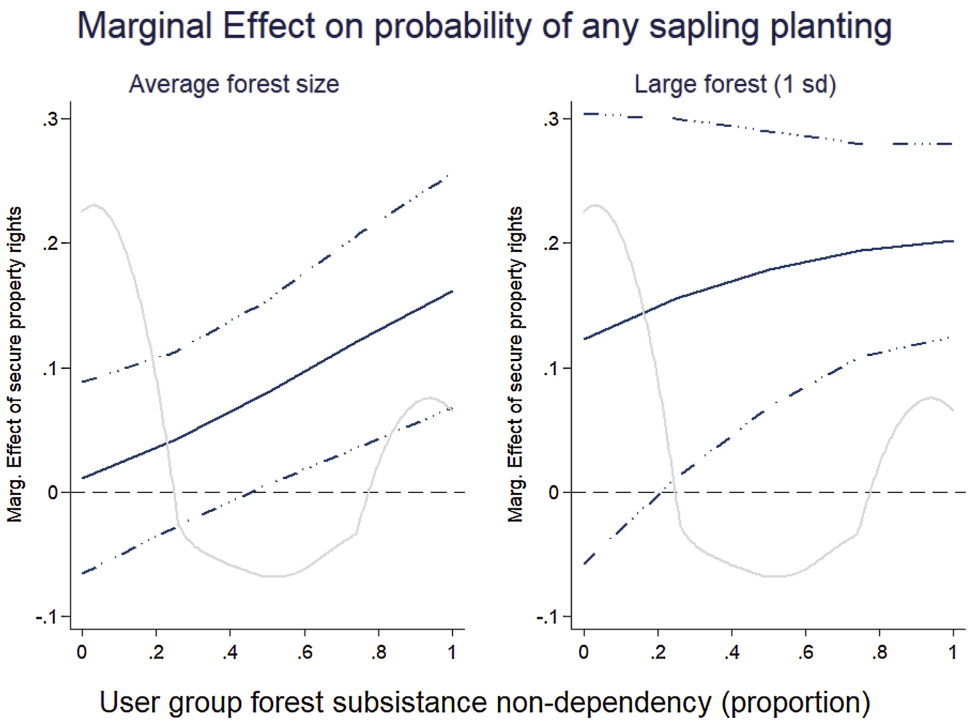

Fig. 1. Marginal effect of secure property rights on probability of any sapling-planting over user group subsistence non-dependency, at average forest size and forest size greater than one standard deviation from the mean. All other explanatory variables are held at the mean (marginal effect on all dependent variables over all forest sizes are included in the Annex, Fig. A4. Marginal effect plots on all dependent variables with ordered logit models are included in Annex, Fig. A5). Includes the kernel density plot of the user group subsistence non-dependency.

forest with the proportion of individuals in the user group that rely on the forest for commercial activities. We define the level of secured *property rights* by the number of the user groups' three main forest products to which the users hold both de jure and de facto property rights. A body of literature on land rights suggests that property rights are secured only when de jure and de facto rights are aligned with one another (Torpey-Saboe et al., 2015).

We measured *non-dependence on forest for subsistence* by the proportion of individuals in the user group that is not dependent on the forest for subsistence needs. *Forest size* is measured in hundreds of hectares (ha). *Forest commercial value* is also determined by the forester, measured on a five-point scale with zero being normal, 2 being substantially above normal, and -2 being substantially below normal. In addition to forester-determined forest commercial value, we include a measure of the proportion of individuals in the user group that is *dependent on the forest for commercial needs.* We measure *social homogeneity* by calculating an ethnic fractionalization index, a Herfindahl concentration index that represents the probability that any random two people in the group will be of different social groups. We reversed the index to reflect the enabling context of homogeneity instead of heterogeneity. The fractionalization index was calculated with ethnic, religious and caste composition of the user group separately. The minimum value (the most heterogenous) of the three types of social groups was used as the operational indicator of social heterogeneity. We also calculated a dummy variable for *wealth homogeneity* indicating whether there is no great difference in wealth among users in the group.

We control for external interventions in the operational level and governance of planting activities as they also affect the motivations and collective action capabilities of local users. We measured *external support in governance* by the number of external authorities that support forest planting at the collective-choice and constitutional choice level, and *external support in operations* by the number of external authorities that support planting at the operational level. External authorities include foreign government aid agencies, non-forest agencies of national or state governments, forest agencies of national or state government, for-profit regional, national or multinational firms, companies, or corporations, as well as not-for-profit, private, voluntary regional, national and multinational organizations.

Table A1 in Appendix displays the summary statistics of each variable, Table A2 in Appendix displays the survey question used to construct the variables. About 38% of the user group-forest pairs undertake any seedling-planting activities, and 24% any sapling-planting activities. About 18% of user group-forest pairings undertake sustained seedling planting, and 12% sustained sapling-planting. Since saplings are more expensive than seedlings, it is not surprising that more groups plant seedlings compared to the number of groups planting saplings. Overall, in about 40% of all observations, groups undertook any planting of seedling or saplings (including those who sustained planting), and 18% undertook sustained planting of seedling or saplings.

To test our hypothesis, we use logistic regression and allow the intercept to vary randomly by country. A varying-intercept model captures unobservable macro social, economic and political settings, such as "economic development, demographic trends, political stability, government resource policies, market incentives, media organization" (Ostrom, 2009), that may affect user groups' forest use, including the likelihood of investing in forest improvement activities. We also include interactions of secured property rights and non-subsistence dependency, secured property rights and forest size, and non-subsistence dependency and forest size to model the moderating effect of non-subsistence dependency and forest size on secured property rights in our second hypothesis. Through a likelihood-ratio test, we confirm that the inclusion of the interaction variables better fits the observed data than without. We estimated separate models for each dependent variable of (1) seedling planting, (2) sustained seedling planting, (3) sapling planting, and (4) sustained sapling planting.[4]

[4] To account for the clustering caused by user groups that depend on multiple forests, or by sites for user-groups-forests in the same site, we also ran a robustness check with country fixed-effects and clustered errors at the user-group and site level separately, with a smaller sample as some countries have observation numbers that are too small to compare strictly within. The results are similar to the main models. These fixed-effects results are included in Appendix Table A5. We also conducted robustness checks excluding observations of forest size outliers, and a ordered logit model, seperately. Results are comparable and included in Appendix Table A6 and Table A5.

