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EFFECTIVENESS OF CERTIFICATION AND LAND TENURE INTERVENTIONS TO CONSERVE FORESTS

Nathalie Doswald, Sasha Murat, Martin Prowse

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Effectiveness of certification and land tenure interventions to conserve forests

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About this IEU Learning Paper

This systematic review and meta-analysis provide an updated and rigorous synthesis of causal evidence on the effectiveness of land tenure reforms and environmental certification in advancing forest conservation, livelihoods, and climate change mitigation in developing countries. Land tenure reforms had sufficient high-quality evidence to support a meta-analysis. The limited number of impact evaluations of certification schemes highlights an urgent need for methodologically robust studies in this area. The meta-analysis of land tenure reforms reveals no statistically significant average effect on deforestation rates, livelihoods, or carbon stock outcomes. That said, participatory forest management schemes and reforms that clarify communal or Indigenous rights appear to perform better than top-down titling interventions implemented in isolation. Despite the small number of studies in each outcome category, patterns of heterogeneity observed in the moderator analyses point to the importance of factors such as intervention scale, implementation actors, and colonial legal heritage. These dimensions may help explain variations in effectiveness and should be systematically integrated into future research and programme design.

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Abstract

This report synthesizes the results of a systematic review and meta-analysis assessing the effects of two forest policy instruments—land tenure reforms and environmental certification—on forest conservation, livelihoods, and climate change mitigation in developing countries. Building on a companion evidence gap map, the analysis includes studies with strong causal inference designs and uses standardized effect sizes across comparable outcome categories. The report begins with a summary of the methodological approach used for evidence selection, data extraction, and statistical modelling. It then presents results separately by intervention and outcome type, explores heterogeneity through moderator analyses, and discusses the presence of potential publication bias.

Findings on land tenure interventions do not produce consistent or statistically significant effects across almost all outcomes. However, positive effects appear more likely in contexts where reforms involved participatory management or were supported by complementary governance conditions. The linkage with participatory management is very much in line with the current global push for stronger recognition and promotion of locally governed conservation approaches. The small number and heterogeneity of certification studies precluded inclusion in the meta-analysis, revealing a critical evidence gap. The results highlight the importance of contextual factors in shaping intervention effectiveness and reinforce the need for more causal designs when evaluating conservation initiatives.

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ABBREVIATIONS

CFM	Community forest management
CI	Confidence interval
DID	Difference-in-differences
EGM	Evidence gap map
FSC	Forest Stewardship Council
GCF	Green Climate Fund
NGO	Non-governmental organization
NTFP	Non-timber forest products
PELIS	Plantation Establishment and Livelihood Improvement Scheme
PFM	Participatory forest management
REDD	Reducing emissions from deforestation and forest degradation
SE	Standard error
ToC	Theory of change
WLS	Weighted least squares

I. INTRODUCTION

A. THE PROBLEM, CONDITION, OR ISSUE

Forests are critical global commons that sustain biodiversity, stabilize the climate through carbon storage, regulate water cycles, and provide livelihoods for over a billion people worldwide (Psistaki, Tsantopoulos and Paschalidou, 2024; Xofis, Kefalas and Poirazidis, 2023). Yet, tropical deforestation continues at alarming rates, undermining climate goals and threatening ecosystems and the well-being of forest-dependent communities (Food and Agriculture Organization of the United Nations, 2020; Secretariat of the Convention on Biological Diversity, 2024). The drivers of deforestation are well-documented, including expansion of commercial agriculture, extractive industries, infrastructure development, and shifting cultivation, often facilitated by insecure or unclear land tenure, which weakens incentives for sustainable land-use and enables forest encroachment by outside actors (Pacheco and Meyer, 2022).

At the same time, market-based conservation mechanisms such as environmental certification are increasingly promoted to incentivize sustainable forest management (Di Girolami, Kampen and Arts, 2023). Certification schemes, like those governed by the Forest Stewardship Council (FSC), aim to reward responsible forest practices through access to premium markets and reputational gains. Both land tenure reform and certification are now key tools in forest conservation and climate mitigation efforts, often embedded in national REDD+[1] strategies or multilateral development programmes.

Despite wide adoption and policy endorsement, the effectiveness of these instruments remains empirically contested (Di Girolami, Kampen and Arts, 2023). Land tenure reform is often assumed to enhance stewardship and reduce deforestation by securing community or individual rights to forests (Pacheco and Meyer, 2022). Yet, evidence from recent studies reveals mixed results: in some contexts, tenure formalization reduces forest loss such as in Ecuador (e.g. see Holland and others, 2017) or the Argentine Chaco (Camino and others, 2023), while in others, it either has no impact or is associated with increased deforestation such as in Madagascar (e.g. Rasolofoson and others, 2015) and Mexico (Blackman and Villalobos, 2021), particularly when reforms lack enforcement or exclude conservation conditions.

Likewise, certification has shown potential to improve forest management and social safeguards, but rigorous evidence on its environmental effectiveness remains limited and geographically narrow (see Di Girolami, Kampen and Arts, 2023, for a recent example). Studies often lack standardization in outcome measurement or fail to isolate certification effects from broader policy or market dynamics. This lack of clarity limits policymakers' ability to prioritize among forest interventions or design them to be more context-sensitive and equitable. Despite widespread implementation, the empirical evidence regarding the effectiveness of these interventions remains fragmented and context-dependent.

B. THE RATIONALE OF THIS SYSTEMATIC REVIEW

This review responds to the need to synthesize the best available causal evidence and focus exclusively on studies employing experimental or quasi-experimental designs capable of attributing

[1] REDD stands for reducing emissions from deforestation and forest degradation.

observed impacts to interventions. By pooling standardized effect sizes and examining heterogeneity across ecological and governance contexts, the review offers a clear picture of what works, for whom, and under what conditions. In doing so, it moves beyond anecdotal evidence and isolated case studies to generate actionable insights for forest policy design, investment prioritization, and climate finance programming.

However, forest governance is inherently complex, as interventions operate across multiple ecological, institutional, and socioeconomic contexts. Land tenure reforms may yield positive outcomes in certain settings by reducing land conflict and encouraging investment in sustainable land-use but may be less effective where legal recognition is weak or enforcement mechanisms are lacking. Similarly, certification schemes can incentivize sustainable practices, but their success is often influenced by market access, institutional capacity, and the willingness of producers to comply with standards that may impose short-term costs. Given the diversity of contexts and mechanisms through which these policies are implemented, evaluating their aggregate effectiveness requires a systematic synthesis of high-quality evidence.

This systematic review and meta-analysis therefore play a dual role: it consolidates robust empirical findings on the impact of land tenure and certification policies in developing countries, and it highlights the enabling and hindering factors that mediate their effectiveness, thus providing both a quantitative summary of outcomes and a qualitative understanding of the mechanisms behind them.

C. WHY THIS REVIEW IS IMPORTANT

This systematic review and meta-analysis address the need for a rigorous and up-to-date assessment of the effects of land tenure reforms and environmental certification on forest conservation in developing countries. While previous reviews have focused on instruments such as protected areas or payments for ecosystem services, no systematic review currently provides a quantitative synthesis of causal evidence for these two specific policy instruments in relation to outcomes such as forest cover, livelihoods, and climate change mitigation.

The most recent reviews tend to cover a broader set of interventions, without systematically disaggregating the effects of certification or land tenure reforms, or they limit their analysis to correlations without estimating comparable effect sizes across studies. This constrains the ability to draw generalizable conclusions that can inform effective public policy in diverse contexts.

This review seeks to fill that gap by gathering and analysing only methodologically robust studies capable of estimating attributable impacts. In doing so, it contributes to strengthening the evidence base for guiding decisions on the design, implementation, and financing of forest conservation interventions.

D. OBJECTIVES

This review will address the following primary research questions:

Land tenure reforms

1) To what extent have land tenure reforms been effective in achieving improved forest cover, enhanced livelihoods, or climate change mitigation at the individual, household, community, firm, and/or landscape levels in developing countries?
2) What factors influence the effectiveness of land tenure reforms for forest conservation in developing countries?

Environmental certification

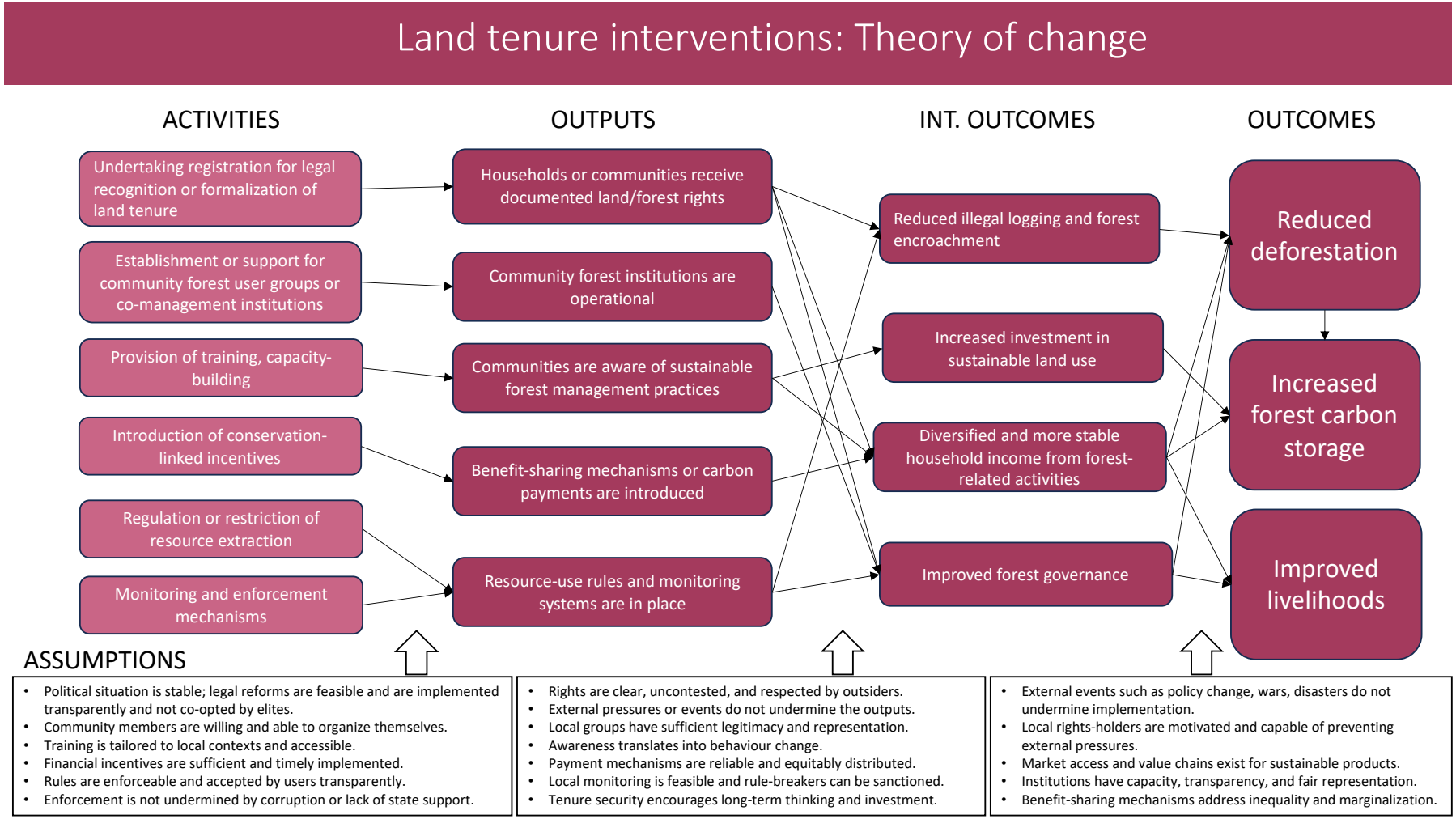
3) To what extent has environmental certification been effective in achieving improved forest cover, enhanced livelihoods, or climate change mitigation at the individual, household, community, firm, and/or landscape levels in developing countries?
4) What factors influence the effectiveness of environmental certification schemes in the context of forest conservation in developing countries?

E. THE INTERVENTION AND HOW THE INTERVENTION MIGHT WORK

Both land tenure reforms and environmental certification are widely promoted in developing countries as mechanisms to address deforestation and improve forest governance. These interventions operate through different but sometimes complementary pathways.

Land tenure reforms seek to clarify and secure rights over land and forest resources, aiming to reduce conflicts, foster good governance, incentivize sustainable land management, and improve long-term stewardship. Figure 1 shows the theory of change (ToC) for land tenure reforms. Compared with land tenure change, the literature surrounding the causal mechanisms for environmental certification is less well established (Bertzky, Doswald and Prowse, 2024; Di Girolami, Kampen and Arts, 2023), making it harder to develop a good ToC that includes causal linkages and assumptions. We thus provide a descriptive ToC based on existing evidence.

Figure 1. Theory of change for the effectiveness of land tenure interventions on the outcomes of reduced deforestation, increased carbon storage and improved livelihoods



Environmental certification schemes seek to promote sustainable forest management practices by leveraging market-based incentives. Certification processes establish environmental and social standards that land managers or firms must meet to obtain certification status. Immediate outputs include compliance with environmental standards, adoption of improved forest management practices, and enhanced access to premium markets or financial incentives. These outputs are expected to lead to intermediate outcomes, such as improved harvesting practices, reduced rates of deforestation, greater biodiversity protection, and strengthened labour conditions. Over time, these improvements are anticipated to result in final outcomes including increased forest cover, climate change mitigation through sustainable management practices, and socioeconomic gains for certified producers and workers.

Accordingly, this review will assess the effects of land tenure reforms and environmental certification both separately and comparatively, focusing on their respective contributions to forest cover, livelihoods, and climate change mitigation outcomes. By explicitly considering the distinct causal pathways of each intervention, the review aims to provide a more precise and policy-relevant synthesis of evidence.

II. METHODS

A. THE OVERALL SYSTEMATIC REVIEW DESIGN APPROACH

An effectiveness review was conducted to assess the extent to which land tenure reforms and environmental certification impact forest cover, livelihoods, and climate change mitigation in developing countries. Accordingly, the review includes only primary studies that estimate the effects of these interventions and apply study designs capable of attributing observed outcomes to the interventions themselves.

The analysis is based on a subset of studies identified through the companion evidence gap map (EGM) (Bertzky and others, 2025). Only experimental and quasi-experimental studies with experimental or quasi-experimental designs, such as difference-in-differences (DID), matching, or regression discontinuity designs, were included.

Eligible effect estimates were synthesized using statistical meta-analysis, generating pooled estimates of impact for each intervention-outcome combination. This quantitative synthesis is complemented by moderator analysis and assessment of heterogeneity, with the aim of identifying patterns in effectiveness across contexts.

1. INTERVENTION-OUTCOME FRAMEWORK FOR THE REVIEW

The intervention-outcome framework used in this review builds on the categories and classifications presented in Figure 1. It provided a structured basis for organizing the evidence and selecting eligible studies and is consistent with the structure adopted in the companion EGM (Bertzky and others, 2025).

