



Land titles and deforestation: evidence from Peru's oil palm sector

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ABSTRACT

The rapid expansion of oil palm (*Elaeis guineensis*) production in the Amazon adds urgency to the quest to understand the relationship between land titling initiatives and deforestation. Titling may help slow deforestation used to stake claims to land, but it also could encourage capital intensive commodity agriculture like oil palm by formalizing land rights and reducing the risks of investment. 'Forest-friendly' titling regulations, common in Amazonian countries, oblige new owners to conserve forest, but these requirements can easily be dodged if forest is cleared preemptively. To understand the effect of these initiatives, it is important to look closely at both the spatial distribution and temporal sequencing of titling, deforestation, and commodity crop expansion. Using a novel property dataset (n = 6072) and difference-in-difference approach, we analyze how land titling over 20 years in the Amazonian department of Ucayali, Peru influences the timing and extent of deforestation on individual parcels with and without oil palm. We find that 75% of oil palm is planted on titled land, compared to only 30% for other crops. Titling is associated with a small decline in deforestation, regardless of whether there is oil palm, yet properties are largely cleared well before the titling process begins and few oil palm properties retain the 30% forest cover required by Peru's Forestry Law. Key informants suggest that the profitability of oil palm drives land transactions and creates markets for deforested land, while contradictory regulations and limited resources hinder enforcement of regulations.

1. Introduction

Many of the world's most carbon-rich and biodiverse tropical forests are found in regions with insecure or contested land tenure (Rakotonarivo et al., 2023). Governments and development agencies promote land titling to achieve both environmental and livelihood goals. Zero-deforestation trade policies, such as the EU Deforestation Regulation (EUDR), further spur formalization by requiring traceable, legally sourced commodities, prompting governments to formalize tenure so producers can demonstrate compliance, and secure market access (Regulation (EU), 2023/1115; Ministerie van Landbouw, 2024).

Although insecure tenure is widely associated with increased deforestation, the effects of titling on forest cover vary by context and are particularly complex for individual-level titling (Robinson et al., 2014; Holland et al. 2017; Lipscomb & Prabakaran 2020; Probst et al. 2020). Experiences in Ecuador, Peru, and Brazil have shown that

formalizing land through titling can reduce deforestation motivated simply to claim land, encourage long-term investments in land management, and create the conditions necessary for incentive-based conservation programs (Buntaine et al., 2015; Robinson et al., 2014; Holland et al., 2017; Lipscomb and Prabakaran, 2020). As such, one outcome of titling is that a legally recognized and mapped landowner also becomes more governable and can be held accountable for environmental damage; and ought to adhere to regulations (Álvarez-Berrios et al., 2021; Siegel and Veiga, 2009; Scott, 1998). Conversely, titling can hasten deforestation when it opens land markets that replace traditional, low impact land uses with intensive commercial agriculture, where a land title can reduce the risk to investments (Buntaine et al., 2015; Robinson et al., 2014; Probst et al., 2020). In fact, development economists often see titling as the best means to convert land to capital, unlock credit access, and intensify economic activities (De Soto, 2000). To reduce deforestation, land administration experts advocate for

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pairing titling with environmental restrictions (Kukkonen, 2024), such as preserving forest cover or conducting impact assessments prior to titling, though it is often unclear which restrictions are enforced and whether they effectively prevent deforestation during the titling process.

Oil palm, a capital intensive and commercialized commodity, is expanding rapidly in the Peruvian Amazon, often at the expense of forests (Vijay et al., 2018; Rausch et al., 2020). Proximity to roads and processing mills are well-documented predictors of deforestation from oil palm (Vijay et al., 2018; Furumo & Aide, 2017; Glinskis & Gutiérrez-Vélez, 2019). Deforestation rates vary between smallholders and industrial producers, though their expansion is often interconnected (Glinskis and Gutiérrez-Vélez, 2019; Bennett et al., 2018). Smallholders depend on infrastructure developed by industrial actors, and land frequently changes hands through speculation or illegal transactions (Dammert, 2017). Industrial producers, in particular, are assumed to require titles before clearing land, minimizing the risk of investing in areas with insecure tenure. This pattern is evident in Ucayali, where the company Ocho Sur secured titles prior to clearing >6400 ha of forest and was later fined (Carving Up the Amazon, 2024; Dammert, 2017). Deforestation can also occur in anticipation of titling, a pathway more commonly linked to smallholders, who often operate informally before acquiring formal property titles (Glinskis & Gutiérrez-Vélez, 2019; Bennett et al., 2018). Regulations in the titling process aim to restrict deforestation by requiring land classification to determine suitability for agriculture and mandating authorizations from environmental authorities for land-use changes. Yet, the timing of forest clearing in relation to titling, as well as the differences among types of oil palm producers, remains poorly understood. This gap obscures the processes key to slowing deforestation, namely how forest safeguards required in titling are circumvented and by whom. We analyze this relationship in Peru, which hosts the second-largest forest cover in Latin America (73.3 million hectares) and where nearly 100,000 landholders reside in public forests without formal land tenure (USAID, 2016). The study site is a rapidly expanding oil palm frontier located within 130 km of Pucallpa, the regional capital (population 310,750 in 2024; Peru Cities by Population, 2024).

Experimental evaluations of land registration provide valuable causal evidence on how titling affects forest loss (Wren-Lewis, Becerra-Valbuena, and Hounghbedji 2020). However, because randomized designs remain rare, researchers typically rely on quasi-experimental methods. Quasi-experimental approaches, such as difference-in-difference (DiD) models, help unravel the titling-deforestation sequence by controlling confounding factors and isolating the influence of titling in regions where multiple deforestation intersect (Probst et al., 2020; L'Roe et al., 2016; Blackman et al., 2017). Conducting quasi-experimental studies is challenging because titling is neither geographically nor temporally random and precise data on land titling are often lacking, particularly in the Peruvian Amazon, where informal and/or contradictory land claims are widespread and centralized cadasters are incomplete or unavailable (Killeen, 2024). To address these challenges and supplement our descriptive analysis based on the regional database, we produce a novel property dataset ($n = 6072$) spanning three districts and twenty years in Ucayali, Peru that combines information about the timing of titling from the national public registry (SUNARP) with deforestation data from GeoBosques and a map of 2019 oil palm plantings. We apply a multi-period DiD model (Callaway and Sant'Anna, 2021) to assess the relationship between land titling and deforestation at this oil palm frontier. We compare deforestation rates before and after titling on parcels that are not being used for oil palm and parcels under oil palm production by 2019. We also draw on interviews with government agencies and NGOs about titling protocol and adherence to forest safeguards during titling. Finding ways to formalize land tenure for oil palm without driving forest loss is an urgent gains urgency, particularly as nations like Peru work to regularize land rights to improve forest regulation for biodiversity and carbon conservation targets and to allow producers to comply with international policies like

the EUDR (Brack, 2023).