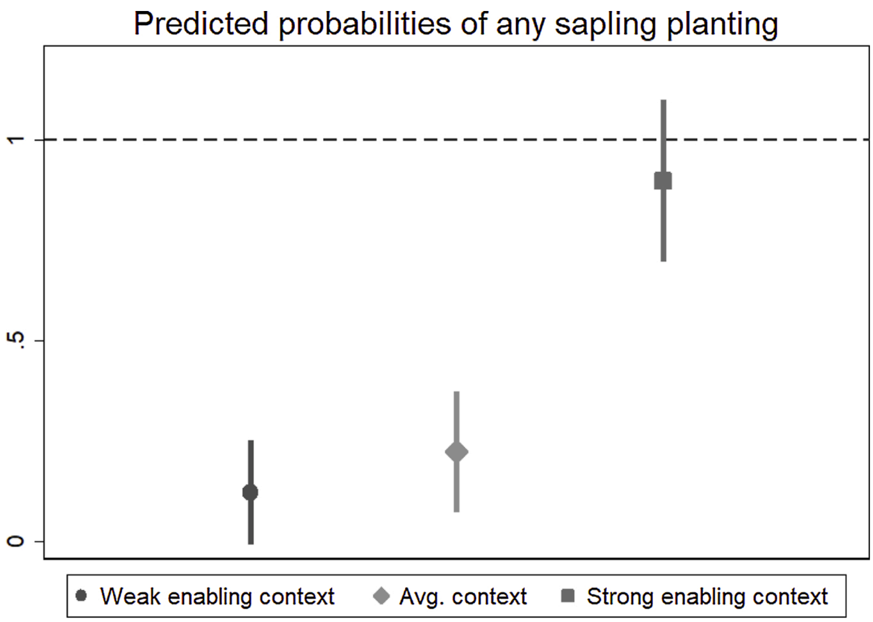

Fig. 2. Predicted probabilities of any sapling-planting across weak, average and strong enabling contexts. For each of these scenarios we combine three contextual factors (secure property rights, user group commercial dependency, and subsistence dependency on the forest) and set them to the minimal, average, and maximum values. All other variables in the models are held constant at their mean or modal values. However, the statistically significant increase in predicted probabilities of a weak to strong enabling context is only present for any sapling-planting, not other dependent variables in the analysis.

4. Results

Our results support our hypotheses regarding the enabling potential of several biophysical, social, and institutional factors. These enabling contextual factors have a stronger effect on the more costly planting activities, such as *sustained* seedling, and any or sustained sapling-planting activities. Table 2 shows the results of the logistic regression models, with coefficients displayed as odds-ratios, and Table A3 in the Annex presents changes in the predicted probabilities for planting activities at different values of all significant independent variables, holding all other variables constant.[5] Our main findings are that: (1) User groups who use forest resources primarily for commercial purposes are more likely to undertake any sapling-planting activities; (2) Subsistence non-dependent user groups who enjoy secure product property rights in larger forests are more likely to carry out occasional and sustained planting of both seedlings and sapling;) (3) The probability of users investing in any sapling planting activities increases significantly when a combination of several enabling contextual conditions are present.

4.1. User groups that use forest resources primarily for commercial purposes are more likely to undertake any sapling planting activities

User groups who place greater commercial value on the forest—who are more dependent on the forest for commercial purposes—are more likely to undertake any and sustained sapling planting activities. The effect on sustained planting is larger than any planting. The commercial value of the forest as assessed by a third-party forester has no effect on the likelihood of user-initiated forest improvement, suggesting that it is not forest characteristics, but the users' relationship with the forest that affects tree planting behavior. Table A3 in the Appendix shows the difference in the likelihood of planting between when the independent variable is at its minimum and its maximum values, holding all other variables constant at their means or modes (depending on whether the variable is continuous or ordered). The probability of any sapling planting increases by 23 percentage points as the commercial dependence variable changes from its minimum value (0) to its maximum value (1). The probability of sustained sapling planting increases by 22 percentage points. The effect of sacred value is not consistently statistically significant for any of the dependent variables.

4.2. Users enjoying secure property rights over forest products are more likely to carry out planting of both seedlings and trees. This effect is moderated by forest size and user group subsistence non-dependency

Users who enjoy secure property rights to the most important products from the forests that they access –that is they hold both de jure and de facto rights to harvest these products –are much more likely to decide to invest their time and effort to carry out collective planting of seedlings and saplings. While the variable for secure property rights does have a significant effect for sustained seedling planting and sapling planting in the models without interaction terms (Table 2 Models 3, 5 and 7), a more nuanced story about the effects of property rights emerges when we consider how other contextual variables affect this relationship. We theorized that the importance of secure property rights will likely depend on the size of the forest as well on the degree to which the users depend on the forest for their subsistence needs (which also proxies the users' discount rates and opportunity costs). The results support these interaction effects (Table 2 Models 2, 4, 6 and 8). Because the magnitude and statistical significance of interaction effects across the ranges of variables in non-linear models are difficult to interpret from the regression coefficients alone (Ai and Norton, 2003; Franzese and Kam, 2009), we calculated the marginal effect of secured property rights across varying degrees of user group dependence on forests for subsistence, and across different forest sizes. Fig. 1 plots the marginal effect of secured product rights on any sapling planting, for non-subsistence dependency with average forest size and for forests one standard deviation above the mean size. The marginal effect plots of models for all dependent variables and over a larger range of forest sizes are displayed in Fig. A4 in the Annex. The marginal effect plots for the ordered logit models are included in Annex, Fig. A5.

For user groups with forests of average size (around 2700 ha), secure product property rights increase the likelihood of any sapling-planting when the user group has little dependency on forest for subsistence needs. As forest size increases, the opportunity cost decreases, and secure tenure becomes more important as a conditioning factor to planting. Having property rights over one more of its main forest

[5] We set the wealth inequality variable, measured as a dummy, at 0.5, for about an equal amount of user groups has unequal and equal wealth within individuals in the user group

products increases the probability of any planting of tree saplings by 8–17 percentage points for groups with more than half of their members not subsistence-dependent. User group property rights over all three main forest products increases the probability of any planting of trees by 24–51 percentage points. User groups that (1) have at least 20% of members not dependent on forests for their subsistence needs; (2) enjoy secure property rights to at least one forest product, and (3) are using larger forests (one standard deviation above mean forest size around 8900 ha), are 18–20 percentage points more likely to plant trees., For very large forests (two to three standard deviations above the mean size—15,200 to 21,500 ha), subsistence dependency on the forest no longer moderates the effect of secure property rights on any tree planting. The effect of property rights is even stronger, however, as the forest size increases –an effect increase of 21–25 percentage points (see Fig. A2 in the Appendix). The results are similar for any planting of seedlings, except that the moderating effect of non-subsistence dependency is not statistically significant.

Secure property rights over forest products also increase the probability of *sustained* planting, but only in larger forests. When the user group uses a forest over one standard deviation larger than the mean size, having secure property rights for one of its main products increases the probability of sustained sapling and seedling planting by about 13–20 percentage points (see Fig. A3 in the Appendix). The enabling effect of larger forests is especially strong for users who are more dependent on the forest for subsistence needs.[6]

4.3. The probability of users investing in any sapling-planting activities increases significantly when users enjoy a combination of several enabling conditions

To estimate how the presence of a combination of enabling contextual factors affects the predicted probability of users undertaking forest improvement activities, we use our estimated regression coefficients to calculate the combined effect of three main independent variables that we found to have a statistically significant effect in the four models ($p < 0.05$). As few forests in our sample exceed the size of one standard deviation above the mean, we calculated these predicted probabilities holding forests and other control variables constant at their means. The three contextual factors that we varied in this analysis are: (1) secured property rights; (2) user group non-dependency on forests for their subsistence needs (and its interaction with forest size); (3) and the degree of users' commercial dependency on the forest.