The framework focuses specifically on two intervention types, land tenure reforms and environmental certification, and assesses their effects on three outcome domains: forest cover, livelihoods, and climate change mitigation.

2. CRITERIA FOR INCLUSION AND EXCLUSION OF STUDIES IN THE REVIEW

This systematic review includes only primary studies that evaluate the effects of land tenure reforms and environmental certification schemes, implemented with the explicit objective of promoting forest conservation in developing countries. The selection of these interventions is based on the concentration of evidence identified in the companion EGM (Bertzky and others, 2025), which identified a critical mass of rigorous studies in these two areas of intervention.

Land tenure reforms include studies that assess the effects of various forms of recognition and strengthening of rights over forest resources. These interventions focus on land tenure security or forest-friendly titling, including legal recognition of collective territories, including Indigenous lands, community forest management, or land ownership. Further interventions focus on participation in government-led or co-managed programmes such as participatory forest management (PFM), forest co-management, joint forest management, community forestry, or distinctions based on concession type or type of forest zoning unit. Some studies also focus on institutional arrangements such as management type to differentiate intervention groups.

Environmental certification refers primarily to studies that evaluate certification under the standards of the FSC. In the included studies, this intervention was operationalized in terms of whether a forest area, management unit, or producer was certified under FSC, as well as information on duration of certification or compliance with audit requirements.

Only studies employing experimental or quasi-experimental designs that allow for causal attribution were included. Qualitative studies were excluded, although mixed-methods studies were included when the quantitative component met the design and reporting standards. To be eligible for meta-analysis, studies needed to provide sufficient statistical information to compute standardized effect sizes, such as means and standard deviations per group, standard errors (SEs), confidence intervals (CIs), or *t*-values.

Studies conducted at multiple units of observation – that is, households, communities, firms, districts, regions, and countries – were eligible. Interventions had to be implemented in forest ecosystems, including terrestrial forests, mangroves, and agroforestry systems, with an explicit conservation objective. Studies conducted in countries classified as Annex I under the Kyoto Protocol were excluded to maintain focus on developing-country contexts.

Regarding outcomes, all relevant quantitative indicators reported by the studies were included if they corresponded to one of the three domains defined in the protocol: forest cover, livelihoods, and climate change mitigation. For forest cover, examples of indicators include forest area change, deforestation rate, share of forest cover retained, and difference in forest area between treated and control units. For livelihoods, examples include annual income, value of production, revenue from forest products, household consumption, and livestock holdings. In the mitigation domain, the indicator is carbon stock (*t/ha*).

Due to the heterogeneity of reported outcome indicators in terms of units, time frames, and definitions, they were grouped into analytically comparable categories for inclusion in the meta-analysis. Forest cover indicators were grouped as *annual deforestation rate* and *differences in forest cover under different management regimes*. Livelihood indicators were standardized into *income per adult*, *income per household*, and *annual per capita expenditure*. Mitigation outcomes were grouped under *carbon stock*, typically expressed in tons of carbon per hectare (*tC/ha*).

This set of inclusion criteria ensures that the studies considered in the meta-analysis are based on methodologically sound and statistically comparable evidence, allowing for a rigorous evaluation of how land tenure reforms and environmental certification affect key forest conservation outcomes across diverse ecological, institutional, and social contexts.

3. Searching for evidence

The primary evidence base for this systematic review and meta-analysis is drawn from the set of studies identified and screened through the companion EGM (Bertzky and others, 2025). The EGM employed a comprehensive search strategy across multiple academic databases and repositories, as detailed in the section “Search databases and repositories” of the EGM report. This process yielded a total of 4,752 studies, which were systematically screened and catalogued. In the end, 117 new studies were included in the EGM, which, combined with previously identified literature, resulted in a total of 305 studies.

From this initial pool, a focused subset of studies was selected for inclusion in the meta-analysis, based on three specific eligibility criteria: first, that the intervention assessed related to either land tenure reforms or environmental certification; second, that the study reported outcomes related to forest cover, livelihoods, or climate change mitigation; and third, that the study meets methodological standards, that is, it employed experimental or quasi-experimental designs that supported credible causal inference. Studies with high risk of bias were retained in the broader EGM data set but excluded from this review.

Applying these criteria, a final sample of 24 studies on land tenure reforms and five studies on environmental certification was included to undertake a meta-analysis. This selective process ensured that the analysis was grounded in the most methodologically rigorous and thematically

relevant evidence available, allowing for a robust synthesis of the effects of these policy instruments on key conservation and development outcomes.

B. DATA COLLECTION AND ANALYSIS

1. SELECTION OF STUDIES

The selection of studies for this systematic review and meta-analysis was based on the subset of 24 studies on land tenure reforms and five on environmental certification originally retained through the EGM on forest conservation interventions.

Some studies were excluded from the quantitative synthesis despite being included in the EGM, due to limitations in the availability or quality of statistical data required for standardized effect size estimation. In the case of land tenure reforms, seven studies were excluded.[1] Two studies reported only adjusted regression models without providing group-level descriptive statistics or reported effects that could not be decomposed into standardized metrics. Two studies lacked standard deviations or SEs and estimating them would have required strong distributional assumptions. Another used non-parametric methods without providing sufficient variance information. The remaining two were based on spatially aggregated data or pixel-level remote sensing information, which made the reconstruction of variance measures challenging under the assumptions required for meta-analysis.

In the case of certification, two studies were excluded. One of them employed the synthetic control method with a single treated unit per country and did not report group-level variance information (such as standard deviations, SEs, or sample sizes), which made the estimation of standardized effect sizes extremely challenging. The other study, although reporting statistically significant coefficients and SEs from mixed-effects models, used a binary outcome without providing baseline deforestation probabilities for either the treatment or control groups. Estimating standardized effect sizes in this case would have required strong assumptions about group variances and outcome distributions, and therefore the study was excluded from the quantitative synthesis.[2]

In addition, outcome variables were grouped into analytically comparable categories to allow for effect size estimation across heterogeneous studies. However, this standardization process also led to the exclusion of studies reporting indicators that could not be harmonized within any of the outcome domains. For land tenure reforms and forest cover, the following indicators were excluded: incidence of forest fires – grouped, land conversion rate, and signs of anthropogenic damage (*m^2/ha*). For certification and forest cover, excluded indicators were probability of deforestation, percentage cleared, and forest cover change (percentage). For certification and livelihoods, one study reporting malnutrition (number of persons) was also excluded.

Due to the small number of studies on environmental certification (three for forest cover, one for livelihoods, and none for mitigation) and the high heterogeneity of reported outcomes, as evidenced by the incompatible indicators listed above, all certification studies were ultimately excluded from the meta-analysis. The remaining data could not be standardized across studies without introducing unacceptable levels of estimation error. This highlights a critical evidence gap and underscores the importance of generating more robust, causal evidence on environmental certification schemes. Expanding the empirical base on these interventions is essential not only to assess whether they are

[1] Excluded studies from quantitative synthesis for land tenure reforms – Bocci and Fortmann (2023); Gulzar, Lal and Pasquale (2024); West (2024); Pagiola, Honey-Rosés and Freire-González (2016); Putraditama, Kim and Sánchez Meador (2019); Bruggeman, Meyfroidt and Lambin (2015); Scullion and others (2014); Carranza and others (2013); Nelson and Chomitz (2011).
[2] Studies excluded for certification – Bocci and Fortmann (2023); Rana and Sills (2018).

achieving their intended conservation and development goals, but also to understand under which conditions and implementation models are most effective. Without such evidence, it remains difficult to guide policy decisions, allocate funding strategically, or improve the design of certification programmes in practice. Instead of providing a meta-analysis, we offer a short narrative synthesis of the causal certification studies that are available.

Following these exclusions and the regrouping of outcome indicators, the final pool of included studies allowed for a consistent and robust estimation of effect sizes. Table 1 presents the harmonized indicators retained for meta-analysis and the number of included studies per intervention-outcome combination.

Table 1. Standardized outcome indicators and number of studies included by intervention

INTERVENTION	OUTCOME	INDICATOR	NO. OF PAPERS
Land tenure reform	Forest cover	Annual deforestation rate	8
		Difference in forest cover levels under different management regimes	2
	Livelihood	Annual income per adult	2
		Annual income per household	2
		Annual per capita expenditure	2
	Mitigation	Carbon stock	2

2. DATA EXTRACTION AND MANAGEMENT

Data extraction for this review was conducted on the final set of 17 studies on land tenure reforms and three studies on environmental certification retained after applying all inclusion and exclusion criteria. The process involved compiling both methodological features and the qualitative and quantitative data necessary for statistical synthesis, using standardized tools developed for this review. While initial metadata such as geographic region, year, and scale of intervention were imported from the EGM database, all remaining information was systematically extracted from the full texts of the included studies and, when necessary, supplementary materials.

This involved the identification of methodological features and the retrieval of statistical parameters required for conducting heterogeneity tests and estimating combined effect sizes through a random-effects meta-analysis. The variables extracted included effect size estimates, which were either coded as reported (for instance, regression coefficients) or computed using available group-level data such as means and standard deviations. In cases where studies reported multiple outcome measures within the same domain and with consistent directional effects, grouped effect sizes were constructed. Sample sizes for treatment and control groups were also recorded. When disaggregated figures were not available and the study employed matching techniques, it was assumed that both groups had equal sample sizes, in line with the design of matched samples. Additional statistics, such as SEs, standard deviations, and CIs, were extracted where available to allow the computation of effect size variances. When such values had to be inferred, such as estimating a standard deviation from a CI, the procedure used was documented explicitly.

In some instances, the published version of a study lacked sufficient information to compute effect sizes directly. In such cases, supplementary materials hosted on online platforms were consulted to retrieve missing data, including tables, appendices, or figures.

Beyond quantitative data, qualitative characteristics were also extracted to support moderator analysis. These included information on the model used, the dependent and independent variables, the type of dependent variable (e.g. categorical or continuous), and the variable format. In addition, further effort was made to extract or reconstruct, either from the main texts or from external sources, a set of contextual variables relevant to heterogeneity analysis. These included the type of implementing entity (e.g. government, non-governmental organization (NGO)), the duration of the intervention in years, the year the intervention began, the time between implementation and outcome measurement, participant characteristics (such as target group composition), the political system in place at the time of implementation, and the colonial heritage of the country where the intervention occurred.

Finally, a number of contextual variables, such as geographic region, year of publication, and scale of intervention (e.g. national, subnational, community level), were imported directly from the EGM database.

3. Assessment of risk of bias in included studies

The risk of bias assessment was completed during the development of the EGM. In that context, all studies were critically appraised using a structured domain-based framework adapted from Cochrane's risk of bias tool (Sterne and others, 2016), with particular focus on key bias domains such as selection bias, confounding, and measurement of outcomes. Based on this appraisal, studies were categorized into a three-tier system reflecting the level of causal inference and risk of bias.

For this review, we only selected causal studies, defined as those using experimental or quasi-experimental designs that enable a robust estimation of attributable impact. These include randomized controlled trials, DID approaches, instrumental variables, propensity score matching, and other quasi-experimental strategies. These studies are considered to carry a low risk of bias and are methodologically suitable for quantitative synthesis.

As such, all studies included in this review have already undergone a rigorous quality assessment and are deemed sufficiently robust to support the meta-analytic estimation of intervention effects.

4. Measures of treatment effect – methods for handling dependent effect sizes

To allow for meaningful synthesis across studies using different measurement approaches, all effect sizes were standardized using Hedges' *g*. This was either calculated directly from reported values of Cohen's *d* or derived from partial Cohen's *d* estimates in cases where only regression coefficients and SEs were available. In those cases, the pooled standard deviation was reconstructed using the coefficient's SE and the reported sample sizes for the treatment and control groups. The coefficient was then divided by the estimated standard deviation to obtain partial *d*, which was subsequently converted to Hedges' *g* to correct for small sample bias.

From these calculations, additional statistical values were derived to support the meta-analysis. These included the SE of Hedges' *g*, odds ratios and their natural logarithms, the SE of the log odds ratio, and the *Z*-statistic used to assess the direction and strength of each effect. Precision, defined as the inverse of the SE, was also computed to facilitate the assessment of publication bias.

The meta-analysis employed a random-effects model to pool standardized effect sizes. This choice reflects the expectation that the true effects estimated by each study may vary across settings, populations, and intervention modalities, rather than representing a single common effect. A fixed-effects model would have assumed homogeneity of effects, which was not supported by the diversity of the included evidence base.

Several assumptions were applied when studies lacked full statistical reporting. For binary outcomes, the standard deviation was approximated using the square root of the binomial variance. In studies employing matching methods that did not report disaggregated group sizes, equal sample sizes for treatment and control groups were assumed, consistent with the matched design. When a single study presented multiple regression results related to the same intervention-outcome pair and the effects were all in the same direction, a grouped effect was constructed by calculating a weighted average based on sample size.

As previously described in the study selection section, studies that did not report sufficient statistical information or relied on non-parametric methods that would have required strong distributional assumptions to estimate standardized effects were excluded from the quantitative synthesis.

5. Unit of analysis issues

The unit of analysis in this meta-analysis corresponds to individual study-level effect sizes, which may be based on outcomes reported at various aggregation levels, including plot, household, community, or administrative units, depending on the structure and design of each included study. Since some studies reported multiple effect sizes for the same intervention-outcome pair, we applied specific criteria – detailed below – to ensure consistency and comparability across the evidence base.

When studies reported subgroup results, such as by region, forest user type, or management arrangement, individual effect sizes were coded separately to enable their use in potential moderator analyses. In the overall meta-analysis, grouped effects were used if they were provided by the study or could be reconstructed from disaggregated subgroup data.

For studies reporting outcomes at multiple time points, such as yearly follow-up estimates, the most recent effect size was selected for inclusion unless earlier measurements were deemed more appropriate, either because they better reflected the causal effect of the intervention or ensured comparability with similar studies.

When multiple model specifications were presented within a study, preference was given to estimates that adjusted for observable confounders through matching procedures, inclusion of control variables, or weighting techniques. In cases where both adjusted and unadjusted models were available, the adjusted estimates were used. If several adjusted models were reported, the most comprehensive or clearly preferred specification was selected.

Finally, a significance-based selection rule was applied in cases where studies presented multiple effect sizes for a given indicator but none of the estimates were statistically significant. In such cases, the results were excluded from the meta-analysis if they did not contribute evidence of a directional effect and could introduce bias into the pooled estimates. In the end, this did not entail excluding any study but only some of their variables; for example, in the case of Miteva, Loucks and Pattanayak (2015), we opted to analyse “malnourished in 2008,” which was significant at the 5 per cent level, rather than “change in main street lights 2000–2008”, which was not significant, since both outcomes could be considered under livelihood.

6. Assessment of heterogeneity

Statistical heterogeneity across effect sizes was assessed using standard indicators, including the Q statistic, degrees of freedom, and the I^2 statistic, which quantifies the percentage of total variation across studies that is due to heterogeneity rather than chance. These statistics were computed for each intervention-outcome combination included in the meta-analysis.