2. Background & study site

2.1. Land titling and forests in Peru

The Amazon has long faced high levels of insecure and contested land tenure. Since the 1990s, the Peruvian government and international agencies like the Inter-American Development Bank (IADB) have supported the formalization of individual private landholdings. One of the largest efforts, the Rural Land Cadaster, Titling, and Registration Project (PTRT I through III), received >\$160 million from the IADB between 1996 and 2015. These programs aim to promote economic development and improve land tenure security and forest conservation (IADB, 2014).

In the 1990s, Peru decentralized responsibility for titling individual rural land to regional agrarian agencies like Dirección de Saneamiento Físico Legal de la Propiedad Agraria (DISAFILPA) (Monterroso et al., 2017). Titling efforts have since continued across municipalities. According to DISAFILPA officials, the process typically takes six to eighteen months, starting with land surveys and ending with the registration of titles in SUNARP. DISAFILPA grants newly formalized landholders certificates of possession (*constancias de posesión*), to be renewed annually, before acquiring full property titles (*títulos de propiedad*). Many titles remain unregistered in SUNARP, with landholders often relying on certificates or less formal land transaction documents (*compra-venta*) as proof of ownership.

Land titling in Peru is governed primarily by two laws: Supreme Decree (SD) 1089 (2008), which sets the procedures for titling rural properties, and Law No. 29763 (2011), the Forestry Law, which regulates the use of forested land. According to Article 12 of SD 1089, proof of “direct, continuous, and uninterrupted possession” of the land must be accompanied by evidence of “economic exploitation,” a requirement typically fulfilled by clearing forests and planting crops (MINAGRI, 2008). Reflecting this long-standing emphasis on “productive use,” DISAFILPA typically prioritizes already-cleared or cultivated land when issuing titles. As agency staff explained, once farmers learn that a titling campaign is underway, many begin clearing to demonstrate eligibility. Absentee speculators also clear land to position themselves to receive titles.

If a property to be titled contains forest, then the Forestry Law mandates that landholders complete additional steps to obtain legal authorization to convert forest to agriculture, as forested land cannot legally be owned in Peru (Law No. 29763, 2011; see SM 1.1 for details). In other words, to resolve this contradiction, a parcel must first be “deforested” on paper, i.e., reclassified through an approved land-use change, before any clearing on the ground can satisfy the “economic exploitation” requirement of SD 1089 needed to obtain a title. The authorization process involves an environmental evaluation, typically managed by regional forest authorities with oversight from the National Forestry and Wildlife Service (Law No. 29763, 2011). Forest cover is legally defined simply as land with natural woody vegetation, though the lack of a clearly defined baseline for measurement (e.g., historical vs. current cover) contributes to confusion and inconsistent enforcement. In reality, authorizations are rare: a 2024 investigation of official records from Ucayali and Loreto found that only four authorizations were issued between 2012 and 2018, covering roughly 75 ha, despite 209,409 ha cleared (Carving Up the Amazon, 2024).

Peru's Forestry law contains other environmental safeguards, such as requiring new title holders to preserve at least 30% of their original forest cover and protect riparian vegetation, but enforcement is often weak or nonexistent (Law No. 29763). Additionally, the law stipulates that land titles should only be granted on land with a Best Land Use Capacity (BLUC) classified for agriculture based on soil studies. However, as of the most recent assessment available (2011), only 57% of Peru's land had been assigned a BLUC (Hinojosa and Salazar, 2016), and

only an estimated 16% of farmers operate on land officially classified as suitable for agriculture (García, 2024).

2.2. Land titling and deforestation from oil palm

Land titling clearly plays a central role in shaping land use and deforestation in Peru's oil palm sector (Bennett et al., 2018; Dammert, 2017; Glinskis and Gutiérrez-Vélez, 2019). Yet, while studies highlight associations between titling and oil palm expansion, few establish clear causal links. For example, Bennett et al. (2018) found that titling programs in the Peruvian Amazon tend to be concentrated where farmers grow oil palm and offer preferential treatment to smallholders seeking to establish oil palm. Among 252 smallholders in Ucayali, 81% of oil palm growers had fully titled land, versus just 29% of other farmers (Bennett et al., 2018). Taken together, these results suggest regional policies promoting oil palm shape the allocation of titles.

Adding further complexity, smallholders and industrial producers follow distinct, though sometimes intersecting, pathways to acquire land (see SM 1.2 for a full breakdown of the types of oil palm producers in Peru). Land titling and the uneven enforcement of environmental regulations, not just differences in scale, help explain the variation in deforestation outcomes across producer types. Smallholders often integrate oil palm into existing agricultural plots such as fallows and pastures (Glinskis and Gutiérrez-Vélez, 2019). Industrial oil palm plantations, however, require large, contiguous tracts of land for monoculture palm cultivation, and are more likely to clear primary forests for plantations (Glinskis and Gutiérrez-Vélez, 2019; Dammert, 2017; Furumo and Aide, 2017), in part to avoid uncertain land tenure in deforested and degraded land (Gutiérrez-Vélez et al., 2011, see Kongsager and Reenberg, 2012 for parallel trends from Indonesia).

Despite the potential conflicts, many industrial producers purchase titled, cleared land from smallholders, who, with few assets apart from land, may sell their property for short-term economic gain. These transactions enable industrial producers to bypass environmental regulations (Dammert, 2017). As noted earlier, this loophole has been exploited by companies like Ocho Sur, which, between 2012 and 2015, acquired 232 individual titled parcels in Ucayali, many still forested. Rather than applying for a change in land use, as mandated under Peru's Forestry Law, Ocho Sur proceeded to clear the primary forest. These actions were later ruled illegal by the Ministry of Agriculture, resulting in formal charges and fines (Dammert, 2017; Sax, 2020; Carving Up the Amazon, 2024). The Ocho Sur case illustrates how titling, when misused, can facilitate large-scale deforestation while allowing industrial producers to sidestep key environmental safeguards.

Despite the uncertainties with titling and compliance with forest safeguards, formal land tenure is essential for participation in sustainability initiatives. The Roundtable on Sustainable Palm Oil (RSPO), the leading certification for oil palm, requires that producers comply with both national and international laws, including proof of land ownership, to attain certification (RSPO, 2018). In Peru, both small and large oil palm producers have pursued, and in some cases achieved, RSPO certification to improve the competitiveness of their products in global markets (Charry et al., 2020).

