Titling indigenous communities protects forests in the Peruvian Amazon

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Developing countries are increasingly decentralizing forest governance by granting indigenous groups and other local communities formal legal title to land. However, the effects of titling on forest cover are unclear. Rigorous analyses of titling campaigns are rare, and related theoretical and empirical research suggests that they could either stem or spur forest damage. We analyze such a campaign in the Peruvian Amazon, where more than 1,200 indigenous communities comprising some 11 million ha have been titled since the mid-1970s. We use community-level longitudinal data derived from high-resolution satellite images to estimate the effect of titling between 2002 and 2005 on contemporaneous forest clearing and disturbance. Our results indicate that titling reduces clearing by more than three-quarters and forest disturbance by roughly two-thirds in a 2-y window spanning the year title is awarded and the year afterward. These results suggest that awarding formal land titles to local communities can advance forest conservation.

tenure reform | decentralization | deforestation | degradation | REDD

Over the last three decades, dozens of developing countries have decentralized forest governance, a phenomenon driven by fiscal and administrative constraints, local community demands for participation, and external pressure from donors (1–3). By one estimate, almost a third of all developing country forests are now managed by local communities, well over twice the share currently found in protected areas (1, 4). Granting indigenous groups and other local communities formal legal title to forests is a leading mechanism being used to implement decentralization, particularly in Latin America (5, 6). For example, by the end of 2000, Latin American and Caribbean countries had awarded local communities formal title to at least 100 million ha of forest (7).

Even as forest tenure reform has gained momentum, however, forest clearing and degradation in developing countries have persisted (8, 9). According to the United Nations Food and Agriculture Organization, the overall rate of deforestation in these countries remains "alarmingly high." For example, in both Latin America and Africa, deforestation averaged one-half of 1% per year in the first decade of the 21st century, five times the global rate (9). Forest clearing and degradation have contributed to a host of global and local environmental problems, including climate change, biodiversity loss, soil erosion, and flooding (8, 10–12).

Given these two concurrent trends, it is important to understand the effect of community titling on forest cover change in developing countries. Previous theoretical and empirical research suggests that it can either stem or spur forest damage. [This paragraph and the next draw from the publication by Blackman et al. (13).] It has long been known that ill-defined property rights can, in principle, create incentives for agents to overexploit natural resources (14, 15). Research focusing specifically on tropical forests has shown that weak property rights can spur forest damage in a variety of ways: by enabling landless migrants to colonize frontier areas (16, 17), by strengthening land managers' preferences for productive activities that provide quick but unsustainable returns (18, 19), by creating incentives for squatters to clear forests to establish use rights or block competing claims (20, 21), and by preventing land managers from participating in payments for environmental services and reducing emissions from deforestation and degradation initiatives (22, 23). In principle, granting title to indigenous communities could mitigate each of these problems.

Previous research also suggests that titling can increase forest cover change, however. Giving title to entire communities instead of individual households can recreate common-pool resource problems on a local level, which the communities may or may not be willing and able to address (24, 25). Community forest management can be undermined or co-opted by powerful private and public sector actors (26–28). Finally, by improving communities' access to credit and extending their planning horizons, titling can raise the returns on agriculture relative to forests, thereby encouraging extensification (29, 30).

Hence, the net effect on forest clearing and degradation of granting title to communities is an empirical matter. However, as discussed in the next section, we know little about it. Although numerous studies have examined the effect of preexisting tenure type on forest cover change, rigorous studies of the effect of titling initiatives that change the tenure status of indigenous communities are rare. The latter studies are more relevant to policy decisions about future titling and are better positioned to disentangle tenure's effect from the effect of confounding factors.