In addition to these summary metrics, forest plots were generated to visually represent the distribution of effect sizes and the pooled estimates. These graphical outputs facilitated the identification of potential outliers and the overall consistency of findings across studies.

7. Assessment of reporting biases

All studies included in this meta-analysis employed experimental or quasi-experimental designs capable of estimating causal and attributable impacts. These designs are generally considered to carry a low risk of bias and were deemed suitable for inclusion in this review.

Beyond this initial risk of bias screening, additional steps were taken to assess the quality and reliability of the synthesized evidence. To evaluate potential publication bias, Egger's test was applied in cases where at least eight effect sizes were available for a given outcome category. This threshold follows established methodological guidelines, as the test's reliability is substantially compromised in smaller samples. Although Egger's test can be computed with fewer studies, such results are generally unstable and may lead to misleading interpretations. For this reason, outcomes with fewer than eight effect sizes were not subjected to formal testing for publication bias.

When applicable, funnel plots were generated to enable a visual inspection of potential asymmetry in the distribution of effect sizes. However, visual assessments were interpreted with caution, particularly in cases with limited sample size, where patterns may be driven by sampling variability rather than true publication bias.

The overall reliability of combined estimates was further informed by the level of heterogeneity and the precision of effect sizes. These metrics were evaluated jointly with their associated p-values to assess whether pooled results could be considered robust.

8. Data synthesis

The meta-analysis was carried out separately for each outcome domain where at least two comparable effect sizes were available. Standardized effect sizes and their variances were used to compute pooled estimates of intervention effects. Given the expected diversity in study settings, populations, and implementation modalities, a random-effects model was applied in all cases.

All statistical analyses were conducted using Python, which provided the framework for estimating combined effects, assessing heterogeneity, and conducting subsequent sensitivity and moderator analyses. Meta-analyses were performed only when a minimum threshold of data availability and comparability was met to ensure the robustness of the pooled estimates.

9. Heterogeneity

Since moderator analysis was conducted using regressions where the unit of observation is each study, it was ensured that the number of moderators does not exceed the total number of studies included. Importantly, categorical variables were transformed into dummy variables for their inclusion in the model. To avoid multiple variables related to the same topic, these were grouped into coherent categories according to data extracted from the studies.

Considering the methodological limitation regarding the number of moderators that can be included, the analysis focused on theoretically relevant moderators to explain the observed heterogeneity across all intervention-outcome groups. Specifically, the year of intervention start and colonial heritage was included in all cases. The latter may be particularly relevant for land tenure reforms due to its direct influence on national legislation and institutional structures, and for environmental certification because it may indirectly affect compliance levels and the effectiveness of internationally adopted standards at the local level. In cases where the number of included studies

allowed the inclusion of additional moderators, entity type and scale of intervention were also considered.

We chose to include all moderators simultaneously in a single model because this allows us to isolate each moderator's net effect by controlling for correlations among variables and improving estimate precision with a limited number of studies; moreover, this approach maximizes statistical power by leveraging all the data in one fit and reduces the risk of false positives by avoiding multiple comparisons, more faithfully reflecting the theoretical framework that these factors operate jointly.

Table 2 provides a description of the moderators included in the analysis.

Table 2. Moderator variables considered for explaining heterogeneity across forest conservation studies

MODERATOR	DESCRIPTION
Entity type	Type of entity implementing the intervention
Scale	Scope of the intervention
Year of intervention start	The year in which the conservation intervention was initially implemented
Colonial heritage	Colonial background of the country

To minimize the number of dummy variables required for categorical moderators and preserve degrees of freedom in the regression models, categorical moderators were grouped into broader and analytically meaningful categories.[3] These transformations enabled the inclusion of categorical variables without overfitting the models.

Moderator analyses were conducted using weighted least squares (WLS) regression, where each observation (i.e. effect size) was weighted by the inverse of its variance. This approach accounts for the fact that effect sizes with higher precision (i.e. lower SE) should contribute more to the estimation of moderator effects. Unlike ordinary least squares, WLS provides more efficient and unbiased estimates in meta-analytic contexts, particularly when variance in precision is substantial across studies.

10. ESTIMATED EFFECT SIZE AND HETEROGENEITY

To assess the robustness of the meta-analytic findings, we examined the distribution of effect sizes within each outcome category in order to identify potential outliers. This involved both visual inspection of forest plots and verification of the underlying values. No extreme values or anomalous patterns were detected in the outcome variables, and thus no studies were excluded on the basis of outlier status. As a result, all included effect sizes were retained in the final analyses, and no alternative models excluding potential outliers were required. This supports the processes followed and internal consistency of the evidence base. It suggests that the overall results are not driven by a small number of influential studies.

[3] "Entity type" was recoded into four categories – government; government + community; NGO + community; government + NGO + community. "Colonial heritage" was grouped into three categories – Latin, Anglo, and not colonized – to reflect historically rooted legal-institutional differences. "Scale of intervention" was simplified into three levels – national, subnational, community level.

III. RESULTS

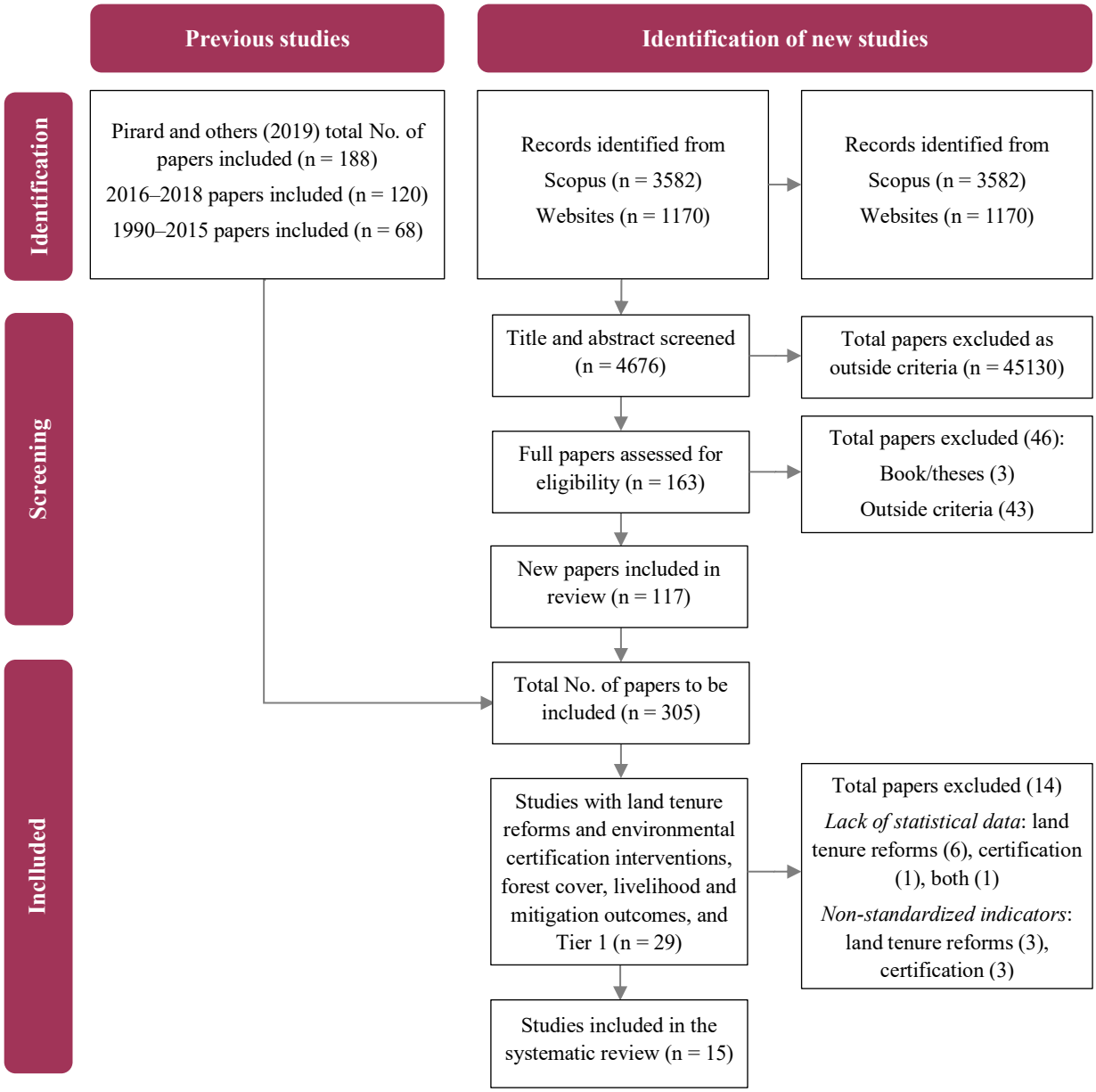
A. DESCRIPTION OF STUDIES: SEARCH RESULTS AND CHARACTERISTICS OF THE EVIDENCE BASE

1. RESULTS OF THE SEARCH

As outlined above, a total of 163 studies were assessed at the full-text stage. Of these, 46 were excluded, primarily because they were not empirical studies (books or theses, $n = 3$) or because they fell outside the scope of relevant interventions or outcomes ($n = 43$). In the end, 117 new studies were included in the EGM, which, when combined with previously identified literature, resulted in a total of 305 mapped studies.

From this pool, 24 studies on land tenure reforms and five studies on environmental certification were selected for potential inclusion in the meta-analysis, based on pre-established criteria regarding methodological design and the relevance of outcomes related to forest cover, livelihoods, or climate change mitigation. However, 14 of these 29 studies were subsequently excluded from the quantitative synthesis due to missing statistical data ($n = 8$) or the use of outcome indicators that could not be standardized ($n = 6$). As a result, 15 studies were retained for the meta-analysis. Notably, due to the small number of certification studies and their high heterogeneity, none were ultimately included in the meta-analysis. Instead, a short narrative synthesis has been included.

Figure 2. PRISMA flow diagram of study selection for the systematic review on forest conservation interventions



Source: Adapted from Page and others (2021); Bertzky, Doswald and Prowse (2024).

2. CHARACTERISTICS OF INCLUDED STUDIES

In this section, we report descriptive results for the review based exclusively on the set of studies included in the meta-analysis. This provides an overview of the characteristics and distribution of the evidence base for land tenure reform interventions, as no certification studies were included in the quantitative synthesis due to a lack of comparable data. We start by presenting the results of the search and screening process, followed by a summary of the characteristics of the included studies. A descriptive narrative of the environmental certification papers is provided in section IV.D.

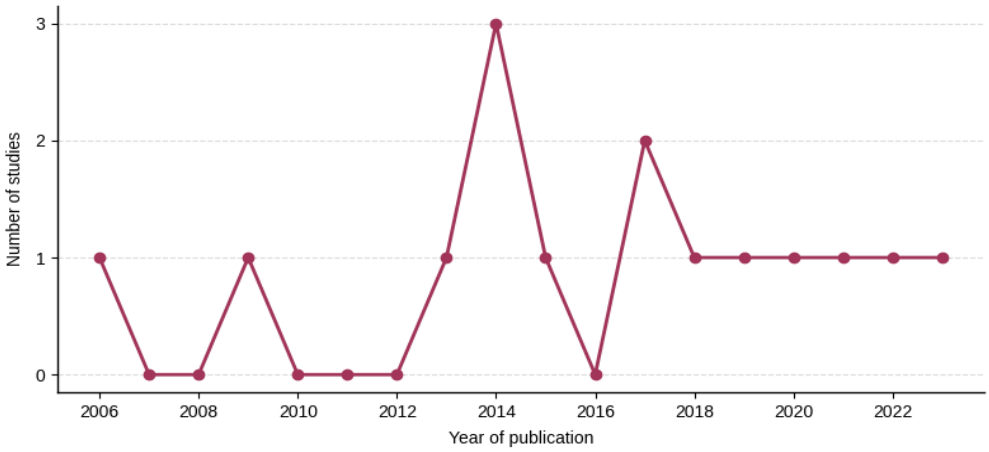
a. Publication trend over time

Figure 3 illustrates the publication trend of included land tenure studies included in our review from 1990 to 2024. Although the methodological scope of the EGM began in 1990, the earliest included publications relevant to this systematic review were published in 2006. Notable early contributions

include Jumbe and Angelsen (2006), Somanathan, Prabhakar and Mehta (2009), and Takahashi and Todo (2013).

Since then, the number of publications has grown, reflecting increasing academic and policy interest in forest governance reforms. A total of 15 studies were ultimately included, with eight studies (53 per cent of the total) published between 2016 and 2023. The peak in annual publications occurred in 2014, with three studies.

Figure 3. Publication trend over time



b. Geographic distribution

The included studies span three major developing regions (Africa, Latin America, and Asia) reflecting a diverse set of governance and socio-ecological contexts for forest conservation (see Figure 4 and Figure 5). While the regional chart provides a summary of the number of studies per continent, the country-level map reveals that a smaller number of countries concentrate most of the evidence. Ethiopia stands out with three studies, followed by Kenya with two. Other countries represented include Brazil, Mexico, India, Madagascar, Cambodia and Bhutan, each with one study. One study was classified as multi-country, covering Argentina, Paraguay and Bolivia. This distribution suggests that despite global interest in land tenure and forest governance reforms, empirical evidence remains geographically concentrated in a few key countries, highlighting opportunities to expand the research base in underrepresented regions.