2.3. Study area: Ucayali, Peru

Ucayali is home to 47% (55,600 ha) of Peru's oil palm, more than any other department (MapBiomass Perú, 2022). About 96% of land in Ucayali (9.84 million ha) is biophysically suitable for oil palm (Pirker et al., 2016). In 2016, the Ucayali Regional Government released a competitive plan for oil palm, designating 228,000 ha of both cleared and forested land for cultivation (Ivanova et al., 2020). As predicted, titling projects prioritized areas for oil palm (Bennett et al., 2018). The government pledged to title land for 1000 oil palm producers annually (Gobierno Regional de Ucayali, 2016) and due partly to this campaign, Ucayali lost more forest than any department in Peru, averaging 25,900

ha per year from 2001 to 2023 (GeoBosques, 2021).

Once primarily inhabited by Indigenous peoples and characterized by low-intensity land use, a significant wave of settlers began in the 1940s around Pucallpa facilitated by the construction of the F. Basadre Highway connecting to Lima (Bax et al., 2016). Most settlers lacked formal land titles or certificates of possession (Ichikawa et al., 2014). The United Nations Office on Drugs and Crime (UNODC) first introduced oil palm to Ucayali in the 1990s as an alternative livelihood for coca farmers (Bennett et al., 2019). This initiative established smallholder oil palm associations and, with international funding, built Ucayali's first oil palm processing mill in 1998 (Bennett et al., 2019). Similarly, in 2015, a DEVIDA¹-funded project helped title land for 4500 oil palm producers, offering technical and administrative support (Gobierno Regional de Ucayali, 2016; see Gunderson, 2024 for more historical details). By 2020, Ucayali was home to over 3000 oil palm producers and ten processing mills (Fig. 1), more than any other department (Charry et al., 2020; Rausch et al., 2020). Cultivation is concentrated in five districts (Campoverde, Neshuya, Padre Abad, Nueva Requena and Curimana), near mills and along the F. Basadre Highway (Bennett et al., 2019).

Smallholders typically cultivate plots between 5 and 50 ha and together account for over half of the area planted in oil palm (Fort & Borasino, 2016). At least twelve private oil palm companies also operate in Ucayali, with plantations up to 10,000 ha in size (Bennett et al., 2019). Campaigns to promote oil palm in the region typically combine government-funded titling and infrastructure development (Charry et al., 2020). Together, with rising demand in domestic and export markets, these efforts fuel both smallholder and industrial oil palm expansion.

3. Methods

3.1. Describing oil palm, deforestation and titling trends in Ucayali

To assess the relationship between land titling and deforestation for oil palm in Ucayali, this study integrates multiple publicly available datasets with property information obtained from the Regional Directorate of Agriculture in Pucallpa during fieldwork conducted in August 2023 (SM 2.1 for details). The anonymized property dataset includes the boundaries of 28,621 parcels surveyed as of December 2022 and comprises parcels registered in the regional database by DISAFILPA; some of these parcels are also registered in the national database (SUNARP).

We used deforestation data from GeoBosques (2021), Peru's official forest monitoring dataset, which uses 30-meter resolution Landsat imagery to map forest cover and loss from 2001 to 2021. We also applied the global oil palm dataset from Descals et al. (2021), which uses Sentinel-1 and Sentinel-2 imagery from 2019 to map closed-canopy oil palm plantations at 10-meter resolution to distinguish between smallholder and industrial plantations based on factors such as the size of the cultivated area, the density of road networks, and the age of tree plantings. We use the Descals classification, rather than parcel size, to distinguish smallholders from industrial producers because parcels in the department are small (average = 13 ha) and landholders often own multiple adjacent parcels, making parcel size an unreliable indicator of production scale. However, because the dataset is only available for a single year our classification reflects oil palm presence only in 2019. We used MapBiomass Perú, Collection 2.0 (2022) to identify parcels with other types of agriculture.

We summarized patterns of land titling, oil palm cultivation, and forest cover change across Ucayali from 2001 to 2021, and also in the

¹ DEVIDA stands for the National Commission for Development and Life Without Drugs, an agency in Peru that helped fund projects combating illicit coca cultivation in the Amazon with financial support from international organizations, including USAID.

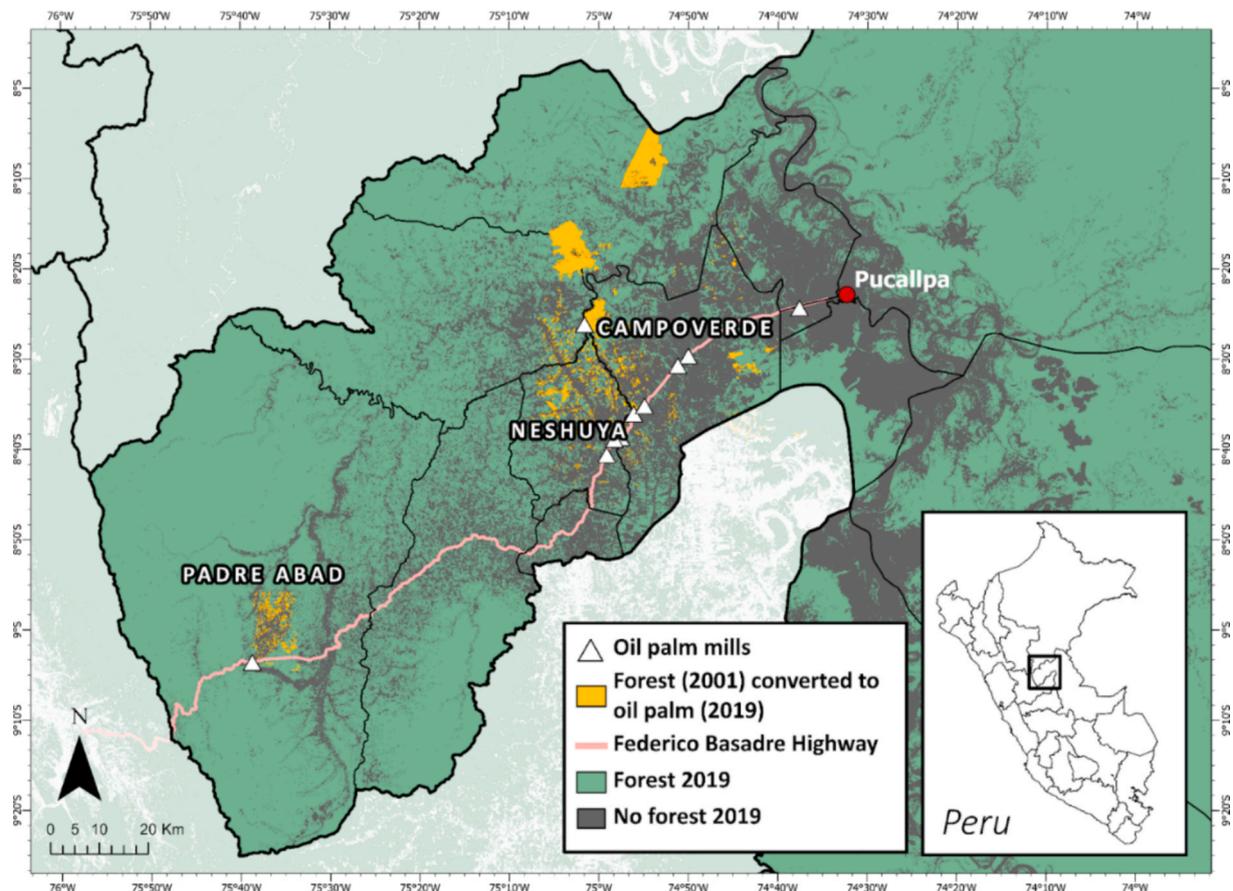


Fig. 1. Map of study site in Ucayali, Peru. Districts of focus for the modeling are labeled. Map lines delineate study areas and do not necessarily depict accepted national boundaries. Data sources: [MapBiomass Perú, 2022](#); [Rausch et al., 2020](#); and [OpenStreetMap, 2023](#).