We analyze the effect of granting title to indigenous communities on forest cover change in the Peruvian Amazon. One of

Significance

Developing countries are increasingly granting local communities legal title to forests. Almost a third of forests in the global south are now managed by local communities, more than twice the share currently found in protected areas. However, we know little about the effects of titling on forest clearing and disturbance, which remain urgent problems. We use community-level longitudinal data derived from high-resolution satellite images, along with statistical techniques that control for confounding factors, to measure the effect of titling indigenous communities in the Peruvian Amazon. Results indicate that titling significantly reduces both clearing and disturbance, at least in the short term. The implication is that awarding formal land titles to local communities can protect forests.

SUSTAINABILITY SCIENCE

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the world's largest remaining contiguous primary forests, the Peruvian Amazon is increasingly threatened by forest clearing and degradation. Titling there has been extensive: More than 1,200 indigenous communities accounting for more than 11 million ha received title between 1975 and 2008 (31). We focus on the effect of titling from 2002 to 2005 on forest cover change from 2000 to 2005. *Supporting Information* provides additional background on our study area, including forest cover change and governance, indigenous communities, and the titling process. To identify the effect of titling on forest cover change, we use high-resolution remotely sensed data on both forest clearing and forest disturbance, along with statistical techniques that aim to control for confounding factors (32).

Evidence Base

More than 100 published papers explore the relationship between preexisting tenure security and/or tenure type on the one hand and forest cover on the other (20, 21, 33–35). Two recent meta-analyses conclude that, in general, preexisting tenure security is associated with lower rates of forest cover change regardless of the form of tenure (36, 37).

Although these studies are valuable, they do not directly address the policy questions with which we are concerned: Does changing land tenure affect forest cover? If so, how? Studies of policies and programs that have changed land tenure are likely to provide more informative answers to those questions. One reason is that they are better positioned to disentangle tenure's effects from the effects of confounding factors. As one of the meta-analyses cited above makes clear, preexisting tenure type is often correlated with unobservable confounding factors because the historical processes that assign tenure types typically are not random (37). For example, in many Latin American countries, over hundreds of years, powerful private landowners acquired the forestlands that would be most productive when converted to agriculture (e.g., because they were most accessible or had the most fertile soil), leaving other forest lands for peasant communities and the state. In such countries, tenure type is strongly correlated with confounding factors. Unfortunately, studies of the effect of preexisting tenure on forest cover generally do not try to control for these factors. The meta-analysis noted above examined 150 peer-reviewed publications and found only 36 studies that attempted to control for confounding factors and only two studies (other than of protected areas) that used quasi-experimental methods for that purpose (37). Controlling for confounding factors is more straightforward when tenure has changed relatively recently as a result of a titling initiative. In such cases, it is easier to observe, and design an empirical strategy to control for, the treatment assignment process.

To our knowledge, only two published studies use quasi-experimental methods to evaluate the effects of changes in land tenure on forest cover: the studies by Buntaine et al. (38) and Liscow (29). However, neither focuses on the effects of a national-level campaign aimed at indigenous communities. Buntaine et al. (38) use satellite data, along with matched difference-in-difference models, to measure the effect on forest loss of an initiative that titled indigenous communities in a single province of Ecuador (Morona-Santiago) during the early 2000s. They find no evidence that titling reduced forest loss in the 5 y after title was awarded. Liscow (29) exploits a natural experiment, the massive land reform associated with the Sandinista revolution, to identify the effects of changes in tenure security on forest cover in Nicaragua. Using landholder-level cross-sectional data, along with instrumental variables models, he finds that all other things being equal, properties with relatively secure title, including properties held by individuals, cooperatives, and indigenous communities, had less forest cover per hectare than properties without such title. He hypothesizes that this correlation reflects the effect of tenure security on credit access, agricultural productivity, and, ultimately, the return to deforestation. However, the study does not focus exclusively on indigenous communities. *SI Comparison with Previous Evaluations* discusses possible reasons for differences between our results and the results of Buntaine et al. (38) and Liscow (29).

In addition to studies of the effects of preexisting tenure on forest cover, two other strands of literature are relevant. One examines the effect of community forestry on a range of social and environmental outcomes (e.g., refs. 39–41). Meta-analyses of this literature suggest that generalizing about such effects on the basis of these studies is risky, given that some have methodological limitations and that idiosyncratic factors tend to be important (42, 43).