Fig. 2 show the predicted probability of any sapling-planting for an average-sized forest, under three different tree-planting scenarios: (1) weak enabling context (in which all significant independent variables are kept at their minimum values), (2) an average enabling context (significant independent variables are kept at their average values), and (3) a strong enabling context (significant independent variables are kept at their maximum values). The numerical values of the predicted probabilities and confidence intervals are displayed in Annex Table A4. When a combination of these enabling contextual factors changes from a "weak enabling context" to "average enabling context" to a "strong enabling context", the probability of any sapling-planting increases significantly. The probability of any sapling-planting increases from 0.12 to 0.22 to 0.90 respectively, an overall increase of 78 percentage points. However, the statistically significant increase in predicted probabilities of a weak to strong enabling context is only present for any sapling planting, and not for the other dependent variables.

It is also worth noting the significance of the effect of external support for planting governance on the probability of user group undertaking more costly planting activities such as sustained seedling, any sapling and sustained sapling planting. This result is consistent with previous studies that found the link between local groups to external organizations to aid local collective action throughserving the role of a third-party monitor to avoid free-riders and local elite capture (Andersson and Ostrom, 2008; Andersson, 2013; Ostrom, Schroeder and Wynne, 1993; Cox, Arnold and Tomas, 2010; Wright et al., 2016; Persha and Andersson, 2013; Andersson et al., 2018a, b). The effect is particularly strong for sustained tree-planting, the costliest of all forest improvement activities in our data. With all other variables held constant, user groups with external support are about twice as likely to undertake any sapling-planting and sustained seedling-planting, and 4.5 times more likely to undertake sustained sapling-planting compared to user group-forest pairs without external support. Another factor that we expected to affect collection action is social and economic homogeneity. However, contrary to our hypothesis, we find no quantitative evidence in support of such variables being associated with collective forest improvement activities.

5. Discussion

Our results support the claim that several contextual factors—including institutional, social, and biophysical contexts –affect the likelihood of user groups carrying out costly collective forest improvement activities. What explains these patterns? Why do these contextual variables matter for forest restoration activities, such as tree planting? Here we discuss possible interpretations of our results.

Our result suggests that certain contextual factors influence the users' perceived long-term value of their use of forest resources independently from external interventions. These factors influence individual users' preferences and motivations for investment in future forest products. The perceptions are related to the extent to which the users' value and discount the benefit of any future benefits related to forest use, including the commercial dependency on forest products and secure property rights, as well as constraining factors of subsistence dependency and small forest size that influence the users' opportunity costs. Consistent with the literature on on-farm tree planting, our results suggest that users are motivated to plant primarily for commercial reasons. We find that the users' commercial dependency on the forest rather than forest-product values drives this motivation. Moreover, users with secure property rights can be more certain that they will be able to realize the long-term benefits of tree planting and forest restoration. On the other hand, the economically disadvantaged users who struggle to meet some of their current, basic livelihood needs are likely to discount the value of benefits that will materialize only in the distant future. Subsistence dependency, as well as forest size, also capture indirectly users' perception of the opportunity costs associated with undertaking forest improvement activities. For example, users who depend on the forest for immediate subsistence needs and only have access to smaller forests would be more reluctant to support restoration activities if they perceive that these constrain their ability to continue using the forest to meet their immediate subsistence needs (e.g. grow crops, collect fuelwood) on the forest land dedicated to restoration activities.

The finding that social context conditions the positive effect of biophysical and institutional factors is especially significant for policy design and evaluation. It suggests that analyses which only examine the independent effect of institutional or biophysical factors may falsely conclude a null effect or obtain a biased effect size. For example, our

[6] While we find that large forests sizes significantly enable users to undertake any planting and sustained planting, the number of observations of large forests in our sample is small. Only 10% of the 213 observations in our sample have forests larger than one standard deviation from the mean.

analysis shows that while secure property rights enable users to undertake sustained forest improvement activities, we may not see the enabling effect of property rights in highly subsistence-based communities due to higher future discounts and opportunity costs. The implication is that the effect of property rights on forest restoration activities is highly context dependent.

Our analysis has several limitations. First, our use of cross-sectional observational data constrains our analysis because our observational data is from one point in time per site –it does not include observations over time, which means that our analysis is merely correlational at this point. Second, we cannot be certain that all contextual factors are completely exogenous to the user groups' forest improvement activities. Collective forest improvement activities may further reinforce collective action or influence perceived benefits and costs of planting that are captured by the contextual factors, causing endogeneity. For example, user groups may expand their commercial activities based on certain non-timber forest products because their forest improvement efforts have increased supply of those products. Increased economic wellbeing from forest improvement may also alleviate the user group's subsistence dependency on the forest. Governance initiatives for managing forest improvement efforts may increase the collective action capability of user groups, which in turn may enable them to obtain other institutional support such as more secure property rights or more external support (Meinzen-Dick, 2007; Erbaugh and Oldekop, 2018; Kerr et al., 2014).

Another shortcoming in using data from single site visits is that we cannot examine the long-term outcome of user-initiated tree planting. We do not know if the user groups who planted are also successful at maintaining the young trees planted to realize the long-term benefits from their investments. However, by also looking at regularly repeated planting activities (and not just any and occasional planting), it seems reasonable to assume that the user groups that are engaged in regular and repeated planting activities are motivated to assume the cost of planting again in the future because they realized the long-term benefits of the first planting. Future research would benefit from analyzing longitudinal observations, which would help to clarify and isolate the causal direction between contextual factors and forest improvement. Although beyond the scope of this paper, future longitudinal studies could also move beyond forest improvement activities as outcomes and include temporal variation in forest outcomes, such as stem density, basal area, and species diversity, as well as measures of human wellbeing

Additionally, our results indicate the need for further research on factors that improve the collective governance of improvement activities. While our hypothesized factors that contribute to collective governance including wealth equality and social homogeneity are not statistically significant, the control variable of external intervention specifically on the governance of planting activities is statistically and substantively significant. While most studies of user-initiated reforestation focus on household characteristics that enable household-level planting, this result suggests that future research on reforestation of common property forests could also more directly investigate factors that enhance users' collective-action capabilities for governance. Such research could build from the design principles for community-based resource management (Ostrom, 2015; Cox et al., 2010). In addition, future research could investigate the effect of governance capabilities on participatory ecosystem restoration on a larger scale (Olsson et al., 2004; Folke et al., 2003), focusing on governance not only within but also between user groups and with external actors.

6. Conclusion

Our findings have the potential to help policy makers and practitioners design more cost-effective interventions for collective restoration activities. Instead of a blanket policy of cash or direct benefits that target all forest users, forest users in different contextual environments may require different combinations of policy instruments. The findings on the types of biophysical, social, and institutional factors that can make a difference, can serve as a diagnostic tool to help donors and NGOs take a more context-tailored approach to intervention design. By focusing efforts in sites with more favorable contexts, practitioners may be able to encourage collective restoration with relatively fewer resource inputs. These benefits could include technical assistance and education as well as cash or non-cash support. Moreover, policies targeting user groups with high commercial dependency on the forest may require less supplementary social or institutional initiatives. Interventions can instead focus on maintaining the commercial value of the forest by expanding the market opportunities of non-timber forest products or sustainable timber operations.