three districts that are the focus of our modeling: Campoverde, Padre Abad, and Neshuya. Using [Descals et al. \(2021\)](#) and [MapBiomass](#) datasets to identify total oil palm area, closed-canopy oil palm by producer type, and other agriculture, we calculated the area of each land use on titled versus untitled land. We also compared forest retention across smallholder, industrial, and non-oil palm parcels and assessed compliance with the Forestry Law's 30% rule for nationally titled parcels in the three districts ($n = 6072$). The law does not specify a baseline year for measuring forest cover; therefore, for the purposes of this analysis, we chose 2001, the first year of [GeoBosques](#) data, as the reference year to assess whether parcels maintained at least 30% of their 2001 forest cover after titling.

3.2. Modeling the influence of land titling on deforestation

To evaluate the influence of land titling on annual deforestation, we used a DiD approach to estimate the average effect of titling on deforestation by comparing parcels that received a title in a given year to parcels that have not yet been titled. DiD approaches are widely used by researchers to evaluate the influence of land formalization (registration and titling) on deforestation ([Probst et al., 2020](#); [L'Roe et al., 2016](#); [Blackman et al., 2017](#)), with two-way fixed effect models being the most common specification. However, since there is increasing evidence that simple two-way fixed-effects models can produce biased estimates when treatment occurs at different times across parcels, we use a staggered multitemporal DiD approach following [Callaway and Sant'Anna \(2021\)](#), implemented in the DiD R package that estimates average treatment effects for each group of parcels receiving titles in a given year and aggregates them into an overall effect.

The regional database we were able to acquire includes properties

registered through 2022. The earliest and most common title date in the regional system is 2011 ($n = 12,787$), but this reflects the year that the regional documentation system changed rather than the actual year of title. Other parcels lack title dates ($n = 2,138$), not because they are untitled, but because information is incomplete or inconsistently recorded in the regional registry. Accordingly, we supplemented the database with titling records from SUNARP, the national property registry. Whereas the descriptive analysis drew on the full regional parcel dataset and does not rely on the timing of titling, the modeling limited the sample to parcels in the national database whose titling occurred during a period of rapid change in Ucayali between 2001 and 2011. Both types confer similar property rights, though nationally registered titles offer higher legal security. We specify 'nationally registered title' for parcels in the national registry and 'regionally registered title' for those only in the regional database (see SM 2.2 for a glossary of terms).

Title dates were obtained from SUNARP for parcels within the districts of Campoverde, Neshuya, and Padre Abad, where both smallholder and industrial oil palm operations are present. Obtaining title information from SUNARP involved manually searching the website. Of the 12,760 parcels searched for in SUNARP, 8,230 were found, indicating that approximately 65% of parcels in the regional database were also registered in SUNARP. For parcels with multiple title dates, we retained the earliest date to reflect the initial titling event. We are unable to track subsequent transactions and therefore cannot determine whether parcels changed ownership during our study period.

We started with 8,230 parcels and data preparation involved several key steps (see SM 2.3). First, we removed duplicate parcel records ($n = 11$), and excluded parcels < 0.5 ha ($n = 808$) to ensure accuracy in assigning deforestation and oil palm from remote sensing imagery. Parcels with no forest cover at the beginning of the period (2001) were

also excluded ($n = 1079$). We next overlaid the boundaries of titled properties with both the GeoBosques deforestation data and the Descals et al. (2021) oil palm layers to document annual deforestation and identify whether oil palm cultivation was present by 2019. Parcels identified as oil palm by MapBiomass but not classified by Descals et al. were excluded ($n = 260$) to avoid misclassifying parcels with open-canopy or early-stage oil palm as non-oil palm parcels. This resulted in a final dataset comprising 6072 parcels, of which 1628 had oil palm and 4444 had no oil palm.

For the analysis, the outcome was annual deforestation occurring on a given parcel, which we measured in three ways to serve as robustness checks across our models: (1) a binary indicator, which categorized deforestation as occurring when more than 0.25 ha of forest were cleared in a given year; (2) a continuous variable transformed with the inverse hyperbolic sine (IHS) function to capture the extent of deforestation in ha; and (3) the proportion of the parcel deforested in a given year. We set the threshold for the binary variable at 0.25 ha, meaning that approximately three 30-meter GeoBosques pixels were required to indicate deforestation. We include the district as a control variable to account for differences across the three districts in infrastructure, market access, or other local conditions.

The modeling relies on the assumption that parcels titled later serve as an appropriate counterfactual for those titled earlier. Because titling in Ucayali was not rolled out in a randomized experimental design, we used the Wald Test for parallel pre-trends to assess the degree to which later registering parcels experienced parallel pre-trends to earlier registering parcels. We restricted the modeling analysis to the wave of titling that occurred between 2001 and 2011 in our study region (see Fig. 2), which satisfied the Wald test for parallel pre-trends, and is associated with the late end of the PTRT II implementation in Ucayali. The second peak in titling in 2013 reflects a separate campaign which delivered a reported 848 titles and involved different outreach practices and administrative procedures (COFOPRI, 2013). Finally, to mitigate effects of spatial clustering in titling, we used a balanced panel (furthering narrowing the title years to 2004–2007), such that the modeling sample ultimately includes 2886 parcels where there is plausible evidence supporting the assumption that, in the absence of titling, later- and earlier-titled parcels would have followed similar

deforestation trajectories.

We ran the model for the sample of 2886 parcels and for two subsamples: parcels without oil palm ($n = 1887$) and parcels with oil palm ($n = 999$). To further explore the temporal dynamics of titling, we used an event-study framework implemented in the DiD R package (Callaway and Sant'Anna, 2021). This approach estimates how deforestation changes in the years before and after titling, allowing us to test for anticipatory effects (e.g., pre-titling clearing to meet eligibility requirements) and post-titling responses. We used a balanced panel window of 2 years before and after titling to include as many eligible parcels as possible while also observing effects over an appreciable time window.