The other strand of related literature focuses on titling properties held by individuals (versus communities) in Peru. As discussed below in *SI Background*, Peruvian government campaigns aimed at titling indigenous communities fit into larger contemporaneous efforts to title all manner of rural and urban properties with insecure informal land rights. Although, to our knowledge, no studies have examined the effects of such titling on forest cover, several aim to identify socioeconomic effects. The findings are mixed. For example, Field (44) and Fort (45) find that in urban areas, titling led to an increase in labor supply outside the home, and that in rural areas, it increased on-farm investment. However, Zegarra et al. (46) find that rural titling had few positive effects.

Empirical Approach

To identify the effect of titling on forest cover change, we use indigenous community-level longitudinal data. The principal challenge we face is the usual one in program evaluation: The treatment, titling in our case, was not randomly assigned. As a result, it could be spatially and/or temporally correlated with observed and unobserved confounding factors that affect the outcome, forest cover change in our case. For example, in principle, titling could be correlated across space with proximity to rivers used for transporting logs, a time-invariant community characteristic that likely spurs forest cover change. In addition, in principle, titling could be correlated over time with changes in national timber prices, which, in turn, affect forest cover change. Unless we control for them, such confounding factors can bias our treatment effect estimates.

To that end, we rely on fixed effects, along with a set of control variables that vary both over time and across space. We estimate

$$Y_{nit} = \gamma_i + \delta_t + D^{'}_{it\text{-}z}\beta_{n1} + X^{'}_{it\text{-}z}\beta_{n2} + \varepsilon_{nit} \quad (n = 1,2,3), \qquad [1]$$

where n indexes the type of forest cover change (clearing, disturbance, or both), i indexes communities, t indexes years, z indexes temporal lags, Y is the percentage of the community's forest changed, γ are community-fixed effects, δ are year-fixed effects, D is a vector of contemporaneous and lagged dichotomous dummy variables indicating titling, X is a vector of time-varying control variables, β_1 and β_2 are vectors of parameters to be estimated, and ε is an error term. The parameters in β_1 measure titling's effect on forest cover change. The community-fixed effects control for observed and unobserved time-invariant community heterogeneity, and the year-fixed effects control for observed and unobserved location-invariant temporal effects. We omit the time-invariant control variables like travel time to population centers because they are perfectly correlated with the community-fixed effects. We estimate Eq. **1** using ordinary least squares and cluster SEs at the community level.

A potential concern is that our treatment effect estimates may be biased by unobserved time-varying confounding factors (i.e., factors correlated temporally and spatially with both titling and forest cover change) for which our fixed effects models would not control. However, we believe such factors are unlikely to drive our results for at least two reasons. First, as discussed in *SI Robustness Checks*, lagged dependent variable models that control for at least some time-varying confounding factors generate results that are quite similar to the results from our main models (Table S1).

Second, the location and timing of titling in our study area and period were largely determined by plausibly exogenous factors. Because titling is costly and complex, few if any indigenous communities have undertaken it independently. Rather, the vast majority of titles have been awarded via large-scale titling campaigns led by government agencies and nongovernmental organizations (NGOs). Because almost all communities are situated along rivers, which are the main transportation arteries in the region, each titling campaign started at one end of a watershed and swept toward the other. Much of the funding for these campaigns was obtained from external sources and was allocated piecemeal over time. As a result, multiple campaigns were conducted over the course of several decades. For a variety of reasons, including a border dispute with Ecuador and expanded oil exploration, many of the early titling campaigns were in the northern part of our study area.

We find no evidence in our data of a correlation between the location of titling campaigns and contemporaneous rates of forest cover change (i.e., nonrandom treatment assignment) that could, in principle, confound our efforts to identify the effect of titling on forest cover change. To address that concern, we created a region-level (regions are first-level administrative units in Peru) 2000–2005 panel dataset and then regressed the number of titles awarded to indigenous communities in each region onto the average rates of forest cover change in each region. We fit separate regressions for deforestation, disturbance, and deforestation or disturbance. In all of these regressions, we are unable to reject the null hypothesis that titling is not correlated with forest cover change. These results are robust to inclusion of region- and year-fixed effects and to the clustering of SEs at the region level (Table S2).