On the other hand, where sites have large potential biophysical and social gains yet enabling contexts are weak, our analysis suggests that practitioners may need to take a step back and work to improve these contextual conditions before intervening with policy instruments. In other words, before intervening, they may need to devote additional effort towards creating the enabling conditions that alleviate subsistence needs or other concerns for opportunity costs regarding the use of the forest. This concern is especially relevant for high subsistence-dependent users who have access to small forests. This analysis also cautions of potential inequities in benefits that may result from a uniform, blanket policy to encourage user participation in restoration activities. For example, users who are better off—who are less dependent on forests for subsistence needs and have more secure property rights—are usually in a better position to take advantage of uniform policies that offer direct material benefits than those who are less well off.

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Appendix A

See Fig. A5 and Table A4

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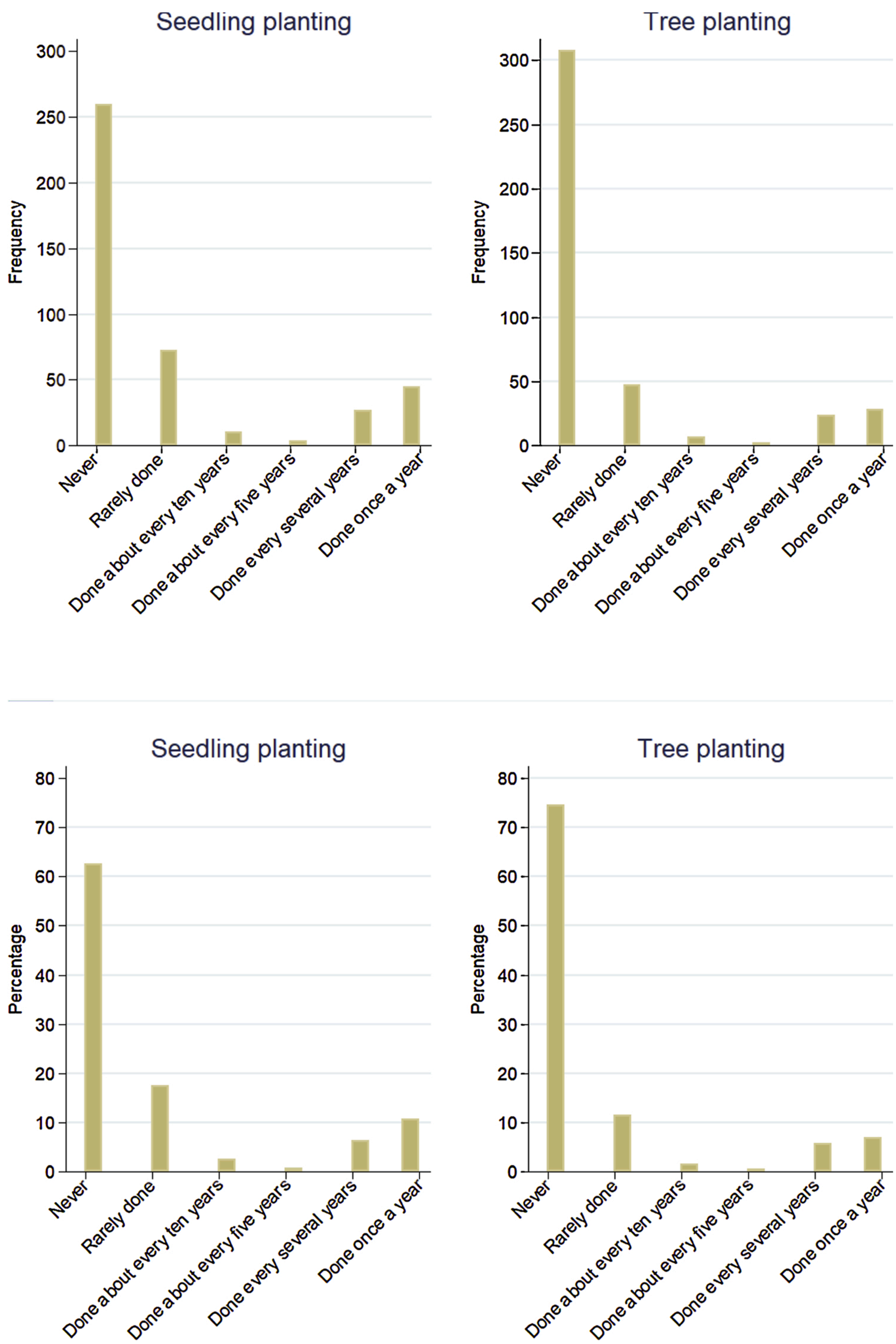

Fig. A1. Histogram of seedling ad sapling planting frequency in the sample of 213 forest user group-to-forest observations, in frequency and percentage.