Note that this parcel-level design assumes independence across units and does not capture potential spillover effects of titling, such as the displacement of deforestation to surrounding areas, infrastructure development, or changes in tenure security that may extend beyond individual parcels. We address the likelihood and potential implications of these types of spillover effects in the discussion.

To ensure the reliability of the findings, we conducted a series of robustness checks to investigate whether relationships differ across parcels when changing the model specifications, such as adding covariates or using different deforestation variables. Overall, the robustness checks revealed that while there are some small differences in the coefficients, the core results remain consistent (see SM 2.4).

3.3. Key informant interviews and policy document review

To complement the quantitative analysis, we consulted key informants in August 2023 and July 2024 in Lima and Pucallpa about our findings from the land use analysis. The unstructured interviews ($n = 21$) involved experts from conservation NGOs, regional forestry and agricultural offices, and national government ministries (MINAM and MINAGRI). Most interviews were one-on-one; others had 3–5 participants for a total of 33 interviewees. We also presented our work at a public event hosted by the Universidad Nacional de Ucayali (UNU) and received feedback from regional government and NGO officers, researchers, and university students. We draw from informant insights to help explain the modeling results and deforestation trends (Section 4.3).

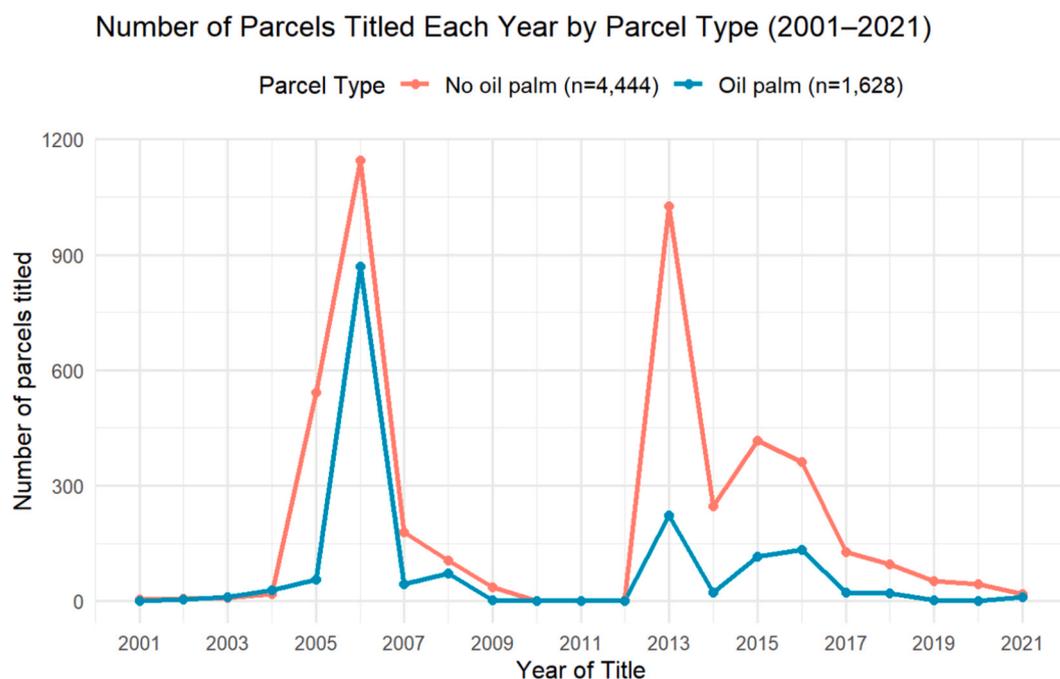


Fig. 2. Timing of parcel titling for oil palm and non-oil palm parcels across Campoverde, Neshuya, and Padre Abad. Data . Source: SUNARP

To ensure confidentiality, we omit informant names and refer only to their general affiliations.²

We also reviewed policy documents spanning 1960–2024 to understand the evolution of legislation governing the titling of individual rural properties in Peru. This included key legislation such as the Forestry Law and its 2024 amendment, with particular focus on provisions influencing land classification and environmental safeguards during titling. Additionally, we studied laws frequently referenced during interviews and consulted legal experts in Peru to validate our interpretations.

4. Results

4.1. Oil palm, titling and deforestation trends across Ucayali

Over the past few decades, both land titling and oil palm cultivation have dramatically expanded in Ucayali. By 2022, over 220,000 ha were titled within 13,693 of the 28,621 parcels in our database for Ucayali (see SM 3.1 for details). By 2019, Ucayali had close to 50,000 ha of oil palm, the majority of which (75%) was cultivated on titled lands—69% of smallholder and 81% of industrial oil palm. Comparatively, only 30% of land used for other agriculture, including pasture, was located on titled plots (Table 1). The pattern was similar across Padre Abad, Neshuya, and Campoverde, our three focal districts, which together accounted for 65% of Ucayali's oil palm area (~32,000 ha) by 2019 (MapBiomass, 2022).

Deforestation has also expanded in Ucayali, particularly in oil-palm producing locations. Over 39,000 ha of forest were cleared on titled parcels with oil palm between 2001 and 2021, with smallholder properties accounting for 53% and industrial producers for 47% of this deforestation. Two Ocho Sur owned plantations contributed about 9700 ha, or 25%, of this total forest loss during 2012–2013.

Deforestation patterns varied across oil palm production modes. About 50% of oil palm on titled properties was planted on land deforested prior to 2001. Industrial oil palm parcels had an average of 60% forest cover at the start of the study in 2001, while smallholder oil palm parcels contain 46% forest cover, and non-oil palm parcels slightly less at 43% (Fig. 3). Deforestation rates on titled parcels with smallholder and industrial oil palm were higher than on non-oil palm parcels. By 2021, industrial oil palm parcels with titles retained only 8% of their original forest cover, compared to 17% on smallholder parcels and 30% on non-oil palm parcels. Similarly, across the three districts, industrial parcels had the lowest levels of forest cover by 2021 (SM 3.2).

The analysis revealed frequent non-compliance with the Forestry Law, which requires parcels to retain at least 30% of their original forest cover. When titled, industrial oil palm parcels averaged just 23% forest cover, and 40% were out of compliance with the legal threshold, relative to a 2001 baseline (Fig. 4). Smallholder parcels averaged 28% forest cover, with 32% out of compliance. In contrast, fewer non-oil palm parcels (17%) were out of compliance, averaging 45% forest cover when titled.