In addition to estimating average treatment effects (Eq. **1**), we use interaction effects to examine potential treatment effect heterogeneity across community type (i.e., to test whether community characteristics moderate the effect of titling on forest cover change). This analysis is limited by a lack of comprehensive baseline (pretreatment) data on community characteristics, and is therefore speculative. The goal is to generate hypotheses that can be tested in future research. For simplicity's sake, we add interaction effects to a model that uses the percentage of the community's forest either cleared or disturbed as a dependent variable and features a single cumulative 1-y lagged titling dummy variable. We interact this titling dummy variable with three time-invariant community characteristic variables: *area*, the size of the community in hectares; *distance to city*, the distance in kilometers to the nearest population center with more than 10,000 residents; and *Pucallpa*, a binary indicator of whether the community is in the region (Ucayali) hosting the city that is the hub of both the logging industry and regulatory monitoring and enforcement in the Peruvian Amazon (Table S3). The choice of these variables was dictated more by data availability than by theory. We estimate

$$Y_{it} = \gamma_i + \delta_t + D'_{it\text{-}z}\beta_1 + D'_{it\text{-}z}C_m\beta_2 + X'_{it\text{-}z}\beta_3 + \varepsilon_{it}, \qquad [2]$$

where C is a vector of community characteristic variables and m is an index of these variables. As a robustness check, we also estimate three separate regressions, each with a single interaction term. To control for multiple hypothesis testing, we adjust probability values on the interaction term coefficients to maintain a constant family-wise type 1 error rate (47).

Data

We created the dataset used in the empirical analysis by compiling indigenous community-level longitudinal data on forest clearing and disturbance (our outcome variables), titling (our treatment variable), and climatological and agronomic drivers of forest cover change (our control variables) for a 750,000-ha study area (Fig. 1 and Table S4). Based on Landsat satellite images, our forest cover change data measure forest clearing and disturbance at a resolution of 30 m × 30 m each year from 2000 to 2005 (a detailed description of these data is provided in ref. 48). Our titling data are derived from records maintained by the Instituto de Bien Común (IBC), one of Peru's leading indigenous community NGOs (31, 49). [For each community, we derive the date title was awarded as reported by the IBC (31) and geolocator information as reported by the IBC-World Resources Institute (WRI) (49). An early version of this paper incorrectly used the date recorded by the IBC-WRI (49), which marks data entry or release, as the date title was awarded, and therefore generated qualitatively different results.] As for our control variables, we use 2000–2005 temperature and precipitation data derived from Moderate Resolution Imaging Spectroradiometer (MODIS) and Tropical Rainfall Measuring Mission (TRMM) satellite products and crop price data derived from district-level agricultural statistics. *SI Variables* details the variables used in our regression analysis. Our regression sample comprises communities in the IBC database that received title during the period spanned by our forest cover change data: specifically, all 51 communities that received title after 2001 (Table S5). A scarcity of pre-2000 satellite data on forest cover change, along with our fixed effects empirical design, limits our ability to include communities titled earlier.*