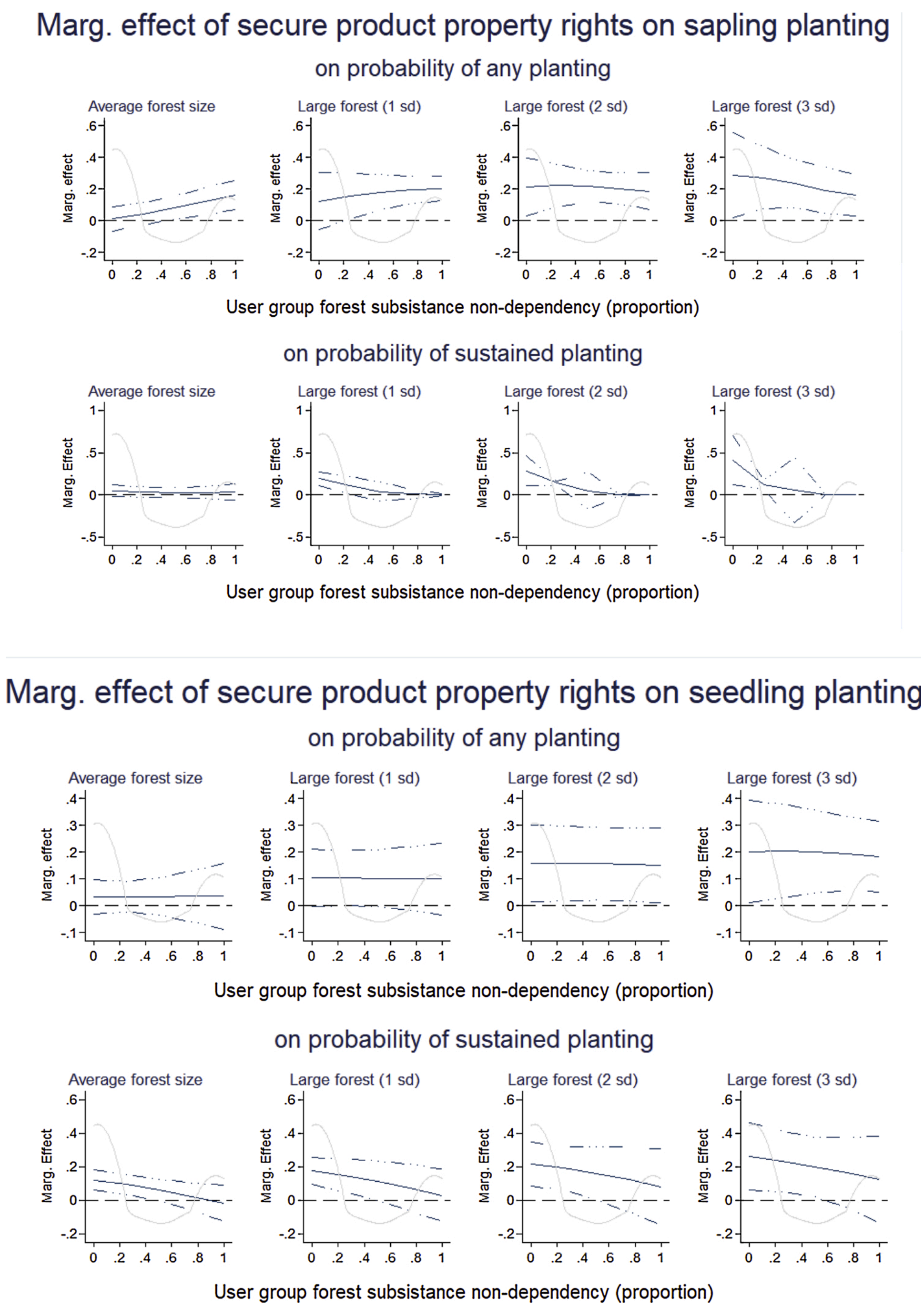

Fig. A2. Marginal effect of secure property rights on the probability of any and sustained planting over user group subsistence non-dependency, at various forest sizes, using main models (Table 2 Models 2, 4, 6 and 8). All other explanatory variables are held at their sample means. Includes the kernel density plot of subsistence non-dependency.

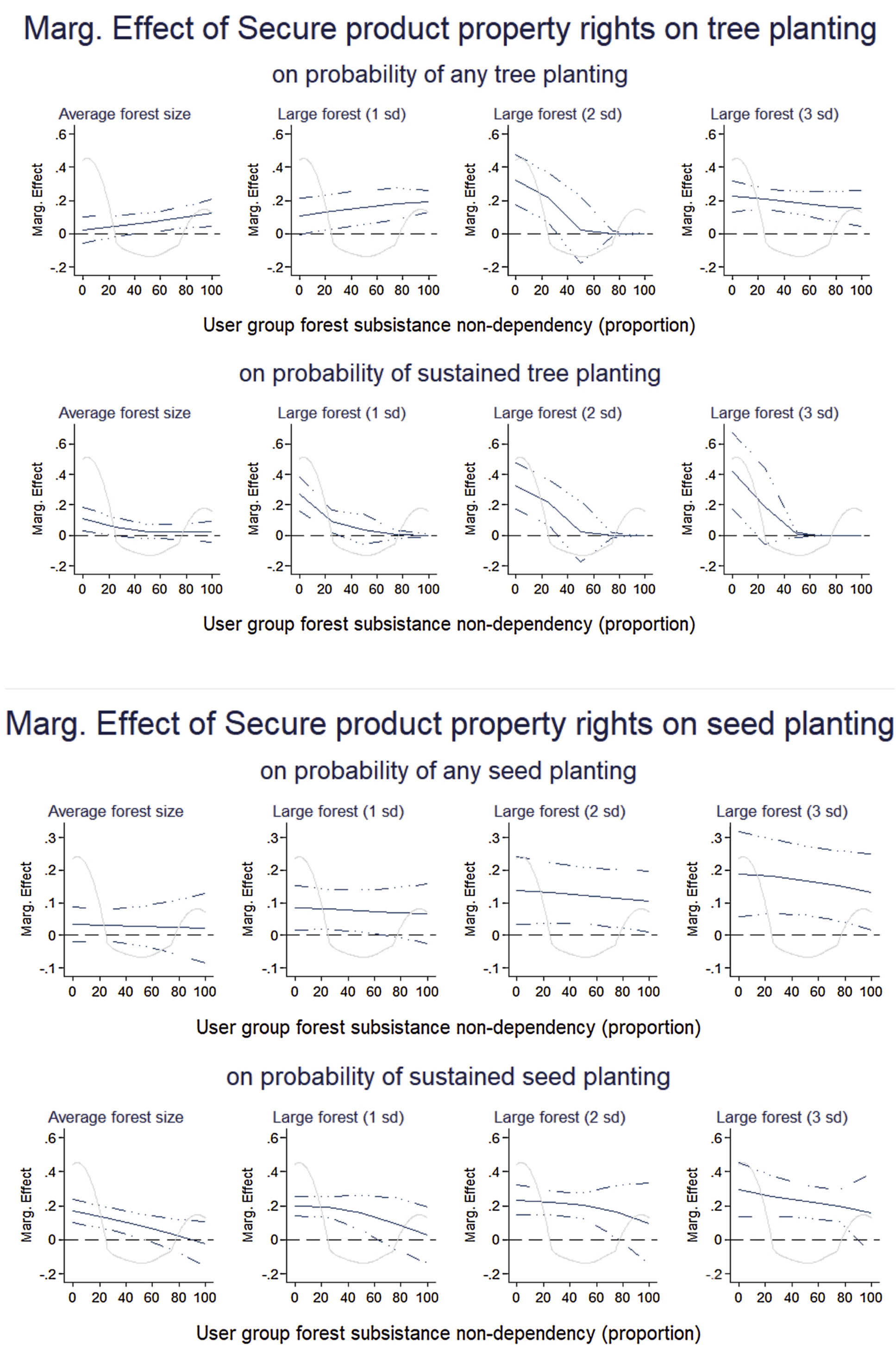

Fig. A3. Marginal effect of secure property rights on probability of any tree planting over user group subsistence non-dependency, at various forest sizes, using country fixed-effects models and clustered standard errors by user group. All other explanatory variables are held at their sample means. See regression results for country fixed-effects models in Annex Table A5. Because of incalculable derivatives at certain forest sizes, for the marginal effect plots all explanatory variables except for *secured property rights* were re-scaled by multiplying each variable by 100, to allow for derivative calculation. Including the kernel density plot of subsistence non-dependency.