4.2. Influence of titling on deforestation

The timing of titling had a small influence on deforestation among properties in Ucayali regardless of whether they had oil palm. Contrary to expectation based on previous analyses (Probst et al., 2020; Buntaine et al., 2015; Robinson et al., 2014), the modeling revealed a decline in the likelihood of deforestation following titling for both oil palm and non-oil palm properties in Padre Abad, Campoverde, and Neshuya (Table 2). Non-oil palm parcels showed a 3.8 percentage point reduction in deforestation likelihood post-titling and a 7.4% reduction in total

deforestation, while oil palm parcels showed a 11.8 percentage point reduction in deforestation likelihood, each statistically significant (Table 2). We also observed a significant decrease in the overall amount of forest cleared across all parcels, although this was not significant for oil palm parcels.

The event study indicates a significant decline in deforestation following titling across all parcels, with the largest reduction observed on oil palm parcels one year after titling, a 25-percentage-point decrease in the likelihood of deforestation (Fig. 5). In contrast, there is no evidence of significant changes in deforestation in the two years preceding titling, regardless of oil palm presence, suggesting that anticipatory clearing is not concentrated immediately preceding titling, and that the timing of prior deforestation is not consistent across parcels. This pattern holds when using alternative outcome measures (SM 2.4). Due to limitations in the sample size that met the parallel trends assumption, we restricted the analysis to two years before and after titling. As a result, we cannot determine whether these patterns hold over longer time horizons. Notably, descriptive analysis shows that much of the forest on parcels in this area had already been cleared prior to titling, suggesting that the post-titling decline observed in the model may partly reflect limited remaining forest on titled parcels rather than a behavioral change alone.

4.3. Insights from key informant interviews

Interviews with regional officials, national-level policymakers, and conservation experts reveal three consistent themes that help contextualize observed land-use patterns in Ucayali.

4.3.1. Contradictory regulatory requirements incentivize pre-titling clearing

During interviews, all seven of the regional land granting officials acknowledged contradictions between SD 1089 and Forestry Law requirements, which in effect, create incentives for anticipatory clearing ahead of seeking title.

[1] “There are tremendous contradictions between the forestry law and the titling law. The forestry law tells me that I should not deforest, and the titling law tells me that I have to do economic work, or I cannot have access to a title” (DISAFILPA official, 7/8/2024, SM 3.3 for original Spanish quotes).

Conservation experts also highlighted how the BLUC framework for land classification, which is part of the Forestry Law, creates incentives for forest clearing ahead of titling. BLUC classification can be altered by clearing land or adding inputs, such as fertilizers, to improve soil quality. In practice, landholders often clear forested or protected areas to reclassify the land as eligible for titling, enabling its legal conversion to agriculture and eligibility for private ownership. While the framework includes a requirement to restore forest cover exceeding allowed conversion limits, this is seldom enforced.

4.3.2. Access to credit and land markets ahead of SUNARP registration

Informants emphasized that landholders often obtain credit before national registration of their titles in SUNARP. Regional officials further explained that regionally registered and nationally registered titles provide comparable rights to landholders, including the ability to sell, subdivide, and use land as collateral. This functional equivalence between regional documentation and national registration likely contributes to the limited behavioral change we observe following registration and helps explain why most clearing occurs prior to the point we classify as “titled” in our analysis.

Interviewees also described active land markets in which smallholders often clear land and later sell parcels to oil palm companies. These transactions are motivated by economic opportunity and the high value of cleared land. As one regional official noted:

² The interviews were deemed not to involve human subjects research, as defined by DHHS and FDA regulations, and were therefore exempt from IRB review in June 2023.

Table 2
Change in likelihood and amount of deforestation on titled parcels (n = 2886) during and after the year of titling in Ucayali, Peru.

	All parcels (n = 2886)	Without oil palm (n = 1887)	With oil palm (n = 999)
Likelihood of deforestation	-0.0583** (0.019)	-0.0381* (0.0576)	-0.1179** (0.0212)
Amount of deforestation (IHS-transformed)	-0.115** (-0.0354)	-0.0741*** (0.0096)	-0.2348 (-0.1082)
Proportion of parcel deforested	-0.0067* (0.0057)	0.0028** (0.0282)	-0.0218*** (-0.0069)

* p < 0.1, ** p < 0.05, *** p < 0.01.

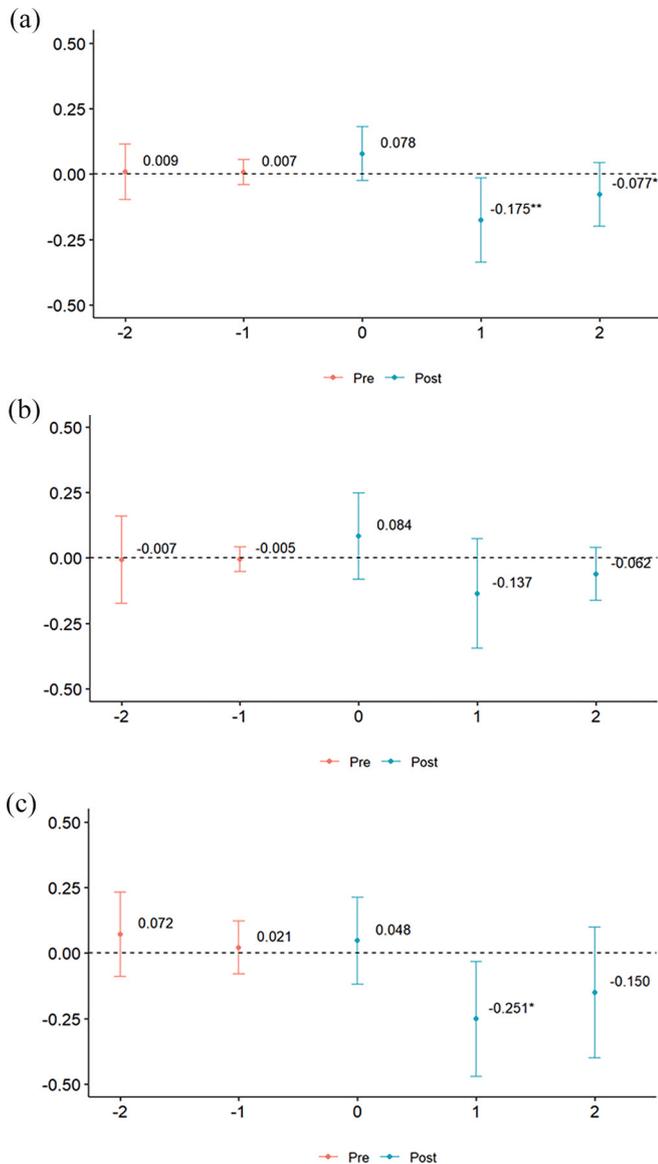


Fig. 5. Event study on the likelihood of deforestation before and after titling on (a) all parcels (n = 2,886) (a) without oil palm (n = 1,887), (b) with oil palm (n = 999) in Ucayali, Peru.