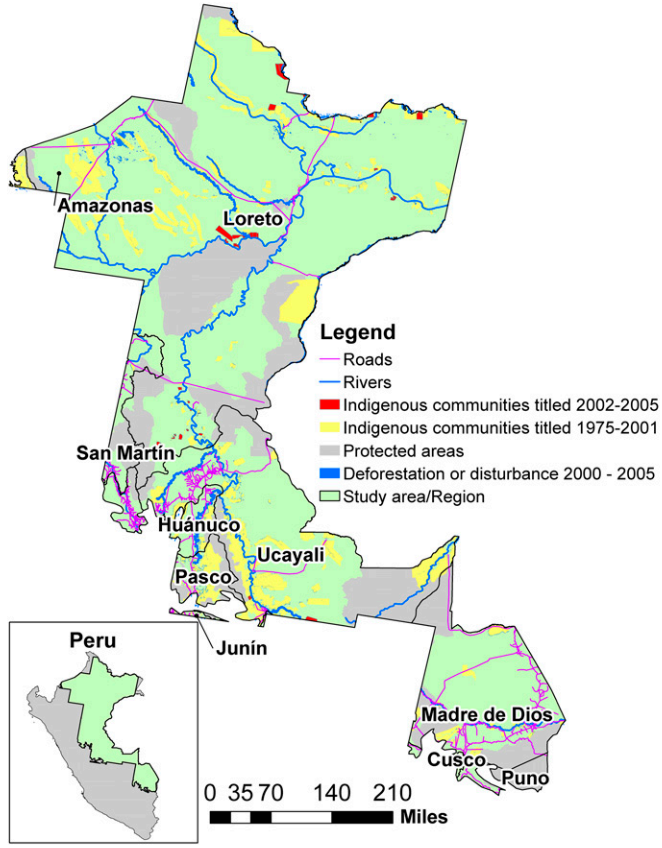

Fig. 1. Study area.

*Prior to 2000, Landsat data needed to generate fine-scale annual maps of forest loss and disturbance are sporadic. As a result, our forest cover change panel begins in 2000. Our fixed effects design requires that for every community in our regression sample, we have at least 1 y of pretitle data on forest cover change. That requirement (along with our inclusion of a 1-y lagged titling dummy variable) implies that we can estimate treatment effects only for communities titled after 2001.

Model Specification

Unlike most land cover change data, ours measure both forest clearing and disturbance and distinguish between them. To exploit that feature, we present results using three dependent variables: *cleared* (clearing in year *t*), *disturbed* (disturbance in year *t*), and *forest cover change* (either clearing or disturbance in year *t*).

We specify our fixed effects models to examine the effect of titling on forest cover change in a 2-y window spanning the year title is awarded and the year afterward. Our relatively short 6-y forest cover change panel limits our ability to estimate longer lived effects. Our main models include two single-year titling dummy variables (*title_0, title_1*) in one specification (A) and a 1-y cumulative lag variable (*title_1c*) in a second specification (B). Estimated coefficients for our treatment variables have straightforward interpretations. For specification A, the coefficient on *title_0* can be interpreted as the marginal effect of titling on the percentage of forest cover change in an average indigenous community in the year title is awarded, and the coefficient on *title_1* can be interpreted as the marginal effect in the first year afterward. For specification B, the coefficient on *title_1c* can be interpreted as the average marginal effect over our 2-y study window.

Results

Main Results. Estimates of Eq. **1** indicate that titling has a statistically and economically significant negative effect on forest cover change within our 2-y study window (Fig. 2 and Table S6). In model 1A, which uses *forest cover change* as the dependent variable and includes single-year titling dummy variables, *title_0* and *title_1* are negative and statistically significant at the 1% and 10% levels, respectively. The implication is that titling reduces forest cover change in the year title is awarded and in the following year. These effects are economically significant. Expressed as percentage reductions from the counterfactual average annual rate of forest cover change of 0.37 percentage points per year (the value of forest cover change predicted by our model when treatment variables are set equal to zero), they imply that titling reduces the percentage of the community deforested or disturbed by 81% in the year in which titling occurs and by 56% in the first year afterward. Although we are unable to reject the null hypothesis that coefficients on *title_0* and *title_1* are the same, these results hint that the effect of titling attenuates over time. Model 1B indicates that the average annual effect over both years is substantial: a 71% reduction.