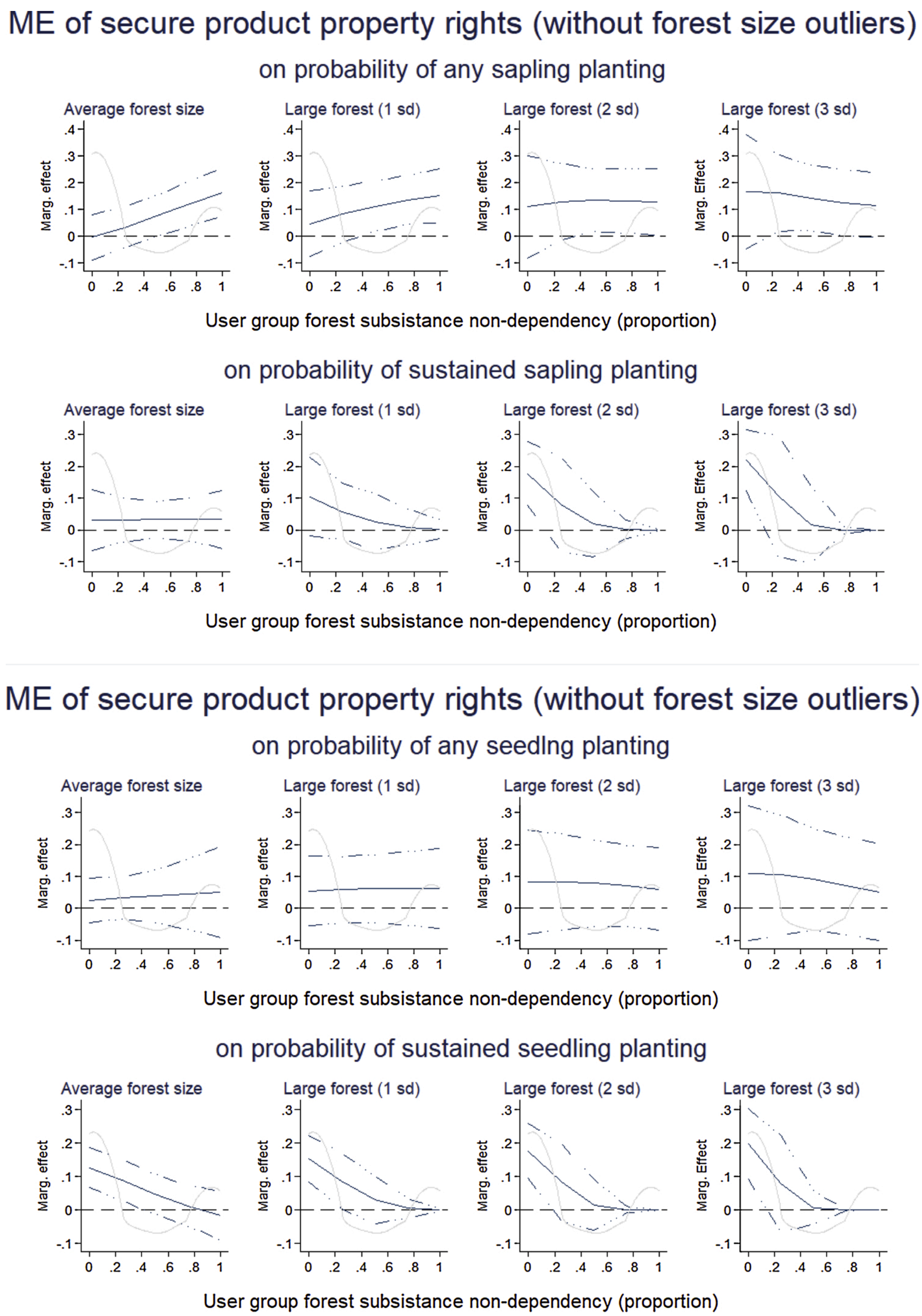

Fig. A4. Marginal effects of secure property rights on the probability of any and sustained planting over user group subsistence non-dependency, at various forest sizes, using main models (Table 2 Models 2, 4, 6 and 8) excluding observations with forest size outliers (larger than two standard deviation). All other explanatory variables are held at their sample means. Includes the kernel density plot of subsistence non-dependency.

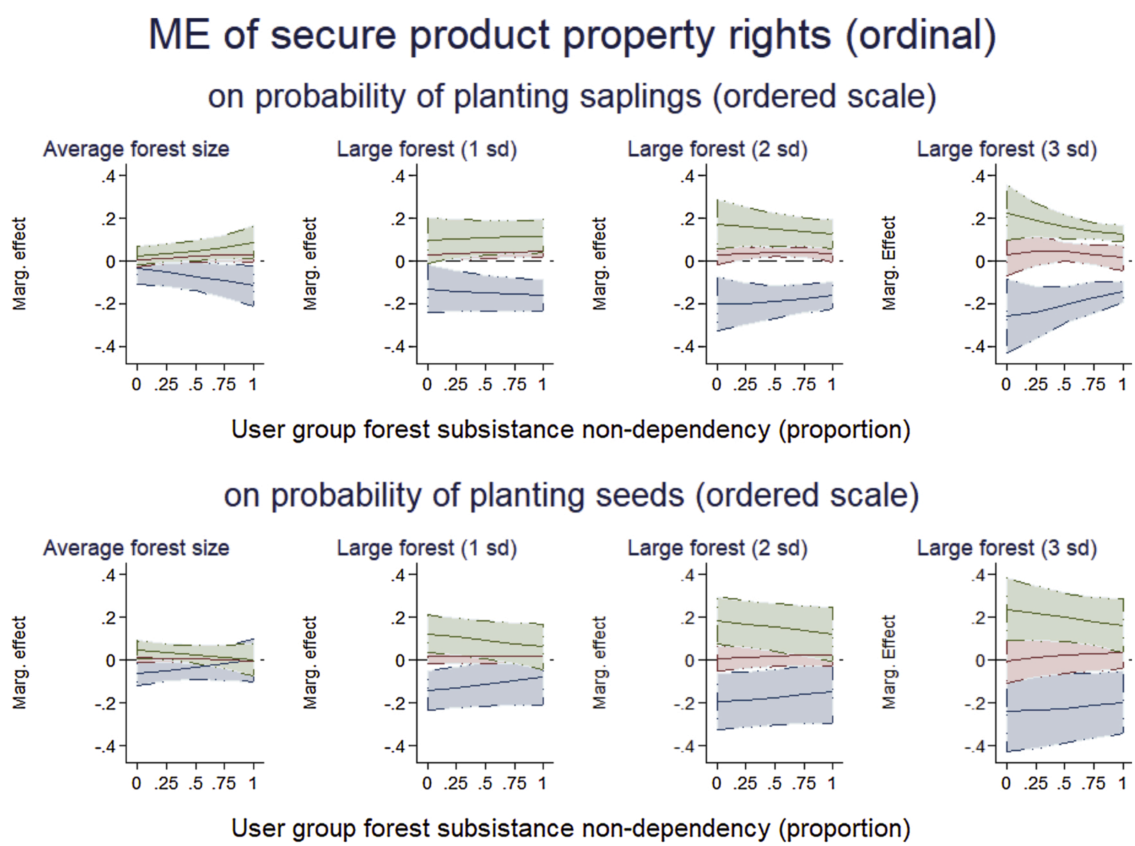

Fig. A5. Marginal effects of secure property rights on the probability of sapling and seedling planting over user group subsistence non-dependency, at various forest sizes, using ordered logistic models (Table A7 Models 1 and 2). All other explanatory variables are held at mean. Including the kernel density plot of subsistence non-dependency. Ordered dependent variable: 0-no planting, 1-occasional planting, 2-repeated planting.