Figure 4. Country-level distribution of studies included in the meta-analysis

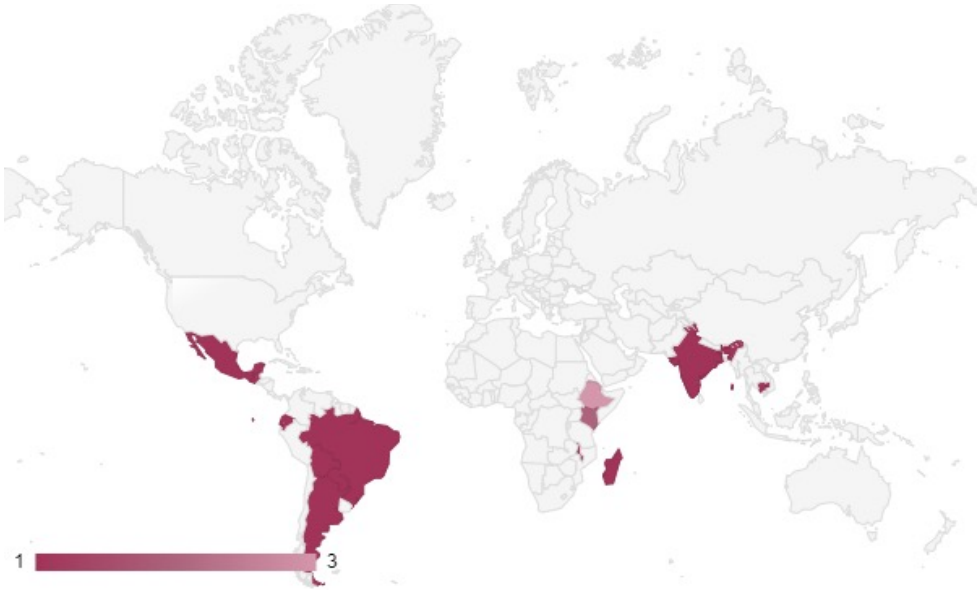
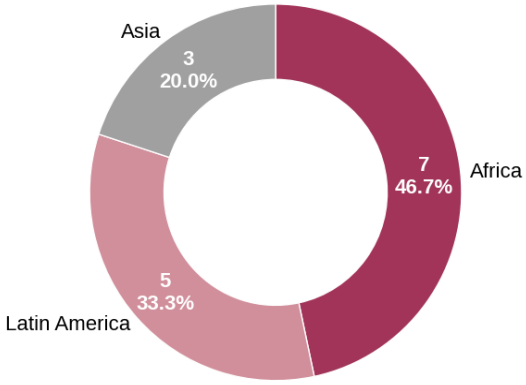


Figure 5. Number of included studies by geographical region



c. Interventions

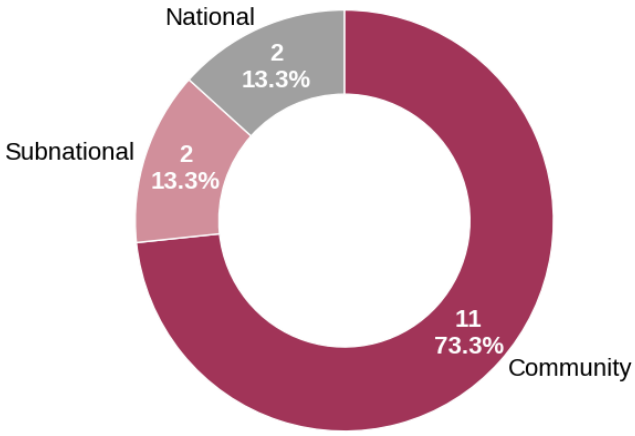
The studies assessed a diverse set of land tenure instruments and institutional mechanisms. Among the most frequent interventions include land tenure security, forest-friendly titling, and land ownership. A significant number of studies also examined participation in specific policy programmes or management arrangements, including PFM, community forestry, forest co-management, joint forest management and Kenya's Plantation Establishment and Livelihood Improvement Scheme (PELIS).[4] In addition, some evaluations included broader governance structures, such as management type, type of forest zoning unit, and concession type.

As shown in Figure 6, most of the analysed interventions (11 out of 15 studies) were implemented at the community level, with only two studies each assessing national or subnational scale reforms. This pattern reflects a predominance of locally implemented or community-driven forest tenure

[4] PELIS is a participatory forest management programme in Kenya that allows community members to cultivate short-term crops in designated forest areas during early reforestation stages, while simultaneously tending tree seedlings, with the dual aim of improving local livelihoods and promoting forest restoration.

reforms within the available evidence base, while evaluations of broader institutional or national-level changes remain comparatively scarce.

Figure 6. Number of studies by scale of intervention

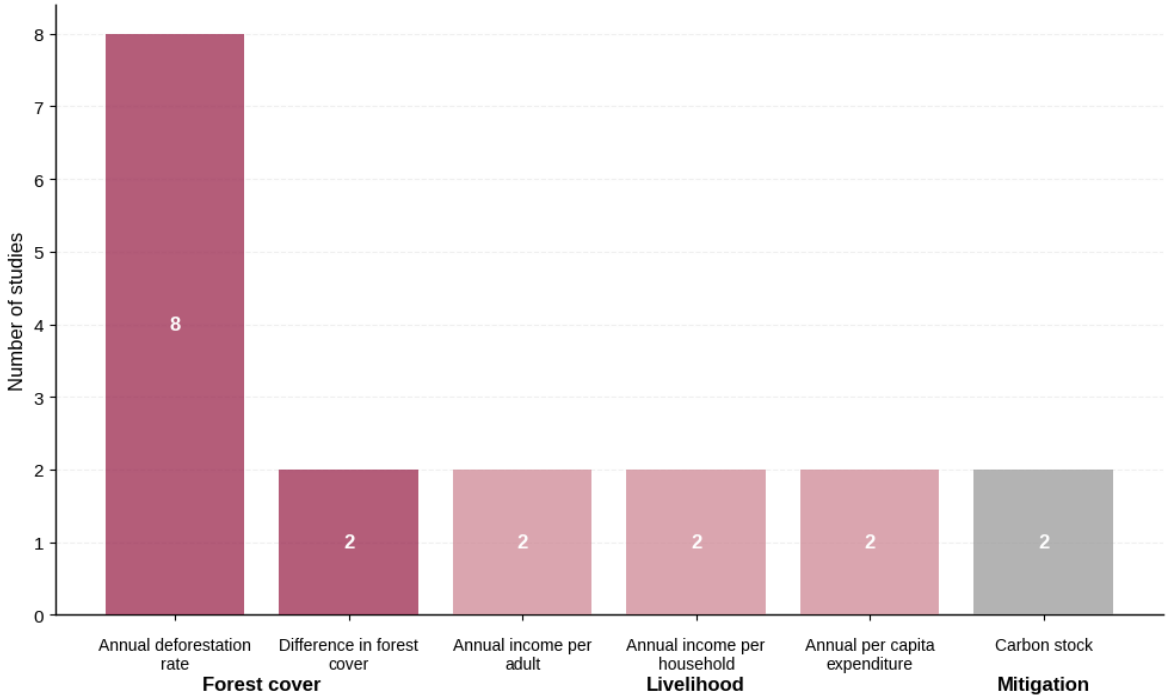


d. Outcomes

Figure 7 displays the distribution of outcome indicators reported in the 15 studies included in the meta-analysis. Most of the evidence focuses on forest cover, with eight studies measuring annual deforestation rates and two studies assessing differences in forest cover levels under different management regimes. Outcomes related to livelihoods are also frequently reported, including annual income per adult (n = 2), annual income per household (n = 2), and annual per capita expenditure (n = 2). Additionally, two studies reported outcomes related to climate change mitigation, specifically carbon stock levels.

The total number of outcome indicators exceeds the number of studies because three papers reported more than one outcome domain. Specifically, Okumu and Muchapondwa (2020) examined both annual per capita expenditure and differences in forest cover levels, Lambini and Nguyen (2022) included annual income per household and carbon stock, and Gelo and Koch (2014) assessed annual per capita expenditure and annual income per adult. This reflects the multidimensional scope of some evaluations, which simultaneously explored multiple channels through which land tenure reforms may influence conservation and development outcomes.

Figure 7. Number of studies by standardized outcome indicator

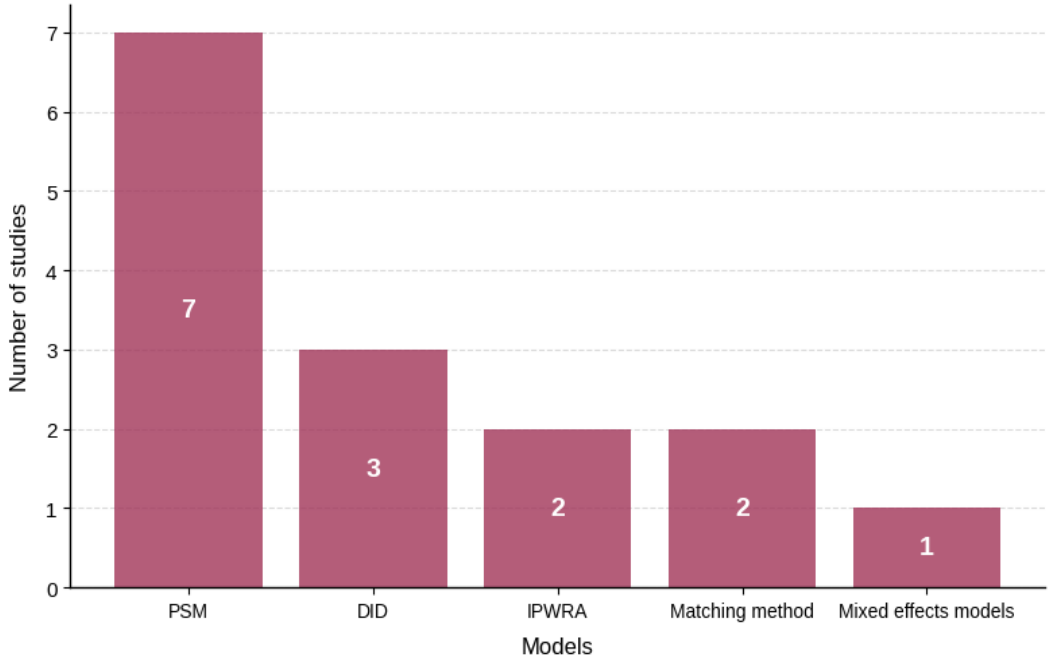


e. Study design of included studies

Figure 8 displays the distribution of estimation models used across the 15 studies included in the meta-analysis. The most frequently employed method is propensity score matching, applied in seven studies, followed by DID in three studies. Additionally, inverse probability weighted regression adjustment and general matching methods were each used in two studies.

Although all selected studies apply quasi-experimental designs that permit causal inference, there is notable variation in the statistical strategies adopted. These differences are important to consider when interpreting heterogeneity in results, as each method carries distinct assumptions and estimation techniques that may influence effect size calculations.

Figure 8. Statistical models used in the included studies



3. Risk of bias in included studies

In line with the methodological focus of this systematic review, a formal risk of bias tool was not applied. This decision was justified by the limited number of included studies and the fact that all employed experimental or quasi-experimental designs capable of estimating causal impacts with relatively low risk of bias. As discussed in earlier sections, eight studies were excluded due to missing statistical information that would have required strong or unverifiable assumptions, and six were excluded because their outcome indicators could not be standardized in terms of units or periods. These exclusions minimized potential bias in the meta-analytic synthesis by ensuring that only methodologically reliable and statistically compatible studies were included.

Nevertheless, among the included studies, some did not directly report all the statistical information needed to calculate standardized effect sizes. All procedures used to address missing information were applied consistently across studies and are fully documented to support transparency and reproducibility.[5] These methodological adjustments were made conservatively and only when sufficient information allowed for reasonably precise estimation. Given the small number of affected cases and the consistent application of transparent criteria, these procedures are not expected to introduce systematic bias into the meta-analytic findings.

4. Synthesis of results

The studies included in this review reflect a geographically and temporally diverse body of evidence centred exclusively on land tenure reforms. Although the broader search initially considered multiple intervention types, including environmental certification, only studies on land tenure reforms met the methodological and statistical criteria required for inclusion in the meta-analysis.

[5] In cases with missing statistical information, the following assumptions were applied: (i) equal group sizes in matched designs when not specified; (ii) estimation of standard deviations from CIs, error bars, or regression SEs; (iii) proportional allocation of sample sizes when partial data were available; and (iv) grouping of multiple outcomes within studies when indicators measured the same construct in the same direction.

This narrowing of scope reinforces the importance of improving the availability and consistency of impact evaluations in underrepresented intervention areas.

The final set of studies spans a variety of regional contexts and governance settings, with most interventions implemented at either the subnational or community scale. The reforms evaluated involve a wide range of institutional arrangements and legal mechanisms, such as forest-friendly titling, recognition of communal rights, and participation in state-led or co-managed forest governance schemes. Despite this diversity, all studies share a focus on formalizing or strengthening rights over forest resources as a means to influence conservation outcomes.

Outcome measurement also shows variation across studies, with most focusing on forest cover, followed by livelihood-related indicators, and a smaller set reporting on carbon stock as a mitigation metric. At the same time, the diversity in outcome definitions and statistical reporting further limited the number of studies that could be included in the meta-analysis, despite their initial relevance.

Although the included studies differ in their specific methodologies and estimation strategies, ranging from matching techniques to regression-based models, all were selected based on strict inclusion criteria and meet the minimum quality standards for causal inference. This ensures that the findings derived from the synthesis rest on a robust and comparable base of empirical evidence.

IV. RESULTS OF THE META-ANALYSIS

In this section, we report the results of the meta-analysis evaluating the effects of land tenure reforms on key forest conservation outcomes. The analysis is structured across three primary outcome domains: forest cover, livelihoods, and climate change mitigation, each disaggregated by specific dependent variables based on the type of indicator reported in the included studies.

A total of six distinct models were estimated, corresponding to the following outcome-variable combinations: (i) annual deforestation rate, (ii) difference in forest cover levels under different management regimes, (iii) annual income per adult, (iv) annual income per household, (v) annual per capita expenditure, and (vi) carbon stock.

For each combination, we conducted a statistical meta-analysis using a random-effects model, generated forest and funnel plots, applied Egger's test to assess potential publication bias, and ran moderator analyses to explore sources of heterogeneity across studies.

A. LAND TENURE REFORM WITH FOREST COVER OUTCOMES

1. EFFECTS OF LAND TENURE REFORM ON ANNUAL DEFORESTATION RATE

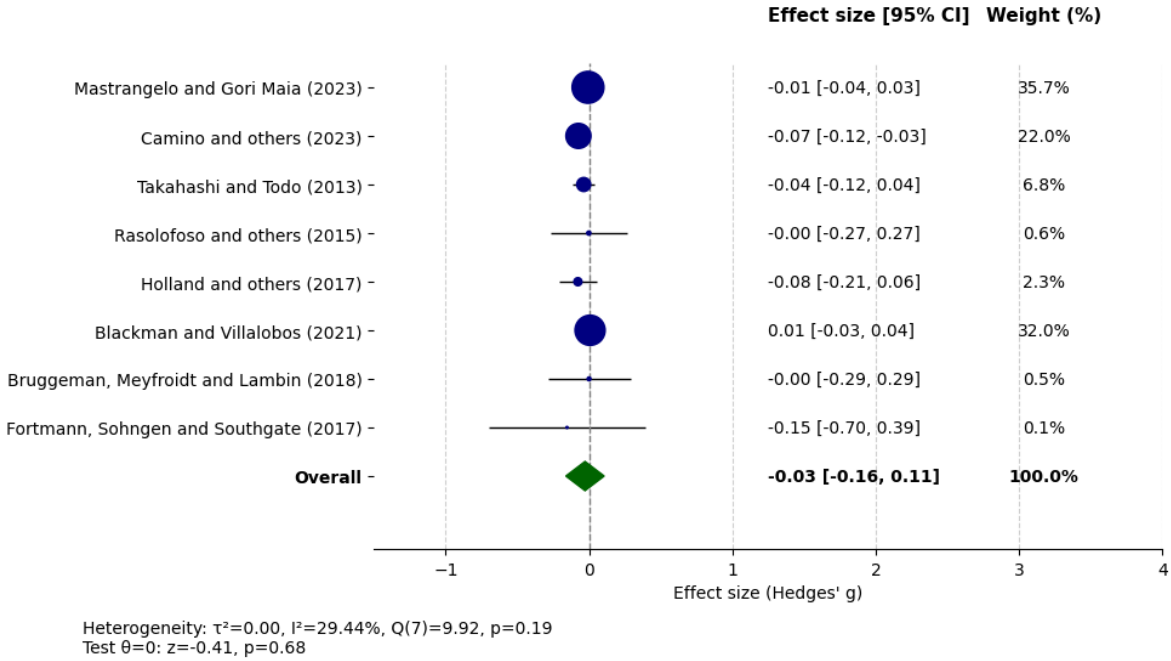
a. Estimated effect size and heterogeneity

This meta-analysis includes eight studies that evaluate the impact of land tenure reforms on annual deforestation rates. The overall pooled effect size is –0.03 (Hedges' *g*), with a 95 per cent CI ranging from -0.16 to 0.11. This estimate suggests that, on average, land tenure reforms have no statistically significant effect on reducing deforestation rates across the sampled contexts ($z = –0.41$, $p = 0.68$).