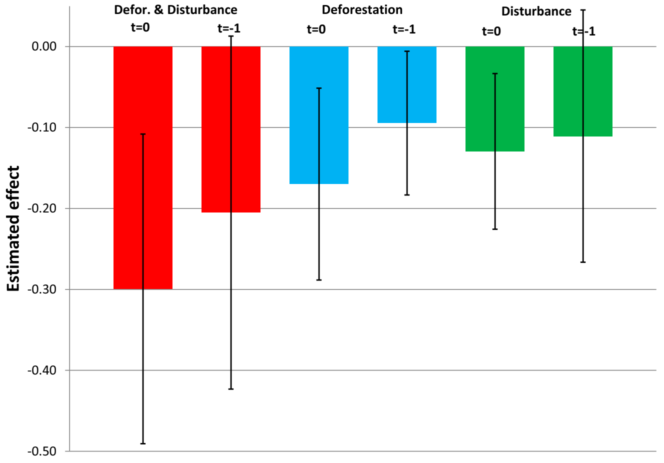

Fig. 2. Titling reduces deforestation and/or disturbance in the year of award and the year after; estimated coefficients on titling variables (models 1A, 2A, and 3A) and 95% confidence intervals.

In model 2A, which uses *clearing* as the dependent variable and includes single-year titling dummy variables, *title_0* and *title_1* are negative and statistically significant at the 1% and 5% levels, respectively. These results imply that titling reduces the percentage of the community deforested by 97% in the year in which titling occurs and by 54% in the first year afterward. In this case, we are able to reject at the 5% level the null hypothesis that coefficients on *title_0* and *title_1* are the same. Model 1B indicates that, on average, titling reduces deforestation by 80% per year during our 2-y study window.

In model 3A, which uses *disturbance* as the dependent variable and includes single-year titling dummy variables, *title_0* is negative and statistically significant at the 1% level and *title_1* is insignificant. Again, this result is economically significant. It implies that titling reduces the percentage of the community disturbed by 67% in the year title is awarded.

Robustness Checks. As detailed in *SI Robustness Checks*, to check the robustness of our results, we estimate models that include lagged dependent and lead treatment variables and that control for spillover. Overall, the results suggest that our results are, in fact, robust (Tables S1, S7, and S8).

Community Characteristics. Turning to our analysis of treatment effect heterogeneity across community type, a Wald test rejects at the 1% level the null hypothesis that coefficients on the three interaction terms included in Eq. **2** are jointly equal to zero. All three coefficients are statistically significant (Table S3, model 14). However, in specifications that include interaction terms one at a time, only *area* and *distance to city* are statistically significant, implying that *Pucallpa* only affects forest cover change conditional on the other two community-level characteristics (Table S3, models 15–17). The signs of *area* and *distance to city* indicate that the negative association between titling and forest cover change is more pronounced in communities that are smaller and communities that are closer to population centers. These effects are economically meaningful. The estimated coefficients in Table S3 (model 14) imply that a 100-ha reduction in the size of an indigenous community reduces forest cover change in the 2-y window spanning the year title is awarded and the year afterward by 1.2 percentage points, and that a 100-km reduction in the distance from the community to the nearest sizable population center reduces it by 0.4 percentage points. We discuss the implications of these findings in the next section.

Discussion and Hypotheses

To identify the effect of land titling on forest cover change in the Peruvian Amazon, we use fine-scale community-level longitudinal data on forest clearing and disturbance, along with fixed effects models that aim to control for confounding factors. We find that, on average, titling reduces forest clearing by more than three-quarters and forest disturbance by roughly two-thirds in a 2-y window spanning the year title is awarded and the year afterward. A preliminary analysis of treatment effect heterogeneity suggests that these effects may be more pronounced in communities that are smaller and closer to sizable population centers. As discussed in *SI Comparison with Previous Evaluations*, our results differ from the results of other published quasi-experimental studies that examine the effect on forest cover of changes in land tenure. These differences may be due to a variety of contextual and methodological factors.