Table A1
Summary statistics of dependent and explanatory variables. The sample differs between models due to differences in missing observations.

	mean	sd	min	max	count
Dependent variables (seedling planting)					
Any seedling planting	0.35	0.48	0.00	1.00	208
Sustained seedling planting	0.17	0.38	0.00	1.00	208
Biophysical contexts					
Forest size	26.70	63.34	0.01	400.00	208
Forest commercial value	0.66	0.94	−2.00	2.00	208
Social contexts					
Sacred value for forest	0.22	0.42	0.00	1.00	208
Commercial dependency	0.30	0.40	0.00	1.00	208
Subsistence non-dependency	0.28	0.40	0.00	1.00	208
Social homogeneity (max)	0.57	0.25	0.16	1.00	208
Wealth equality	0.61	0.49	0.00	1.00	208
Institutional contexts					
Secure property rights	0.82	1.14	0.00	3.00	208
Controls					
External planting governance support	0.92	0.98	0.00	4.00	208
External planting operational support	0.67	0.77	0.00	3.00	208
Dependent variables (sapling planting)					
Any sapling planting	0.23	0.42	0.00	1.00	208
Sustained sapling planting	0.13	0.33	0.00	1.00	208
Biophysical contexts					
Forest size	26.74	63.33	0.01	400.00	208
Forest commercial value	0.66	0.95	−2.00	2.00	208
Social contexts					
Sacred value for forest	0.22	0.41	0.00	1.00	208
Commercial dependency	0.30	0.40	0.00	1.00	208
Subsistence non-dependency	0.29	0.40	0.00	1.00	208
Social homogeneity (max)	0.57	0.25	0.16	1.00	208
Wealth equality	0.62	0.49	0.00	1.00	208
Institutional contexts					
Secure property rights	0.83	1.15	0.00	3.00	208
Controls					
External planting governance support	0.93	0.98	0.00	4.00	208
External planting operational support	0.68	0.77	0.00	3.00	208

Table A2
Questionnaire items used for all variables.

Variable	Operationalization
Any seedling planting	Have individuals in this user group undertaken any of the following management or regeneration activities, and if so, how frequently? Planted seedlings? Planted trees?
Any sapling planting	(0) Never done; (1) Rarely done; Done about every ten years; Done about every five years; Done every several years; or Done once a year
Sustained seedling planting	Have individuals in this user group undertaken any of the following management or regeneration activities, and if so, how frequently? Planted seedlings? Planted trees?
Sustained sapling planting	(0) Never done or Rarely done; (1) Done about every ten years; Done about every five years; Done every several years; or Done once a year
Forest size	What is the size of the forest? Please write the area in terms of hectares, or some local unit of area if area in hectares is not known. If you use a local unit, find out how many local units of area are equal to a hectare.
Forest commercial value	The commercial value of the forest is: (−2) Substantially above normal; (−1) Above normal; (0) Normal; (1) Below normal; (2) Substantially below normal
Sacred value for forest	What are the cultural views of the individuals in this user group about this forest? Most individuals see this forest as: (0) Economic resource; (1) Sacred or Both
Commercial dependency	How many individuals in this user group depend significantly on this forest for their family income arising from commercial activities? (Divided by the number of individuals in the user group)
Subsistence non-dependency	How many individuals in this user group depend significantly on this forest for their own subsistence? (Divided by the number of individuals in the user group)
Social homogeneity (max)	Name the [ethnic] or [religious] or [castes (or other social hierarchy that is specific to the country)] groups in the user group and the number of individuals within each group.
Wealth equality	Given the local definition of wealth, is there a great difference in wealth among households (as locally defined) in the user group? (0) No; (1) Yes
Secure property rights	What is the nature of the group's current legal claim to the harvest or use of this forest product? (0) De jure (by right, as established by law); De facto (as exists, not necessarily by legal establishment); or Contrary to formal law (1) De jure and de facto (they have a formal right and they are exercising it)
External planting governance support	Place check mark(s) in the column(s) representing the activity or activities that is/are undertaken and in the rows indicating the levels at which this organization
External planting operational support	operates. Planting/other maintenance. A1. Operational Activities. A2. Collective-Choice Activities. A3. Constitutional-Choice Activities

Table A3
Changing probabilities of observing planting activities as the values of the independent variables moves from its minimum to maximum.* Only statistically significant independent variables are included, excluding variables included in interaction terms. See Result 2 for the substantive significance of independent variables with interaction terms.

	Predicted probability at Min value	Predicted probability at Max value	Difference
DV: Sustained seedling planting			
External support in governance	0.14	0.63	0.49
DV: Any sapling planting			
Commercial dependency on forest	0.18	0.41	0.23
External support in governance	0.17	0.59	0.32
DV: Sustained sapling planting			
Commercial dependency on forest	0.07	0.29	0.22
External support in governance	0.07	0.51	0.44

*All other variables at mode for binomial or ordinal variables, at mean for continuous variables, and wealth inequality at 0.5.

Table A4
Predicted probabilities (95% Confidence intervals) of planting at weak, average and strong enabling contexts.

		Predicted probability	CI low	CI high
Any seedling planting	Weak enabling context	0.35	0.12	0.58
Any seedling planting	Average	0.4	0.19	0.60
Any seedling planting	Strong enabling context	0.52	0.12	0.92
Sustained seedling planting	Weak enabling context	0.08	−0.03	0.20
Sustained seedling planting	Average	0.21	0.04	0.38
Sustained seedling planting	Strong enabling context	0.31	−0.04	0.67
Any sapling planting	Weak enabling context	0.12	−0.01	0.23
Any sapling planting	Average	0.22	0.07	0.37
Any sapling planting	Strong enabling context	0.90	0.70	1.103
Sustained sapling planting	Weak enabling context	0.05	−0.01	0.11
Sustained sapling planting	Average	0.06	−0.03	0.15
Sustained sapling planting	Strong enabling context	0.46	0-0.02	0.93

Table A5
Logistic regression results of models with fixed-effects, with standard errors clustered by user group. Exponentiated coefficients. Observations in certain countries excluded due to perfect multicollinearity. * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

9.1 Robustness Checks				
	(1) Any seed planting	(2) Sustained seed planting	(3) Any sapling planting	(4) Sustained sapling planting
Biophysical contexts				
Forest size	1.01	1.01	1.00	1.02
	(0.01)	(0.01)	(0.01)	(0.01)
Forest commercial value	1.27	0.73	1.15	0.64
	(0.36)	(0.23)	(0.30)	(0.29)
Social contexts				
Sacred value for forest	1.57	2.74	3.34*	5.99
	(0.84)	(1.78)	(1.89)	(7.10)
Commercial dependency	1.54	7.68	6.58**	81.91**
	(1.34)	(9.25)	(4.70)	(135.48)
Subsistence non-dependency	1.75	15.76	2.39	51.83*
	(1.74)	(22.41)	(2.59)	(89.18)
Social homogeneity (max)	0.10*	0.54	1.53	4.48
	(0.10)	(0.74)	(1.64)	(10.73)
Wealth equality	0.74	0.87	0.75	1.79
	(0.45)	(0.63)	(0.43)	(1.48)
Institutional contexts				
Secure property rights	1.06	6.23**	0.87	2.49
	(0.27)	(3.56)	(0.62)	(2.73)
Interaction terms				
Secure property rights × Forest size	1.01*	1.01	1.01	1.03
	(0.00)	(0.01)	(0.01)	(0.02)
Secure property rights × Subsistence non-dependency	0.88	0.10**	2.89	0.57
	(0.46)	(0.08)	(2.38)	(0.69)
Forest size × Subsistence non-dependency	0.99	0.98	0.98*	0.74
	(0.01)	(0.01)	(0.01)	(0.12)
Controls				
External support in planting governance	1.63	4.06**	2.72*	7.46**
	(0.52)	(2.09)	(1.34)	(4.88)
External support in planting operation	0.87	0.37*	0.68	1.10
	(0.32)	(0.19)	(0.42)	(0.90)
Country intercepts				
Guatemala		351.45***	4.08	263.67*
		(624.63)	(6.48)	(608.55)
Indonesia	0.86	4.74	0.59	11.99
	(0.77)	(5.63)	(0.57)	(22.00)
Kenya	0.55	7.84	0.55	3.03
	(0.45)	(9.11)	(0.52)	(6.49)
Madagascar	0.17		3.29	2.51
	(0.25)		(3.44)	(4.88)
Nepal	2.60	0.43	0.04*	0.04*
	(2.28)	(0.58)	(0.05)	(0.05)
Tanzania	0.10	3.46		
	(0.18)	(6.56)		
Uganda	0.01***		0.04*	
	(0.02)		(0.06)	
N	200.00	133.00	201.00	144.00
AIC	192.09	129.39	154.54	83.45
BIC	258.05	184.30	220.61	139.88
Biophysical contexts				
Forest size	1.01	1.01	1.00	1.02
	(0.01)	(0.01)	(0.01)	(0.01)
Forest commercial value	1.27	0.73	1.15	0.64
	(0.37)	(0.24)	(0.25)	(0.32)