Among the included studies, individual effects vary in direction and magnitude. For example, Camino and others (2023) reports a significant negative effect (-0.07; 95 per cent CI: -0.12 to -0.03) and contributes 22.0 per cent to the pooled estimate, suggesting that land tenure reform may help reduce deforestation in that context. In contrast, Blackman and Villalobos (2021) shows a small positive effect (0.01; 95 per cent CI: -0.03 to 0.04) and carries a high weight (32.0 per cent), while Mastrangelo and Gori Maia (2023) also contributes substantially (35.7 per cent) with a near-zero, non-significant effect (-0.01; 95 per cent CI: -0.04 to 0.03). The remaining studies contribute smaller weights and present a mix of results, some with wide CIs due to low precision.

Between-study heterogeneity was low to moderate. The I^2 statistic was 29.4 per cent, and the Q-test was not significant [$Q(7) = 9.92$, $p = 0.19$], indicating that most of the variation across studies can be attributed to random sampling error rather than true differences in effects. This consistency provides moderate confidence in the pooled estimate, although contextual factors and implementation differences should be considered when interpreting results.

Figure 9. Forest plot of the effect of land tenure reforms on annual deforestation rate (random-effects model)

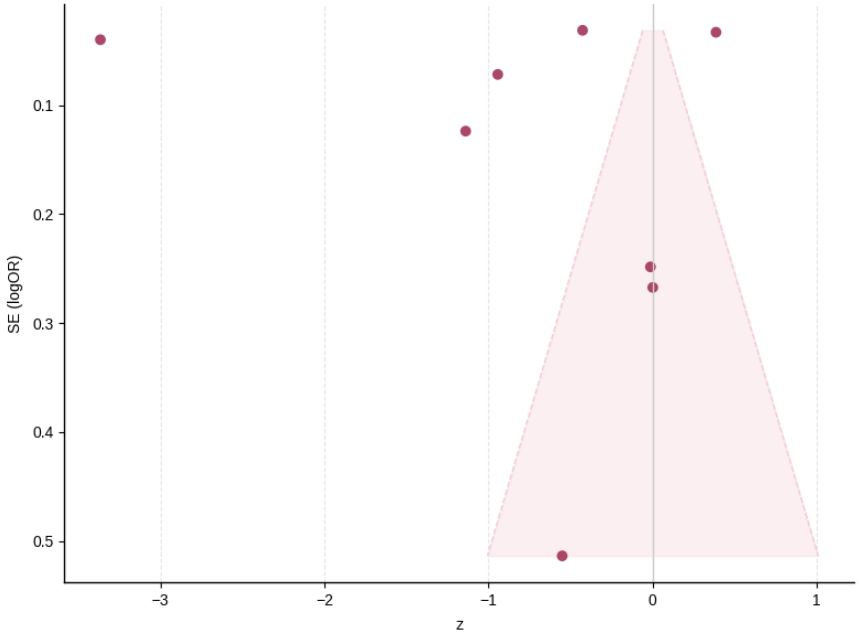


Heterogeneity: τ^2=0.00, I^2=29.44%, Q(7)=9.92, p=0.19
Test θ=0: z=-0.41, p=0.68

b. Publication bias

Publication bias was assessed using Egger's regression test and a funnel plot. The p-value for the intercept in the Egger's test is 0.519, indicating no statistically significant evidence of small-study effects or publication bias. The funnel plot also supports the conclusion that the results are unlikely to be driven by selective reporting.

Figure 10. Funnel plot to assess publication bias for annual deforestation rate studies



c. Moderator analysis

Given the relatively larger number of studies in this outcome group (n = 8), we conducted a multivariate moderator analysis using WLS regression. The model incorporated six moderators: year of intervention start, colonial heritage, type of implementing entity (e.g. government or NGO in partnership with communities), and scale of intervention (community, national, or subnational). Although none of the moderators reached statistical significance, the direction of some coefficients suggests that smaller-scale interventions, particularly those implemented at the community level, might be associated with stronger effects on deforestation reduction. These exploratory patterns, while not conclusive, could inform future research on the contextual factors that shape intervention effectiveness.

Table 3. Moderator analysis for the effect of land tenure reforms on annual deforestation rate

Model: WLS; n = 8; R^2 = 0.97

	coef	std_err	ci_lower	ci_upper	p-value	signif
const	27.32	48.92	-648.92	594.29	0.68	ns
Year of intervention start	0.01	0.02	-0.30	0.32	0.68	ns
Colognial heritage grouped_not colognized	0.09	0.19	-2.34	2.53	0.71	ns
Entity type_government+community	0.10	0.18	-2.13	2.33	0.67	ns
Entity_NGO+community	-0.05	0.19	-2.46	2.36	0.83	ns
Scale of intervention_national	0.07	0.03	-0.31	0.44	0.27	ns
Scale of intervention_subnational	0.04	0.06	-0.73	0.82	0.61	ns

Note: **p<0.01, *p<0.05, ns: not significant

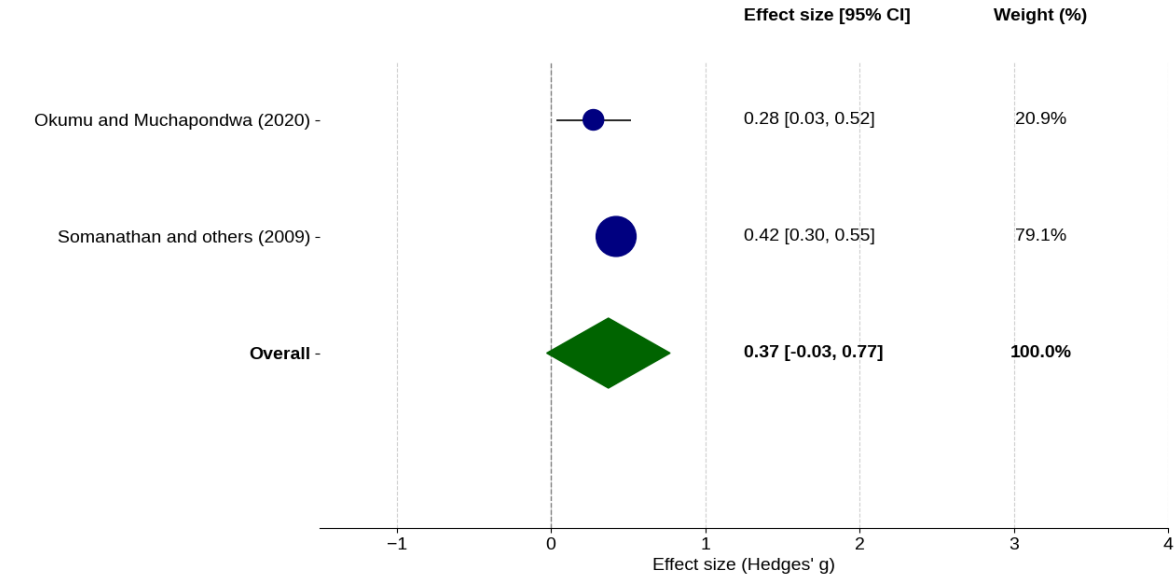
2. Effects of land tenure reform on difference in forest cover levels under different management regimes

a. Estimated effect size and heterogeneity

This outcome includes two studies and yields a moderately large positive pooled effect (Hedges' g = 0.37; 95 per cent CI: -0.03 to 0.77), although the result is not statistically significant at the 5 per cent level (p = 0.07), but it is at the 10 per cent level. The CI includes zero, suggesting that the effect should be interpreted with caution, and heterogeneity is low (I^2 = 11.66 per cent), indicating consistency between the included studies.

Both studies report positive effects, with Okumu and Muchapondwa (2020) estimating a smaller effect size (0.28; 95 per cent CI: 0.03 to 0.52) and contributing 20.9 per cent of the weight, while Somanathan, Prabhakar and Mehta (2009) reporting a slightly larger and more precise estimate (0.42; 95 per cent CI: 0.30 to 0.55) with a dominant contribution of 79.1 per cent to the pooled result. These findings suggest that in contexts where land is managed under community-based or participatory regimes, forest cover levels may be higher compared to those under state or less participatory arrangements.

Figure 11. Forest plot of the effect of land tenure reforms on difference in forest cover levels under different management regimes (random-effects model)



Heterogeneity: τ^2=0.00, I^2=11.66%, Q(1)=1.13, p=0.29
Test θ=0: z=1.82, p=0.07

b. Publication bias

Given that this subgroup comprises only two studies, the Egger's test could not produce interpretable results. The test regression fails to return valid statistics, and the p-value for the intercept is not available. With such a limited number of observations, the regression is not reliable for assessing funnel plot asymmetry. The funnel plot does not suggest strong asymmetry, although the small sample size limits the ability to draw robust conclusions about publication bias. In line with good meta-analytic practice, no definitive interpretation is made in this case.

c. Moderator analysis

Given the limited number of studies (n = 2), only one moderator, the year the intervention started, was included in the weighted least squares regression. The analysis returned a statistically significant result, but this should be interpreted with caution due to the lack of degrees of freedom and the perfect fit (R^2 = 1.00) likely driven by the small sample size. Despite statistical significance, the practical implications remain uncertain, and no firm conclusions about temporal trends can be drawn from this model.

Table 4. Moderator analysis for the effect of land tenure reforms on differences in forest cover levels under different management regimes

Model: WLS; n = 2; R^2 = 1.00

	coef	std_err	ci_lower	ci_upper	p-value	signif
const	4.1	0.46	3.21	4.99	0.00	**
Year of intervention start	-0.0	0.0	-0.0	0.0	0.00	**

Note: **p<0.01, *p<0.05, ns: not significant

3. NARRATIVE SYNTHESIS: FACTORS THAT INFLUENCE THE EFFECTIVENESS OF LAND TENURE ON FOREST COVER AND DEFORESTATION

Four of the selected studies report that secure and well-defined land rights can help kerb deforestation (Camino and others, 2023; Holland and others, 2017; Mastrangelo and Gori Maia, 2023; Takahashi and Todo, 2013). For example, formalizing Indigenous and community land titles has acted as a barrier to forest clearing in places like the Amazon and Chaco and encouraged compliance with environmental laws. Further, Holland and others (2017) found that titling programmes that included conservation conditions, such as Ecuador's "forest-friendly" title, significantly reduced deforestation by ~34 per cent relative to untitled lands, whereas titling without such restrictions had no significant effect. Similarly, Rasolofoson and others (2015) and Blackman and Villalobos (2021) concluded that tenure-based reforms (like community forest management (CFM) agreements) alone did not consistently reduce deforestation unless paired with strong restrictions (in this case that prohibited commercial forest use) and governance. Mastrangelo and Gori Maia (2023) also highlights that in many contexts, land titling alone does not reduce deforestation and may even facilitate it if governance is weak. The effectiveness of tenure or forestry rights depends strongly on local socioeconomic and environmental context. Without capacity or governance, tenure reform alone can fail or backfire.

This underscores that simply granting title may not be enough. When tenure reform is coupled with rules or community management responsibilities, forests are better protected. Indeed, giving local communities authority and responsibility to manage forests can lead to improved environmental outcomes when supportive conditions (and as mentioned above, proper restrictions) are in place. Numerous case studies show community forestry helping to slow deforestation and even increase forest cover (Fortmann, Sohngen and Southgate, 2017; Lambini and Nguyen, 2022; Lambrick and others, 2014; Okumu and Muchapondwa, 2020; Somanathan, Prabhakar and Mehta, 2009). In Guatemala's Maya Biosphere Reserve, for example, community forest concessions have been highly effective – deforestation was significantly reduced across all concession types (long-established villages, recent settlers, and even groups not residing on-site), compared to similar areas without community management (Fortmann, Sohngen and Southgate, 2017). The sustainable use aspect of many community forest systems may be a key enabling factor – when communities derive regulated benefits (timber, fuelwood, non-timber forest products) from the forest, they have a vested interest in keeping it healthy. For instance, Bhutan's forest land-use zoning illustrates that even productive use zones can conserve forests: strictly managed forest management units (some involving local community labour and benefit-sharing) cut deforestation rates roughly in half relative to unmanaged forests (Bruggeman, Meyfroidt and Lambin, 2018).

Not all community-based initiatives succeed in improving the environment; outcomes are mixed when enabling conditions are absent. One major hindrance is weak local institutions or capacity. If a community lacks the organizational structure, skills, or resources to manage and patrol the forest, the result may be continued degradation despite the nominal community management label (Lambini and Nguyen, 2022). High opportunity costs pose another hindrance: when pressure for land or income is high, communities may struggle to restrict forest use. In other words, if turning forest into farms or pastures promises immediate returns and the community regime cannot compensate for that, deforestation may continue. Empirical evidence from Mexico underscores this – nationally, community forestry permits did not yield a clear reduction in tree cover loss except in certain subgroups, suggesting that where the demand for cleared land is high and governance is weak, community management alone is not enough to halt deforestation (Blackman and Villalobos, 2021). Another concern is leakage, where successful protection in one area shifts deforestation to adjacent lands. Guatemala's experience illustrates this: in concessions inhabited by recent migrants

(who had strong farming traditions), deforestation inside the managed area dropped, but some clearing leaked into nearby unmanaged forest as people likely displaced their activities (Fortmann, Sohngen and Southgate, 2017). Finally, a lack of long-term support from governments can hinder community efforts – if policies flip-flop or enforcement backstops are removed, communities may be left vulnerable to external incursions or may become discouraged in their conservation efforts.