Regional government officials reported that there is no agency or monitoring system in place to track compliance after titling, and that the law’s reference to “original forest cover” is inconsistently understood. Some officials believed the baseline should reflect forest at titling; others assumed it referred to historical, pre-clearing extent of forest. This

ambiguity, combined with limited budgets and staffing, and a lack of dedicated monitoring resources, was repeatedly cited as a barrier to the enforcement of pro-forest regulations. Additionally, several interviewees described strong regional political and economic support for oil palm production. One former official explained:

[3] “If it had not been for oil palm, which extended a lifeline to the regional economy, life in Ucayali would be a misery” (Ex-regional official, 7/4/24).

The heavy promotion of oil palm affects titling decisions and enforcement practices and shapes how regional authorities balance agricultural expansion with forest protection. We draw on key-informant interviews and prior studies in the discussion to help interpret the underlying causes of the patterns we observe.

5. Discussion

Ambiguous and contradictory historical requirements for titling in Ucayali complicate the enforcement of pro-forest regulations. While our quantitative results show that oil palm is overwhelmingly established on titled land and that deforestation tends to decline after SUNARP registration, these findings must be interpreted in the context of how landholders navigate titling procedures and participate in regional land markets.

5.1. Understanding the timing of deforestation relative to titling

Based on prior research from the Amazon (Probst et al., 2020; Buntaine et al., 2015; Robinson et al., 2014), we expected to see deforestation increase post-titling, particularly on parcels later converted to oil palm plantations. Like Probst et al. (2020) and Holland et al. (2017), we anticipated that titling would enhance access to credit, enabling export producers to expand their production of oil palm at the expense of forests. Instead, our results indicate that deforestation decreases post-titling on both oil palm and non-oil palm parcels. This decline is explained by the fact that most forest loss occurred well before formal titling, consistent with frontier deforestation patterns elsewhere in the Amazon in which landholders establish claims through clearing and then seek recognition once land is “productive” (Brito et al., 2021). The qualitative findings clarify that conflicting regulations and the availability of credit prior to SUNARP registration both weaken the causal link between titled and contemporaneous land-use decisions. Instead, titling formalizes conditions largely shaped by earlier clearing, investment, and transactions.

5.1.1. Legal requirements facilitate deforestation ahead of titling

The process of acquiring rights and using land in Peru is mediated by policies that operate at cross purposes, leading to confusion even among officials about how to properly administer land. The most striking of these inconsistencies are those between SD 1089 and the Forestry Law, which effectively encourage landholders to clear forested areas in advance of applying for a title. This phenomenon of forest clearing to demonstrate use has a long history across Latin America. In the Brazilian Amazon, for example, it is common to clear undesignated public areas as a preliminary step toward claiming ownership (Brito et al., 2021). Similarly, after Colombia’s recent peace accord, there was a surge in forest clearing in areas formerly controlled by the FARC, as the peace accord created expectations of land redistribution (Murillo-Sandoval et al., 2020).

Furthermore, landholders in Brazil sometimes advocate for legislative changes to retroactively legalize deforested lands, as happened with the 2012 revisions to that country’s Federal Forest Code, mirroring recent changes in Peru’s Forestry Law (Law No. 31973, 2024), which eased titling requirements for previously illicit landholdings in cleared forest. Prior to the 2024 revisions to Peru’s Forestry Law, landholders who received titles on land without BLUC or on land classified as forest

or protection were not authorized to use the land for agriculture. The 2024 amendments to the Forestry Law removed the BLUC requirement for all titles issued before 2024, without replacing it with a new system (Law No. 31973, 2024). This retroactively legitimizes many previously non-compliant titles, including those in our study (Section 4.1), making them eligible for agricultural use regardless of soil suitability or forest cover. By “grandfathering in” past violations, such revisions weaken regulatory safeguards and incentivize future deforestation by signaling that illegal land use can eventually be legalized.

5.1.2. Land transactions between smallholders and industrial producers

Understanding the dynamics of deforestation and titling is further complicated by how land changes hands, usually after a title is conferred, when the land becomes a saleable asset. Previous research has shown that Peruvian smallholders commonly acquire property titles through state campaigns and later sell to industrial oil palm producers (Dammert, 2017; *Carving Up the Amazon*, 2024). This dynamic of smallholder pioneers, often propelled by public projects to settle at forest frontiers, later being displaced or simply remunerated by larger producers consolidating land in the region, is a common occurrence in Peru and across the Amazon (López-Carr, 2021).

As controversies over corporate oil palm surfaced in Peru in the 2010s with Ocho Sur, industrial producers began looking for creative means to avoid responsibility for land clearing (Dammert, 2017). Purchasing cleared land from smallholders carries the risk of conflict when tenure is ambiguous or contested. However, it allows industrial producers to avoid the legal and reputational risks associated with direct deforestation, while still securing the land needed for plantations. This pathway also enables industrial producers to take advantage of the active land markets in this region, where in many cases, a smallholder’s primary asset is land. Smallholders frequently sell to improve their economic standing, and a larger producer or industrial plantation is likely to be able to pay more, creating new economic opportunities for otherwise “displaced” smallholders.

Industrial producers in Ucayali have been known to promote titling for properties they intend to purchase and to encourage smallholders to sell their land for plantations (Dammert, 2017). While this scenario helps explain why some smallholder parcels are cleared prior to titling, the specific role of land transactions in driving these patterns remains uncertain. Because our oil palm dataset captures only plantations present in 2019 and our titling data lack land-transaction records, we could not determine when land changed hands or who was responsible for deforestation. This is a notable limitation in Ucayali, where land turnover is common and transactions among smallholders and industrial producers shape land-use dynamics. To our knowledge, no time-series data distinguish industrial from smallholder oil palm. Future research should develop longitudinal datasets on oil palm expansion and land transfers to clarify how clearing responsibilities shift and whether titling mitigates or redistributes deforestation pressures.

Furthermore, this study does not measure landscape-level changes that may occur because of titling, but such processes are likely present in Ucayali. As titling becomes more widespread, formal land markets develop, making it easier for industrial producers to acquire already cleared land (Gutiérrez-Vélez et al., 2011; Kongsager and Reenberg, 2012). This mechanism aligns with the limited behavioral shift we observe following SUNARP registration: if most deforestation is completed before titles are formalized, and if cleared, titled land is what ultimately circulates in regional land markets, then registration itself may have little influence on producer decisions about forest conversion.

5.2. Challenges to enforcing Forestry Law regulations

The limited direct effect of titling on forest outcomes is also shaped by regulatory ambiguity and enforcement constraints. Although the Forestry Law requires landholders to retain 30% forest cover, this mandate is undermined by unclear procedures for authorizing forest

clearing, limited monitoring capacity, and regional priorities that favor oil palm expansion. As a result, oil palm producers are often operating outside this requirement by the time titles are issued.