(continued on next page)

Table A5 (*continued*)

9.1 Robustness Checks

	(1) Any seed planting	(2) Sustained seed planting	(3) Any sapling planting	(4) Sustained sapling planting
Social contexts				
Sacred value for forest	1.57	2.74	3.34*	5.99
	(0.79)	(1.74)	(1.73)	(8.42)
Commercial dependency	1.54	7.68	6.58**	81.91
	(1.58)	(9.01)	(4.35)	(185.72)
Subsistence non-dependency	1.75	15.76**	2.39	51.83*
	(1.72)	(16.83)	(2.43)	(97.65)
Social homogeneity (max)	0.10*	0.54	1.53	4.48
	(0.11)	(0.72)	(1.66)	(9.18)
Wealth equality	0.74	0.87	0.75	1.79
	(0.52)	(0.70)	(0.59)	(1.56)
Institutional contexts				
Secure property rights	1.06	6.23**	0.87	2.49
	(0.24)	(3.70)	(0.70)	(2.39)
Interaction terms				
Secure property rights × Forest size	1.01*	1.01	1.01	1.03
	(0.00)	(0.01)	(0.01)	(0.02)
Secure property rights × Subsistence non-dependency	0.88	0.10***	2.89	0.57
	(0.50)	(0.06)	(2.74)	(0.57)
Forest size × Subsistence non-dependency	0.99	0.98*	0.98*	0.74
	(0.01)	(0.01)	(0.01)	(0.14)
Controls				
External support in planting governance	1.63*	4.06**	2.72*	7.46**
	(0.38)	(1.96)	(1.18)	(4.65)
External support in planting operation	0.87	0.37	0.68	1.10
	(0.32)	(0.19)	(0.42)	(0.85)
Country intercepts				
Guatemala		351.45***	4.08	263.67*
		(584.28)	(5.79)	(699.94)
Indonesia	0.86	4.74	0.59	11.99
	(0.78)	(5.11)	(0.45)	(21.46)
Kenya	0.55	7.84	0.55	3.03
	(0.47)	(10.22)	(0.43)	(6.50)
Madagascar	0.17	1.00	3.29	2.51
	(0.27)	(.)	(3.16)	(5.07)
Nepal	2.60	0.43	0.04*	0.04*
	(2.14)	(0.67)	(0.05)	(0.05)
Tanzania	0.10	3.46		
	(0.17)	(5.70)		
Uganda	0.01***		0.04*	
	(0.02)		(0.05)	
N	200.00	133.00	201.00	144.00
AIC	192.09	129.39	154.54	83.45
BIC	258.05	184.30	220.61	139.88

Table A6
Logistic regression results of main models with random effects, excluding observations with forest sizes more than two deviations from mean. Exponentiated coefficients. $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$).

	(1) Any seed planting	(2) Sustained seed planting	(3) Any sapling planting	(4) Sustained sapling planting
Biophysical contexts				
Forest size	1.00	1.01	1.01	1.01
	(0.01)	(0.01)	(0.01)	(0.01)
Forest commercial value	1.27	0.69	1.15	0.73
	(0.30)	(0.24)	(0.32)	(0.35)
Social contexts				
Sacred value for forest	1.37	2.80	2.97	3.42
	(0.69)	(1.87)	(1.68)	(3.27)
Commercial dependency	1.01	4.21	5.59*	30.47*
	(0.72)	(4.29)	(3.85)	(42.01)
Subsistence non-dependency	1.71	22.37*	3.09	20.84
	(1.35)	(30.80)	(2.86)	(36.68)
Social homogeneity (max)	0.19	0.74	4.23	6.91
	(0.18)	(0.94)	(4.76)	(13.28)
Wealth equality	0.74	0.93	0.80	1.42
	(0.35)	(0.63)	(0.43)	(1.20)
Institutional context				
Secure property rights	1.08	4.68**	0.77	1.16
	(0.27)	(2.73)	(0.37)	(1.13)
Interaction terms				
Secure property rights × Forest size	1.01	1.01	1.02	1.03
	(0.01)	(0.01)	(0.01)	(0.02)
Secure property rights × Subsistence non-dependency	1.19	0.13*	3.65*	1.29
	(0.66)	(0.11)	(2.36)	(1.60)
Forest size × Subsistence non-dependency	0.96	0.83	0.94	0.77
	(0.04)	(0.12)	(0.04)	(0.15)
Controls				
External support in planting governance	1.70	3.16*	2.09*	4.19*
	(0.54)	(1.48)	(0.77)	(2.63)
External support in planting operation	0.89	0.58	0.75	1.08
	(0.30)	(0.30)	(0.33)	(0.75)
N	201.00	201.00	201.00	201.00
AIC	205.03	142.39	165.02	97.44
BIC	254.58	191.94	214.57	146.99

Table A7

Ordered logistic regression models with random effects and ordered dependent variables (0-no planting, 1-occasional planting, 2-repeated planting). Exponentiated coefficients. $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$).

	(1) Level of seedling planting	(2) Level of sapling planting
Biophysical contexts		
Forest size	1.01	1.01
	(0.01)	(0.01)
Forest commercial value	1.18	1.00
	(0.25)	(0.28)
Social contexts		
Sacred value for forest	1.71	2.78
	(0.79)	(1.51)
Commercial dependency	1.70	8.24**
	(1.18)	(5.75)
Subsistence non-dependency	2.16	3.25
	(1.63)	(2.95)
Social homogeneity (max)	0.16*	2.78
	(0.14)	(2.99)
Wealth equality	0.86	0.97
	(0.38)	(0.50)
Institutional context		
Secure property rights	1.32	1.03
	(0.27)	(0.45)
Interaction terms		
Secure property rights x Forest size	1.01	1.01
	(0.01)	(0.01)
Secure property rights × Subsistence non-dependency	0.61	1.96
	(0.27)	(1.09)
Forest size × Subsistence non-dependency	0.99	0.97**
	(0.01)	(0.01)
Controls		
External support in planting governance	1.85*	3.05**
	(0.51)	(1.16)
External support in planting operations	0.79	0.62
	(0.22)	(0.27)
N	208.00	208.00
AIC	295.00	216.63
BIC	348.40	270.03

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