B. LAND TENURE REFORM WITH LIVELIHOOD OUTCOMES

1. EFFECTS OF LAND TENURE REFORM ON ANNUAL INCOME PER ADULT

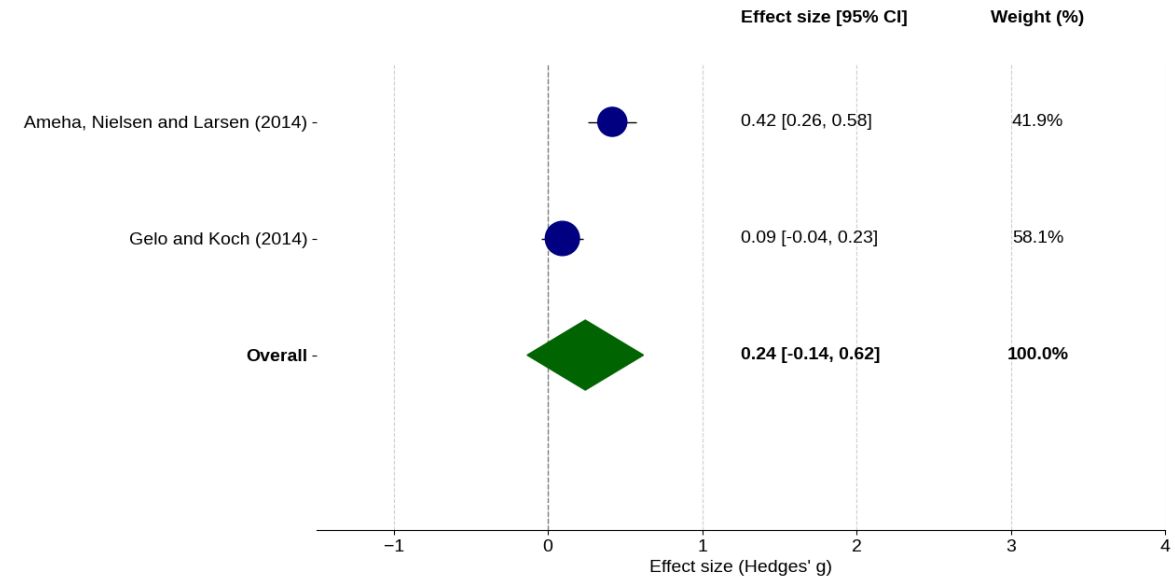
a. Estimated effect size and heterogeneity

This meta-analysis includes two studies reporting on the effects of land tenure reforms on annual income per adult: Gelo and Koch (2014) and Ameha, Nielsen and Larsen (2014). Both studies report positive effects, but only one is statistically significant. The pooled effect size from the random-effects model is 0.24 (95 per cent CI: -0.14 to 0.62), indicating a small positive association between land tenure reforms and adult income. However, the CI includes zero, suggesting the result is not statistically significant.

Ameha, Nielsen and Larsen (2014) reports a moderate and statistically significant effect (0.42, 95 per cent CI: 0.26 to 0.58), while Gelo and Koch (2014) reports a smaller and non-significant effect (0.09, 95 per cent CI: -0.04 to 0.23). In terms of weights, Gelo and Koch (2014) contributes more to the pooled estimate (58.1 per cent), which may help explain why the overall effect is closer to zero despite the stronger result from Ameha, Nielsen and Larsen (2014) (41.9 per cent). This distribution of weights reflects differences in study precision.

Heterogeneity is high in this model, with I^2 = 89.32 per cent and a significant Q statistic [$Q(1)$ = 9.36, p = 0.00], indicating substantial variation between the two estimates that is unlikely due to chance alone. This suggests that contextual or methodological differences between the studies may underlie the divergence in results.

Figure 12. Forest plot of the effect of land tenure reforms on annual income per adult (random-effects model)



Heterogeneity: τ²=0.00, I²=89.32%, Q(1)=9.36, p=0.00
Test θ=0: z=1.26, p=0.21

b. Publication bias

Given that this analysis includes only two studies, standard tests for publication bias such as Egger's regression are not appropriate. As expected, the regression output yields invalid or undefined statistics (e.g. p = nan[6]), and should not be interpreted. Visual inspection of the funnel plot shows that both effect sizes fall outside the pseudo-triangle of symmetry, but any inference should be made with caution due to the very limited number of observations. In this context, publication bias cannot be meaningfully assessed.

c. Moderator analysis

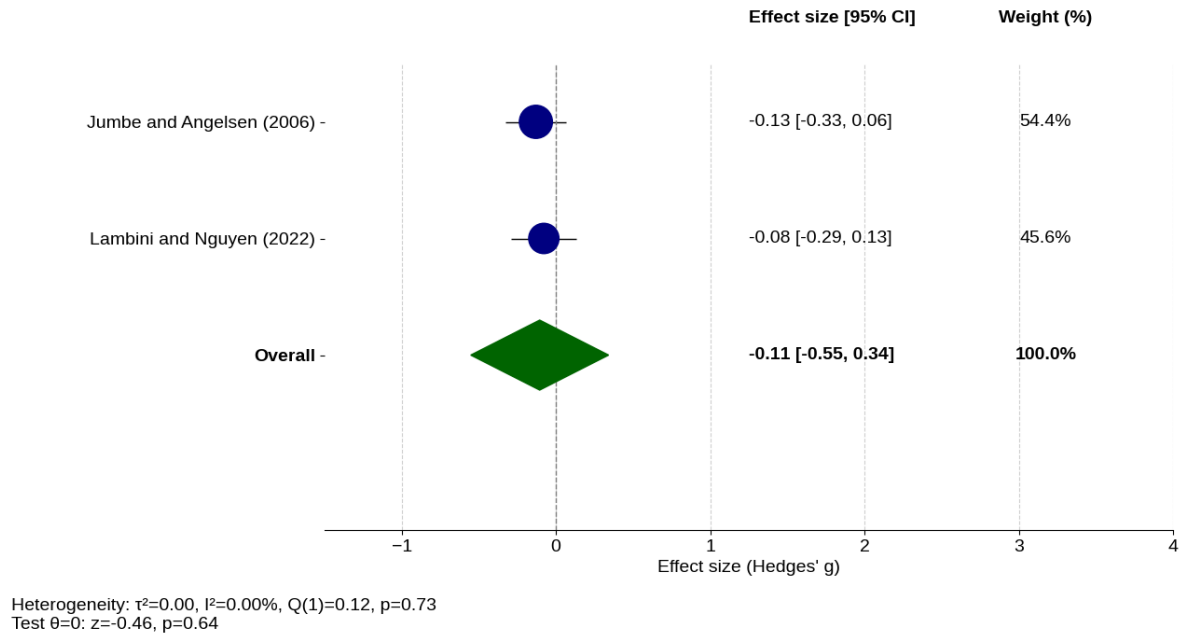
A WLS meta-regression was conducted to explore whether the year of intervention start could explain variation in effect sizes. This was the only moderator included, as both studies shared the same value for colonial heritage ("not colonized"), making this variable uninformative for this subset. However, given the limited number of observations (n = 2), the model returned infinite SEs and missing p-values, preventing any meaningful interpretation. As such, no evidence of moderation can be reported for this outcome, and these results should be interpreted with due caution.

2. Effects of land tenure reform on annual income per household

a. Estimated effect size and heterogeneity

The meta-analysis of two studies evaluating the effect of land tenure reforms on annual household income yields an overall effect size of g = -0.11 (95 per cent CI: -0.55, 0.34), indicating a small, negative and statistically non-significant association. The weights assigned to the studies were relatively balanced, with Jumbe and Angelsen (2006) contributing 54.4 per cent and Lambini and Nguyen (2022) contributing 45.6 per cent of the total. Both studies reported effect sizes with CIs crossing zero, suggesting a lack of clear evidence of impact. There was no observed heterogeneity (I^2 = 0.00 per cent), and the test for overall effect was non-significant (p = 0.64).

Figure 13. Forest plot of the effect of land tenure reforms on annual income per household (random-effects model)



[6] nan = mising value

b. Publication bias

Due to the inclusion of only two studies in this outcome category, standard assessments of publication bias are not reliable. The Egger's regression test could not produce valid results, as expected for models with fewer than eight effect sizes. Similarly, while the funnel plot offers a basic visual assessment, any inference drawn from it must be approached with caution given the limited data. Overall, no conclusive assessment of publication bias can be made for this outcome.

c. Moderator analysis

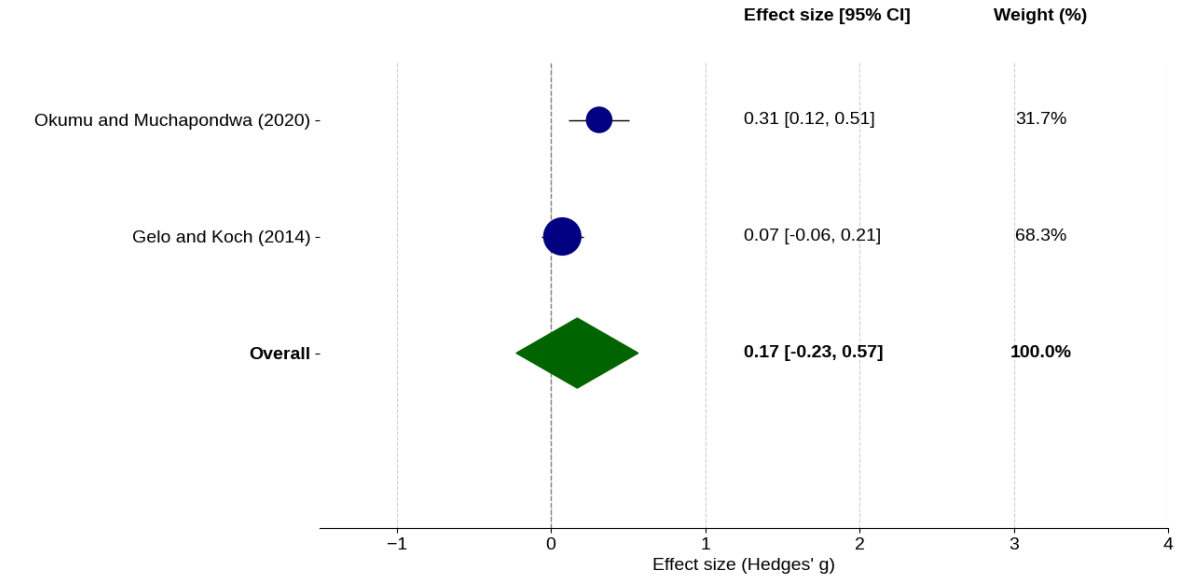
Given the small number of studies (n = 2), only one moderator was included in the analysis: year of intervention start. Colonial heritage was not considered here because both studies shared the same value for that variable (both Anglo), making its inclusion meaningless from a statistical perspective. The model did not yield statistically significant results. The coefficient for year of intervention start was close to zero, suggesting no consistent trend in effect sizes over time. As with other outcomes based on a limited number of studies, these findings should be interpreted with caution.

3. Effects of land tenure reform on annual per capita expenditure

a. Estimated effect size and heterogeneity

The combined estimate from two studies examining the effect of land tenure reforms on annual per capita expenditure yielded a small and statistically non-significant positive effect (Hedges' g = 0.17, 95 per cent CI: -0.23 to 0.57, p = 0.40). The effect is not robust and the CI is wide, indicating a high degree of uncertainty about the true effect direction and magnitude. The analysis shows moderate heterogeneity across studies (I^2 = 74.11 per cent), suggesting that variation in context or study design may influence results. Okumu and Muchapondwa (2020), contributing 31.7 per cent of the weight, reported a stronger positive effect than Gelo and Koch (2014), which carried 68.3 per cent of the weight and reported a much smaller effect. This imbalance in study weights, coupled with heterogeneity, warrants caution in drawing general conclusions from this subgroup.

Figure 14. Forest plot of the effect of land tenure reforms on annual per capita expenditure (random-effects model)



Heterogeneity: τ²=0.00, I²=74.11%, Q(1)=3.86, p=0.05
Test θ=0: z=0.84, p=0.40

b. Publication bias

Egger's regression test was conducted to assess potential publication bias. However, the number of observations ($n = 2$) is below the minimum recommended threshold of eight, rendering the statistical test unreliable. The intercept's p-value could not be estimated and appears as nan, confirming that the model is not informative in this context. Visual inspection of the funnel plot shows only two studies, which are moderately dispersed and do not suggest strong asymmetry. Nonetheless, the limited number of effect sizes prevents any meaningful interpretation of symmetry or bias. Therefore, no conclusions regarding publication bias can be drawn for this outcome.

c. Moderator analysis

Two separate moderator analyses were conducted for this outcome. First, the year of intervention start was included as a continuous moderator, but the model produced non-significant results and showed estimation issues due to the small sample size ($n = 2$). Second, colonial heritage was explored as a categorical moderator. One of the studies was classified as "not colonized", but again, the model yielded no statistically significant associations. Given the extremely limited number of observations and the absence of variation across moderator categories, these results should be interpreted with caution and are not conclusive.

4. Narrative synthesis: factors that influence the effectiveness of land tenure on livelihoods

Strengthening land tenure can bolster livelihoods by providing stability and opportunities for local people, especially with community forest management agreements. Indeed, a core premise of community forest management is that it can deliver economic benefits to local people, and indeed there are documented cases of improved livelihoods under these regimes. Where communities are allowed to sustainably commercialize forest resources, they often see income gains. For instance, in Ethiopia's Dodola forest (a PFM pilot site), community members were permitted to harvest and sell timber; as a result, households in the forest user group earned higher forest-related income and accumulated more livestock (a key asset) than non-members, without any drop in overall income (Ameha, Nielsen and Larsen, 2014). In other words, sharing in the forest's economic value created a net livelihood benefit for participants. Another example comes from Kenya's PELIS, an agroforestry-based community programme: participants could intercrop food crops with young trees on reserve land. This scheme boosted average household welfare by 15–28 per cent (income or consumption increase) relative to non-participants, while also increasing forest cover, which is a clear win-win on livelihoods and environment (Okumu and Muchapondwa, 2020). Community forestry can also diversify livelihoods and make them more resilient. A study of joint forest management in Ethiopia found that although programme rules curtailed some activities (like expanding farmland), households responded by shifting labour into non-timber forest product collection and saw significant increases in earnings (Gelo and Koch 2014). This kind of diversification (beekeeping, medicinal plants, ecotourism, etc.) provides new income streams tied to intact forests. There is evidence from Asia and Latin America that, with the right market linkages, community-managed forests yield products and employment that improve local living standards (Lambini and Nguyen, 2022). Finally, community control over forests can enhance equity if all community members have a voice and share in benefits – for Indigenous and long-standing forest communities, devolved management has, in some cases, meant greater empowerment and retention of profits locally rather than benefits accruing only to outside companies or the state.

Despite these successes, community forestry can struggle to deliver equitable or sufficient livelihoods under various conditions. One major issue is when use rights are too restrictive. If a

programme limits communities to subsistence extraction only (no commercial use), people may face a net loss. This was observed in the Chilimo PFM site in Ethiopia, where rules prevented most commercial harvesting meaning that members of that programme ended up with lower total incomes and fewer assets than those outside the programme because their access to forest resources was curtailed without an adequate alternative (Ameha, Nielsen and Larsen, 2014). Similarly, community conservation initiatives that prohibit traditional practices (hunting, woodcutting) need to replace those sources of food or income; if they do not, households can become worse off. Another hindering factor is the cost of participation. Engaging in patrols, meetings, tree planting, or adhering to new regulations can impose labour and time costs on villagers. In Kenya, members of Community Forest Associations experienced a significant income shortfall (over USD 500 equivalent per year on average) associated with participation, because the current model provided environmental improvements but limited income opportunities (Lambini and Nguyen, 2022). Without external support (e.g. payments or agricultural benefits) to offset these opportunity costs, such communities effectively pay out of pocket for conservation, which is not sustainable for poverty reduction. Elite capture is another common problem: better-off or better-connected community members may usurp disproportionate control or benefits from community forests. Evidence from the PELIS programme showed that while average incomes rose, the poorest and most marginalized households saw little to no benefit with wealthier households able to capture the gains (such as larger plot allotments or better yields), exacerbating local inequality (Okumu and Muchapondwa, 2020). This inequitable distribution undermines the poverty alleviation goal of community forestry and can breed resentment or non-compliance among those left out. Additionally, not all community forestry translates to new income in practice. Some evaluations (e.g. in South Asia) found no significant difference in household income between villages with participatory management and those without, after accounting for selection bias (Lambini and Nguyen, 2022). Such outcomes often stem from weak implementation: promised benefits (like ecotourism revenue or timber dividends) may not materialize due to mismanagement, corruption, or market barriers. In summary, the studies found that community forest management can falter on livelihoods if benefits are too meagre, delayed, or unevenly shared. Furthermore, lack of capacity to add value to forest products, poor access to markets, or exclusion of women and minorities from decision-making are further factors that can hinder broad livelihood improvements. Programmes need to be designed with fair benefit-sharing, support for enterprise development, and inclusion of the poorest to truly succeed on the social level (Lambini and Nguyen, 2022; Okumu and Muchapondwa, 2020).