5.2.1. Ambiguous interpretation and enforcement of the Forestry Law

The Forestry Law’s effectiveness is limited by unclear provisions, which must be clarified to protect forests. The official paperwork issued to new landholders does not mention the obligation to retain 30% in forest. Rather, the title only stipulates that landholders must maintain the same “agricultural land use” (*uso agropecuario*) for at least five years after the title is granted (SM 4.1 for a copy of a property title), along with other conditions unrelated to land use. Our field interviews confirmed uncertainty among both landholders and regional officials regarding how forest cover should be assessed. If legal restrictions on forest clearing are to be based on a historical baseline, landholders must be informed of this well in before titling, to avoid unintentional non-compliance. In this study, we adopt a 2001 baseline for forest cover, based on the earliest availability of forest cover data from GeoBosques. However, if enforcement is tied to forest cover only at the time of titling, this creates a loophole: landholders may preemptively clear land so that they can more easily meet the requirement to conserve 30% of the remaining forest.

In practice, officials prioritize already-cleared parcels for titling to reduce conflicting claims, rather than enforcing environmental regulations. Interviews confirmed that no agency or monitoring system tracks compliance post-titling, so the State does not repossess land or sanction landholders who violate rules. This ambiguity undermines forest conservation during titling but aligns with our findings: most forests are cleared before titling, and deforestation declines slightly once the pressure to clear land for titles subsides.

5.2.2. Regional capacity, autonomy and priorities

The decentralization of land titling in the early 2000s transferred responsibility to DISAFILPA within regional agriculture offices (Monterroso et al., 2017), which now face significant resource constraints (Dammert, 2017). During conversations, regional officials reported that international funding, such as from the IADB during PTRT I through III, is often centralized in Lima, with little reaching regional governments. Lenders cited corruption at regional levels as justification, yet corruption is also prevalent in higher government offices.

While regional authorities manage the titling process, they remain accountable to national laws and must complete steps authorized by national offices. This dynamic, described as “incomplete decentralization” (Monterroso et al., 2017), complicates governance. For example, national laws classify forests as patrimony of the national government, requiring deforestation authorization from ministries in Lima. However, no clear pathways exist to implement this requirement, which is rarely fulfilled (*Carving Up the Amazon*, 2024). Furthermore, when project funding does reach regional titling offices, our interviews indicate that resources are allocated according to the number of parcels titled, with no funds designated for monitoring and no conditions linking disbursements to the enforcement of forest regulations. Together, these gaps in enforcement help explain why titling shows only limited effects on deforestation in our results and why compliance with the 30% forest-retention requirement is effectively nonexistent.

At the same time, oil palm is highly regarded among officials in Ucayali, who often prioritize oil palm producers during the titling process (Bennett et al., 2018). Oil palm serves as a lucrative livelihood strategy for smallholders and plays a central role in Ucayali’s economy. In 2023, palm oil accounted for nearly 51% of the region’s exports, valued at \$41 million USD (Reporte de Comercio Regional Ucayali, 2023). Regional government actions have historically reflected this pro-oil palm stance. In 2012, the Ucayali government registered >5700 ha of forest and later sold it to the oil palm company Ocho Sur U to establish a plantation (*Carving Up the Amazon*, 2024; Dammert, 2017). Thus, granting greater autonomy exclusively to regional authorities may not

ensure conservation benefits in Ucayali, where economic priorities often outweighed forest protection in the past. In Ucayali, new regional zoning plans known as the Zonificación Forestal were approved in March 2024 and presented as a solution to deforestation by delineating areas for agricultural use and forest protection. Yet conservation experts we interviewed remain skeptical, noting that the legacy of retroactively redefining legal deforestation raises concerns that these designations may not be meaningfully enforced over time, instead risking continued informal land occupation and forest loss despite the new zoning framework.

6. Conclusion

Our study in the Peruvian Amazon serves as a warning not to expect land formalization to protect tropical forests at oil palm frontiers, even when titling regulations oblige new owners to conserve forest. Our work also shows the difficulty of detecting an overall effect of titling on deforestation. Our event study showed a decline in deforestation rates on parcels after land titling, but this modeling result merits cautious interpretation. Importantly, much of the forest on these parcels had already been cleared *prior* to titling, in some cases by other actors involved in informal land use and land transactions in previous years. Significant previous forest clearing allowed new owners to dodge laws requiring them to protect 30% of forest on their land. In fact, our descriptive data showed that less than ten percent of original forest remained on titled industrial oil palm properties. In sum, at an oil palm frontier such as Ucayali, titling does not function as a means to regulate and slow deforestation but rather the process formalizes ownership in already deforested landscapes.

Recent changes to Peru's Forestry Law (Law No. 31973, 2024), which retroactively legalized past deforestation, risk compounding this dynamic by prioritizing formalization without oversight. The stakes are growing as titling becomes a proxy for legality under sustainability frameworks like the RSPO and EUDR, which require proof that commodities are legally produced and deforestation-free (RSPO, 2018; Regulation (EU), 2023/1115). With the EUDR compliance deadline approaching, countries like Peru are under pressure to demonstrate adherence, often through rapid titling and registration. Without meaningful monitoring or enforcement, a push to title more land risks reinforcing a cycle in which forest clearing remains a *de facto* prerequisite for recognition.

Breaking the cycle of forest clearing before titling entails significant governance reform. Revising ambiguous rules is an important step, as is building state agencies' capacity to monitor and enforce forest protection post-titling. Governments and donor agencies that fund titling programs in the tropics must build in support to improve land titling agencies' capacity to monitor and enforce forest protection. Forest governance will be further strengthened by building transparent, publicly accessible cadasters that provide up-to-date information on titled parcels, boundary delineations, dates of formalization, and subsequent land transfers, enabling verification of compliance cut-off dates and accountability for land-use decisions. In forested regions marked by contradictory land-use laws and rapid agricultural expansion, such measures can ensure that titling supports, rather than undermines, conservation goals.

CRedit authorship contribution statement

Celeste Gunderson: Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Jess L'Roe:** Writing – review & editing, Visualization, Validation, Methodology, Formal analysis, Data curation, Conceptualization. **Lisa Rausch:** Writing – review & editing, Resources, Conceptualization. **Clare Sullivan:** Writing – review & editing, Resources, Conceptualization. **Holly Gibbs:** Writing – review & editing,

Resources, Methodology, Conceptualization. **Lisa Naughton-Treves:** Writing – review & editing, Resources, Methodology, Investigation, Conceptualization, Funding acquisition.

Declaration of competing interest

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.gloenvcha.2026.103152>.

Data availability

The dataset supporting the conclusions of this article is available on Mendeley Data.

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