Our analysis of the effect of titling on forest cover change in the Peruvian Amazon has several limitations. First, our 2000–2005 annual data on forest cover change span only 6 y of the 40-y period during which indigenous communities have been receiving land titling. A longer panel that covered the 1990s, when almost half of the titling in our study region occurred, would be preferable. Unfortunately, however, the Landsat data needed to generate annual maps of forest loss and disturbance are sporadic for the years before 2000. Second, without a valid instrument or discontinuity, we are not able to control fully for time-varying confounding factors. Third, we lack comprehensive baseline (pretreatment) data on community characteristics that would allow us to draw firm conclusions about treatment effect heterogeneity. Finally, our analysis does not identify the causal mechanisms that drive the negative correlation between titling and forest cover change. Pinpointing causal mechanisms is beyond the scope of our paper, and thus a focus of future research.

Toward that end, we conjecture about these mechanisms. We emphasize that this discussion, like our analysis of treatment effect heterogeneity, is speculative and aimed at generating hypotheses for future study. Although, as discussed below, the temporal pattern of our results provides some hints, we have no hard evidence to support our hypotheses. To underpin this discussion, we develop a theory of change (detailed in *SI Theory of Change* and Fig. S1) that reflects findings from the empirical and theoretical literature (summarized above); the historical and institutional context of titling indigenous communities in Peru (summarized in *SI Background*); and discussions with regulatory agencies, NGOs, and funders of titling of indigenous communities in Peru. It describes six possible mechanisms by which titling could reduce forest cover change in an indigenous community: (*i*) ratcheting up formal regulatory pressure applied by regulatory agencies and other state entities, (*ii*) strengthening informal regulatory pressure exerted by nonstate entities such as NGOs, (*iii*) improving the community's internal forest cover change governance, (*iv*) boosting the community's interactions with public sector entities such as government technical extension and educational programs, (*v*) augmenting the community's interactions with private sector entities such as creditors and input providers, and (*vi*) improving community livelihoods.

We hypothesize that two of those mechanisms, enhanced formal regulatory pressure and enhanced informal regulatory pressure, drove our findings. The main reasons concern the temporal pattern of our results. We find that titling has an effect instantaneously (i.e., in the year it occurs). In addition, as discussed above, our results suggest that this effect attenuates over time. Formal and informal regulatory pressure could have effects that fit this temporal pattern: They could be ratcheted up in the year title is awarded but could quickly dissipate afterward because of limited human and political resources. Three other potential causal mechanisms described in our theory of change seem less likely to have instantaneous, short-lived effects. Any effects that titling has by boosting the community's public sector interactions, augmenting its private sector interactions, or improving livelihoods would likely occur with a lag: It takes time for community members to enroll in public sector programs, contract with banks and input suppliers, and improve their livelihoods enough to affect forest cover change. Finally, enhancing internal community governance would likely have effects that persist beyond a single year. The hypothesis that titling reduces forest cover change soon after title is awarded by ratcheting up formal and informal regulatory pressure is consistent with our (admittedly speculative) findings that the communities where titling has a more pronounced effect tend to be smaller and closer to sizable population centers. It is plausible that in small communities close to centers of regulatory activity, the costs of monitoring by regulatory agencies, NGOs, and other stakeholders are relatively low.

Here, we have shown that titling indigenous communities in the lowland Peruvian Amazon basin reduces forest clearing and disturbance soon after title is awarded, and we have hypothesized that it does so by ratcheting up formal and informal regulatory pressure. This study is among the first spatially explicit analyses of its kind, and the findings strongly support the notion that awarding land title to indigenous and/or local communities can, at least in the short term, help protect forests. The cascading effects include biodiversity protection, carbon sequestration, water resource provisioning, and a host of other ecosystem services considered vital at local to global ecological scales.

Future research can build on this study in at least two ways. Field research combining qualitative and quantitative survey-based methods is needed both to identify the causal mechanisms driving the effects of titling on forest cover change that we have described and to understand better how these effects are moderated by community characteristics. In addition, remote sensing studies like ours can be applied to other countries, and over longer time periods, to monitor and quantify the effects of community land titles on forest governance and conservation.

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