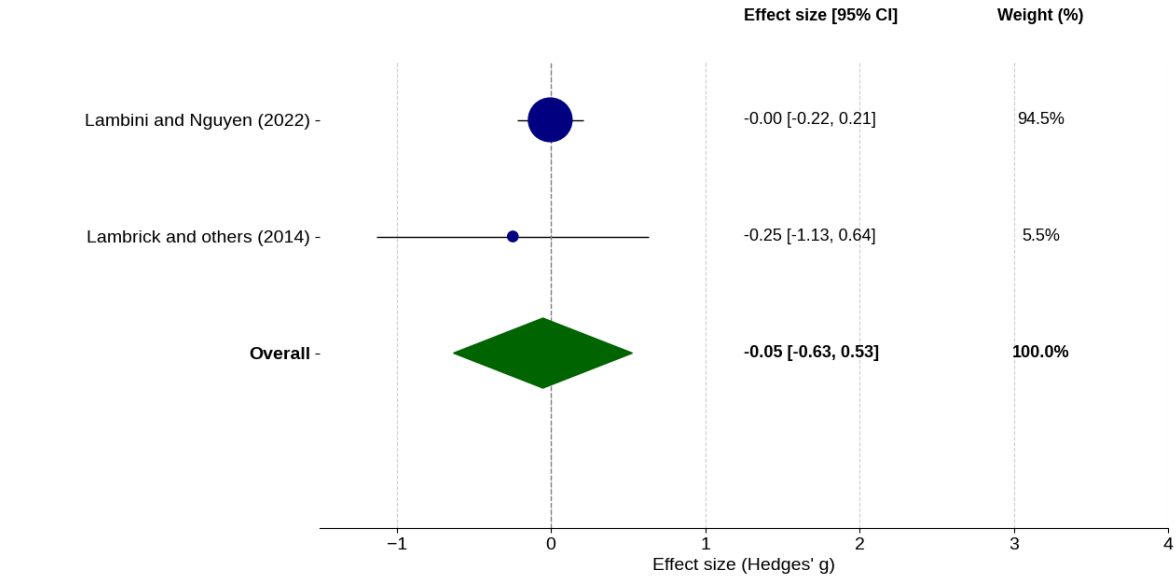
C. Land tenure reform with mitigation outcomes

1. Effects of land tenure reform on carbon stock

a. Estimated effect size and heterogeneity

Two studies assessed the effect of land tenure reforms on carbon stock. Lambini and Nguyen (2022) reported a null effect, with nearly identical carbon stock levels in treated and control areas. In contrast, Lambrick and others (2014) found a negative effect, indicating lower carbon stock in treated areas, although with wide CIs. The meta-analytic estimate suggests a small and statistically non-significant negative effect (g = -0.05; 95 per cent CI: -0.63, 0.53). The heterogeneity across studies was negligible (I^2 = 0.00 per cent), and results were strongly influenced by the larger study, which accounted for 94.5 per cent of the total weight.

Figure 15. Forest plot of the effect of land tenure reforms on carbon stock (random-effects model)



Heterogeneity: τ^2=0.00, I^2=0.00%, Q(1)=0.27, p=0.60
Test θ=0: z=-0.18, p=0.86

b. Publication bias

Given the small number of available studies (n = 2), Egger's test could not be interpreted due to statistical limitations (intercept p-value = nan). The funnel plot shows both studies falling within the expected distribution range, but with such limited data, visual patterns must be interpreted cautiously. No robust conclusions about publication bias can be drawn in this case.

c. Moderator analysis

Given the small number of studies available for this outcome (n = 2), moderator analysis was limited to two variables: year of intervention start and colonial heritage. These moderators were selected because both varied across the included studies. Unlike other subsets where colonial heritage was constant, in this case, one study was classified as "not colonized" while the other had a colonial background, making its inclusion meaningful.

The results from both models were not statistically significant. The coefficient for year of intervention start was close to zero, indicating no detectable temporal trend. Similarly, although the sign of the coefficient for the colonial heritage moderator was negative, the effect was not statistically significant. Given the limited number of observations and wide uncertainty, these findings should be interpreted with caution.

Table 5. Moderator analysis (colonial heritage) for the effect of land tenure reforms on carbon stock

Model: WLS (HC3); n = 2; R^2 = 1.00

	coef	std_err	ci_lower	ci_upper	p-value	signif
const	-0.0	0.03	-0.06	0.05	0.86	ns
Colonial heritage grouped_Latin	-0.24	0.23	-0.69	0.2	0.29	ns

Note: **p<0.01, *p<0.05, ns: not significant, nan: missing value, inf: infinite

2. NARRATIVE SYNTHESIS: FACTORS THAT INFLUENCE THE EFFECTIVENESS OF LAND TENURE ON GREENHOUSE GAS MITIGATION

Land tenure reforms that reduce deforestation directly contribute to climate change mitigation by avoiding CO_2 emissions from forest loss, whether or not articles measure carbon stock. For instance, securing land rights in the Amazon helps maintain the extensive carbon stocks in standing forests; this is critical given Amazon deforestation is a leading source of Brazil's carbon emissions (Mastrangelo and Gori Maia, 2023). In Acre (Brazil), farms with secure tenure not only deforest less but also comply with laws requiring 80 per cent of each holding to remain forested (Mastrangelo and Gori Maia, 2023); such compliance preserves significant carbon sinks. Secure tenure also allows landholders and communities to participate in carbon finance mechanisms. By enabling enrolment in programmes like REDD+ or other conservation payments, tenure reforms align local incentives with global carbon benefits. In short, when people have secure rights to land and forests, they are more likely to manage these resources sustainably for long-term value (including carbon storage) rather than engaging in short-term carbon-releasing land grabs.

One potential challenge may be the lack of direct incentives for carbon stewardship at the local level. If communities and farmers do not receive compensation for the carbon storage value of keeping forests intact, they may opt for land uses that emit carbon (e.g. clearing for agriculture) to support their livelihoods. Evidence from Kenya underscores this point: a community conservation initiative produced positive environmental services but no measured improvement in local "carbon" outcomes, likely because participants bore costs with no carbon payment to offset them (Lambini and Nguyen, 2022).

Leakage is also a carbon concern. If community protection in one area displaces deforestation to adjacent lands, the climate benefit is eroded. In Guatemala, a degree of leakage was observed around some newer community concessions (deforestation moved to nearby unmanaged parcels as pressure was redirected) (Fortmann, Sohngen and Southgate, 2017). Although the overall carbon saved inside the concessions outweighed the leaked emissions (Fortmann, Sohngen and Southgate, 2017), this phenomenon warns that isolated community projects need integration into larger land-use strategies to maximize net carbon gains. Another hindrance is that not all community forestry actually stops degradation. Some programmes allow controlled harvesting which, if poorly regulated, could lead to gradual carbon loss (e.g. overharvesting fuelwood or slow attrition of biomass even if outright deforestation is avoided). Ensuring that community use is truly sustainable is crucial for carbon and this requires technical training, monitoring, and sometimes external oversight or partnerships. Lastly, the initial years of a community forestry project might show little carbon benefit, or even a slight drop in measured carbon, especially if transitioning from a scenario of unmanaged use. For instance, in one Kenyan case the "carbon stock" outcome for participants was slightly negative (though not significant) (Lambini and Nguyen, 2022), possibly because old practices persisted or because forest regrowth takes time to manifest. This indicates that timeline is a factor. Community management might need a longer horizon to yield appreciable carbon sequestration, and short-term assessments could underestimate the benefits. In conclusion, community forest management can be a powerful tool for carbon mitigation but its effectiveness hinges on supportive measures like carbon payments for communities, strong prevention of leakage, sustainable harvest practices, and patience to allow forests to recover. With these in place, the dual goals of empowering local communities and protecting the global climate become mutually reinforcing (Lambini and Nguyen, 2022; Fortmann, Sohngen and Southgate, 2017).

D. NARRATIVE SYNTHESIS FOR ENVIRONMENTAL CERTIFICATION

This section provides a narrative synthesis of five environmental certification studies that could not be included in the meta-analysis due to incompatible outcome measures.

1. THE EFFECTIVENESS OF ENVIRONMENTAL CERTIFICATION ON FOREST COVER OUTCOMES

Five studies focus on the effectiveness of environmental certification on forest outcomes. Takahashi and Todo (2013) found that shade coffee certification in Ethiopia led to a statistically significant reduction in deforestation, decreasing the probability of forest loss by 1.7 percentage points in certified areas. Miteva, Loucks and Pattanayak (2015), analysing FSC-certified logging concessions in Indonesia, reported a 5-percentage point reduction in aggregate deforestation between 2000 and 2008. Rana and Sills (2018) evaluated certification in Brazil using synthetic control methods and found little to no consistent difference in forest outcomes attributable to certification. Similarly, Blackman, Goff and Rivera Planter (2018) and Bocci and Fortmann (2023) did not find statistically significant reductions in deforestation associated with certification. Overall, while some studies identify positive effects on forest conservation, the evidence is mixed, with effectiveness appearing to depend on implementation context and methodological approach. Table 6 summarizes the findings.

Table 6. A narrative synthesis of certification on forest cover

STUDY	INTERVENTION TREATMENT COMPONENT	CONTEXT	FINDINGS
Bocci and Fortmann (2023)	FSC certification of community concessions	Latin America; community scale	Certification was not significantly associated with lower forest loss; effects varied across locations.
Takahashi and Todo (2013)	Shade coffee certification	Africa; smallholder producers	Certification reduced deforestation probabilities in wild coffee forests, with positive spillover effects.
Blackman, Goff and Rivera Planter (2018)	FSC certification	Latin America; subnational scale	No statistically significant impact of FSC certification on deforestation after 16 years.
Miteva, Loucks and Pattanayak (2015)	FSC certification	Asia; national scale	Aggregate deforestation was lower in certified concessions between 2000–2008, driven by reduced clearing and fires.
Rana and Sills (2018)	FSC certification	Brazil, Gabon, Indonesia; subnational scale	Effects were mixed: some reductions (Indonesia), null (Gabon), and even increases (Brazil) in tree cover loss.

2. THE EFFECTIVENESS OF ENVIRONMENTAL CERTIFICATION ON LIVELIHOOD OUTCOMES

Only one study reporting livelihood-related outcomes from certification met the inclusion criteria but could not be included in the meta-analysis due to incompatible metrics. Miteva, Loucks and Pattanayak (2015) used malnutrition as a proxy for welfare and found statistically significant improvements in certified areas. Table 7 summarizes the findings.

Table 7. A narrative synthesis of certification on livelihood

STUDY	INTERVENTION TREATMENT COMPONENT	CONTEXT	FINDINGS
Miteva, Loucks and Pattanayak (2015)	FSC certification of community concessions	Asia; national scale	Certification reduced malnutrition risk and improved household welfare via changes in forest access.

V. DISCUSSION

This meta-analysis aimed to assess the effects of land tenure reforms and environmental certification on forest cover, livelihoods, and climate change mitigation. However, due to the small number of eligible studies and the high heterogeneity in the reported outcome variables, it was not possible to include studies on environmental certification in the quantitative analysis. The exclusion of all environmental certification studies from the quantitative synthesis highlights a critical evidence gap in the forest conservation literature. Certification schemes, particularly those aligned with international standards such as the FSC, are widely promoted as tools for sustainable forest management. However, the lack of comparable, standardized, and statistically robust evaluations limits our ability to assess their actual effectiveness. Di Girolami, Kampen and Arts (2023) also found a lack of high-quality robust studies for which to undertake a qualitative systematic review. Only five met their criteria, with the studies reporting mixed results (two with some positive impacts on deforestation and two showing no impact on deforestation) similar to our findings. This underscores the need for future research to produce high-quality, impact-oriented studies on certification, especially those that report disaggregated and replicable outcome data. Strengthening the evidence base in this area is essential to inform the design, implementation, and scaling of certification projects. This limitation prevents drawing evidence-based conclusions about the effectiveness of that instrument and highlights a significant gap in the literature that should be addressed through more systematic and comparable impact evaluations to support informed policy decisions.

For land tenure reforms, a separate analysis was conducted for six indicators across the three outcome domains. In the domain of forest cover, eight studies assessing the annual deforestation rate were analysed. The combined estimated effect was negative but not statistically significant, indicating that, on average, tenure reforms may be associated with reductions in deforestation, although there is substantial variability across studies. Some individual studies reported notably negative effects, while others found no clear impact. In contrast, the analysis of two studies comparing differences in forest cover levels under different management regimes showed a positive and statistically significant effect (at the 10 per cent level), suggesting that territories with recognized tenure tend to maintain greater forest cover than those under state or unmanaged regimes.

Regarding livelihoods, three indicators were analysed. The combined effects on annual income per adult and annual per capita expenditure, each with two studies, were positive but not statistically significant. For annual household income, which included two studies, a negative and non-significant combined effect was estimated.

In the mitigation domain, two studies measured carbon stock. The combined effect was negative but not statistically significant. Both studies reported lower levels of stored carbon in areas with recognized tenure rights, although with differences in the magnitude of the effect.

To explore the sources of heterogeneity, moderator analyses were conducted using meta-regression. While none of the coefficients were statistically significant, consistent patterns were observed in the direction of the estimated effects. In most cases, more recent interventions were associated with larger effects, which may reflect progressive improvements in the design and implementation of tenure policies, or greater precision in estimates through improved evaluation methods. It was also observed that studies conducted in countries with Latin colonial heritage tended to show larger effects than those in Anglo or non-colonized countries, although these differences did not reach statistical significance. These findings, while exploratory, may provide relevant hypotheses for future research.

Publication bias was assessed using funnel plots and Egger's test when the number of studies permitted it. Given the small number of studies per outcome, these tests lack statistical power; however, visual inspection of the plots did not suggest any evident systematic bias.

Overall, the results suggest that land tenure reforms could have a modest effect on forest conservation and rural livelihoods, but results reported here were almost all insignificant. Across these studies, a few clear patterns regarding factors that support the effectiveness of land tenure interventions emerge.

First, local incentive structures are decisive. Indeed, reforms that align conservation with local livelihood gains tend to succeed on both fronts. For instance, giving communities controlled commercial rights (e.g. regulated harvesting in Guatemala; agroforestry plots in Kenya) produced win-win outcomes (Fortmann, Sohngen and Southgate, 2017; Okumu and Muchapondwa, 2020). In contrast, approaches that expect communities to conserve "for free" (or at a net cost) often falter or face resistance (Lambini and Nguyen, 2022).

Second, the design of rights matters. Simply decentralizing or titling land does not guarantee better outcomes. What matters is how rights are allocated and restricted. We see seemingly contradictory findings that resolve via context: in Madagascar, community management with commercial use performed no better than no management (Rasolofoso and others, 2015), yet in other places community logging concessions work well (Fortmann, Sohngen and Southgate, 2017). The difference lies in implementation quality, market context, and group governance. Likewise, land titling alone had limited impact in some cases (Holland and others, 2017; Robinson, Holland and Naughton-Treves, 2017), but titling combined with conservation rules was very effective (Holland and others, 2017; Robinson, Holland and Naughton-Treves, 2017).

Third, equity and group composition influence success. Several studies flagged that when benefits skew to elites or a community is socially fragmented (by wealth, ethnicity, newcomers versus old-timers), the effectiveness diminishes (Jumbe and Angelsen, 2006). Heterogeneity can breed conflict or non-compliance (e.g. Malawi's mixed outcomes between sites, or leakage in heterogenous Guatemalan groups). By contrast, more homogeneous or closely-knit groups often mobilize better for collective goals (e.g. Cambodia's dependent communities achieved strong conservation) (Lambrick and others, 2014).

Finally, there is a notable trade-off between strict protection and livelihoods. Totally restricting use (whether via protected areas or community rules) may maximize short-term ecological outcomes but at a social cost, whereas allowing sustainable use can deliver moderate conservation plus livelihood gains. Many authors argue for finding a balance. For example, Ameha, Nielsen and Larsen (2014) suggests revising "subsistence-only" community forests to permit some commercial use, to ensure communities benefit and remain committed. In the same vein, Lambini and Nguyen (2022) advises coupling community conservation with payments to even out losses.

Overall, the new evidence reinforces that neither land tenure reforms nor community forestry are silver bullets on their own. Indeed, their success hinges on supportive conditions. When local people obtain secure rights and share in benefits, forests tend to fare better (and store more carbon) while livelihoods improve (Okumu and Muchapondwa, 2020). But if reforms are poorly implemented, in particular lacking enforcement, failing to empower communities, or ignoring local inequities, the intended benefits (poverty reduction, forest conservation, climate mitigation) may be muted or even counteracted (Rasolofoso and others, 2015). The studies thus highlight the importance of context-driven policy design of matching reforms to local social and economic conditions, providing alternative income sources or incentives in high-pressure areas, and ensuring that the "community" in community forestry truly has the capacity and voice to manage its forest sustainably.

A. Overall completeness and applicability of evidence

The estimated effects of land tenure reforms were modest, statistically insignificant in almost all cases, with substantial heterogeneity across studies. While the results are far from conclusive, they provide plausible hypotheses about factors that may explain the variation in outcomes, such as institutional context or specific features of intervention design.

This review did not examine implementation issues, such as governance mechanisms, levels of community participation, or operational challenges as these aspects fell outside the methodological scope of the study. A complementary exploration of these qualitative factors would be important to understand the mechanisms through which reforms do (or do not) lead to positive outcomes.

1. Types of outcomes

The outcomes considered in this review were grouped into three major domains: forest cover, livelihoods, and climate change mitigation. Each of these domains was operationalized through specific, quantifiable indicators, extracted directly from the included studies or calculated based on available data. For instance, forest cover was measured using annual deforestation rates or relative forest cover under different tenure regimes; livelihoods were assessed using income and expenditure indicators; and mitigation was evaluated through carbon stock estimates.

In some cases, a single study contributed evidence to more than one domain, which enhanced the richness of the analysis but also underscored the need for methodological standardization in future evaluations. The selection of outcomes was based on empirical relevance, data availability, and the feasibility of calculating standardized effect sizes. Intermediate, qualitative, or perception-based outcomes were not included, as they cannot be robustly integrated into a quantitative synthesis such as the one conducted here.

2. Relation to the theory of change

The findings of this review partially align with the hypothesized causal pathways outlined in the ToC for land tenure reforms and environmental certification. For land tenure reforms, the ToC posits that securing legal rights and establishing participatory governance structures should enhance incentives for sustainable land management, reduce conflict, and improve long-term forest stewardship. The quantitative results show that land tenure reforms are associated with positive but modest improvements in forest cover and livelihoods, though almost all effects were not statistically significant. These mixed results suggest that while the underlying causal mechanisms may hold in some contexts, particularly those with participatory arrangements and enabling governance conditions, other factors likely mediate the effectiveness of tenure reforms, including implementation quality, institutional capacity, and sociopolitical context. Some of the studies suggest that having constraints on the type of forest activities, such as a restriction on commercial forestry, is necessary to ensure forest conservation outcomes (Holland and others, 2017; Rasolofoso and others, 2015). This may be an important moderating factor in achieving sustainable forest management.

This last point connects to forest certification schemes since in a sense these are a way to mediate commercial CFM undertaken through land tenure changes. The study by Takashi and Todo (2013) is an example of both land tenure reforms with CFM and certification. Indeed, this study is found in both our data sets. Although they found that forests under the coffee certification programme were less likely to be deforested than forests without forest coffee, they did not find a statistical difference.

Our narrative synthesis of the environmental certification studies indicated that some certification programmes have led to reductions in forest cover loss and improvements in household welfare, particularly in contexts where certification was combined with community-based management. These findings suggest that certification schemes may work best when embedded within broader institutional arrangements that promote collective action, monitoring, and local benefit-sharing. Nevertheless, more research is therefore needed to understand the causal relationships, and moderating and mediating factors.

Overall, the evidence confirms that the mechanisms described in the ToCs are plausible and observable in some settings. However, the effectiveness of these interventions remains highly context-dependent, highlighting the need for future evaluations to better account for heterogeneity in implementation modalities, governance structures, and local enabling conditions.

B. Quality of the evidence

All studies included in this meta-analysis employed experimental or quasi-experimental designs that allow for causal inference and are considered to carry a low risk of bias. This initial screening ensured a high methodological standard across the evidence base.

Yet, many studies lacked sufficient statistical detail for inclusion, so they were excluded due to missing data or non-comparable outcome indicators, which, although reducing the sample size, helped ensure the robustness of the meta-analysis.

Among the studies included in the final synthesis, several required conservative assumptions to reconstruct missing values, such as standard deviations or group sizes, based on available information. All such procedures were applied consistently and transparently. Because only a minority of studies required these adjustments, and the criteria for doing so were applied with caution, these methodological decisions are not expected to introduce systematic bias into the results.

Overall, the evidence base is composed of studies with relatively strong designs, but varying levels of reporting quality. This highlights the importance of improving the transparency and completeness of reporting in future impact evaluations to enable more robust and inclusive evidence synthesis.

C. Limitations and potential biases in the review process

The initial selection of studies for this review was limited to those published in English or Spanish and focused exclusively on interventions implemented in developing countries. For inclusion in the systematic review and meta-analysis, only studies employing experimental or quasi-experimental designs capable of establishing causal relationships were retained. As a result, qualitative studies, systematic reviews, and meta-analyses (despite offering valuable insights into forest conservation dynamics) were excluded from the quantitative synthesis.

Another limitation stemmed from the narrow focus on two policy instruments: land tenure reforms and environmental certification. While these are highly relevant and widely implemented strategies, they often interact with other conservation interventions such as payment for ecosystem services, protected area management, or other programmes. These interactions were beyond the scope of this review but represent promising avenues for future research.

Finally, a significant constraint of this study was the limited number of studies eligible for inclusion in the meta-analysis. The small sample sizes within each outcome domain hindered the ability to detect statistically significant effects and restricted the extent to which moderator analyses could be

meaningfully interpreted. This underlines the need for more rigorous, comparable evaluations in the field of forest conservation policy.

D. AGREEMENTS AND DISAGREEMENTS WITH OTHER STUDIES OR REVIEWS

Our companion EGM shows that the existing evidence base is mainly concentrated in studies of regulatory instruments aimed at reducing deforestation, such as protected areas (Ma and others, 2020; Busch and Ferretti-Gallon, 2017; 2023), also includes a significant number of studies on economic instruments such as payments for ecosystem services (Snilsveit and others, 2019; Börner and others, 2020). Land tenure reforms are also identified as a key intervention with a notable presence in the literature, especially in contexts where communities are granted rights to manage forest resources (Wehkamp and others, 2018).

This systematic review complements those earlier efforts, as well as the systematic review by Di Girolami, Kampen and Arts (2023) on certification and CFM, by offering a meta-analytical assessment focused on two specific forest policy instruments – land tenure reforms and environmental certification – and their effects on forest cover, rural livelihoods, and climate change mitigation in developing countries. Unlike broader reviews such as that of Busch and Ferretti-Gallon (2023), which concentrate on the sign and significance of multiple deforestation drivers, this study applies an approach based on standardized effect sizes using random-effects models, enabling more comparable impact estimates across studies. It also differs by incorporating recent studies (published through 2024) and by focusing exclusively on causal evidence from studies, which strengthens the internal validity of the analysis.

We find very few robust papers on certification which is a similar finding to Di Girolami, Kampen and Arts (2023). We note that the heterogeneity and data limitations of the available studies prevented inclusion in the meta-analysis. This finding contrasts with broader syntheses where certification features more prominently and highlights a critical gap in the literature.

In summary, this review aligns with previous findings in suggesting that land tenure reforms may contribute positively to forest conservation and local development outcomes, although their effects were almost all statistically insignificant and context-dependent. It also adds value by refining the quantitative synthesis of existing studies and highlighting persistent evidence gaps, particularly regarding environmental certification, that should be addressed in future research.

VI. CONCLUSIONS

This systematic review and meta-analysis provides an updated and rigorous synthesis of causal evidence on the effectiveness of land tenure reforms and environmental certification in advancing forest conservation, livelihoods, and climate change mitigation in developing countries. While the initial scope covered both interventions, only land tenure reforms had sufficient high-quality evidence to support a quantitative synthesis. This limitation underscores a persistent gap in impact evaluations of certification schemes and highlights an urgent need for more methodologically robust studies in that area.

The meta-analysis of land tenure reforms reveals no statistically significant average effect on deforestation rates, livelihoods, or carbon stock outcomes. However, the findings suggest that tenure reforms can contribute positively to conservation and development objectives when implemented under supportive conditions, such as strong governance frameworks, community participation, and sustained institutional backing. In particular, PFM schemes and reforms that clarify communal or Indigenous rights appear to perform better than top-down titling interventions implemented in isolation.

Despite the small number of studies in each outcome category, patterns of heterogeneity observed in the moderator analyses point to the importance of factors such as intervention scale, implementation actors, and colonial legal heritage. These dimensions may help explain variations in effectiveness and should be systematically integrated into future research and programme design.

In sum, the evidence supports the generation of more causal evidence on land tenure reforms as a tool for forest conservation, with careful attention to design features and enabling conditions. This also applies to robust quantitative data on environmental certification. Expanding the evidence base, particularly through high-quality, disaggregated, and longitudinal evaluations, remains essential to strengthen future decision-making in the forest policy domain.

APPENDICES

Appendix 1. INTERVENTION TYPE, EXPLANATIONS AND EXAMPLES

INTERVENTION TYPE	EXPLANATION
Regulatory instruments	
Land tenure reforms	Land tenure reforms include conservation objectives, such as transfer of property rights and/or consolidation of tenure security, as in the case of Indigenous/local land demarcation and tenure enforcement processes. This includes lands tenured to the communities for community-based forest management with or without ownership.
Economic instruments	
Environmental certification	Environmental certification, with consumer-financed sustainability premiums (for forest products, such as the FSC for timber, or for crops, such as the Roundtable on Sustainable Palm Oil)

Appendix 2. OUTCOMES DEFINITIONS

Direct environmental benefits	
Forest cover	Forest cover is conserved or increased, through active conservation, strict protection or natural regeneration. The typical indicator is the area covered by forest.
Socioeconomic effects	
Livelihood effects	Forest conservation can affect local livelihoods. Livelihoods refer to the means by which a person or community secures the necessities of life, such as food, shelter, and clothing. It includes income-generating activities, and access to resources that support an individual or family's well-being. Effects can be positive, such as when forest conservation leads to enhanced food security, or can be negative when access to forest resources gets restricted for the sake of forest conservation. Indicators include: • Income or expenditure • Food security indicators such as dietary diversity • Number and diversity of livelihood activities
Climate change adaptation	
Mitigation	Greenhouse gas emissions: • Forest area where deforestation has been avoided • Amount of carbon emissions avoided • Amount of carbon sequestered

Appendix 3. STUDIES INCLUDED IN THE META-ANALYSIS

Paper	Full title of the paper	Country	Region	Outcome	Dependent variable
Mastrangelo and Gori Maia (2023)	Does land tenure security reduce deforestation? Evidence for the Brazilian Amazon	Brazil	Latin America	Forest cover	Annual deforestation rate
Camino and others (2023)	Indigenous lands with secure land-tenure can reduce forest-loss in deforestation hotspots	Multi-country (Argentina, Paraguay, Bolivia)	Latin America	Forest cover	Annual deforestation rate
Okumu and Muchapondwa (2020)	Welfare and forest cover impacts of incentive-based conservation: Evidence from Kenyan Community Forest Associations	Kenya	Africa	Livelihood	Annual per capita expenditure
Okumu and Muchapondwa (2020)	Welfare and forest cover impacts of incentive-based conservation: Evidence from Kenyan Community Forest Associations	Kenya	Africa	Forest cover	Difference in forest cover levels under different management regimes
Takahashi and Todo (2013)	The impact of a shade coffee certification program on forest conservation: A case study from a wild coffee forest in Ethiopia	Ethiopia	Africa	Forest cover	Annual deforestation rate
Ameha, Nielsen and Larsen (2014)	Impacts of access and benefit sharing on livelihoods and forest: Case of participatory forest management in Ethiopia	Ethiopia	Africa	Livelihood	Annual income per adult
Jumbe and Angelsen (2006)	Do the poor benefit from devolution policies? Evidence from Malawi's forest co-management program	Malawi	Africa	Livelihood	Annual income per household
Rasolofoso and others (2015)	Effectiveness of community forest management at reducing deforestation in Madagascar	Madagascar	Africa	Forest cover	Annual deforestation rate
Somanathan, Prabhakar and Mehta (2009)	Decentralization for cost-effective conservation	India	Asia	Forest cover	Difference in forest cover levels under different management regimes

Paper	Full title of the paper	Country	Region	Outcome	Dependent variable
Holland and others (2017)	Titling land to conserve forests: The case of Cuyabeno Reserve in Ecuador	Ecuador	Latin America	Forest cover	Annual deforestation rate
Lambini and Nguyen (2022)	Impact of community-based conservation associations on forest ecosystem services and household income: Evidence from Nzoia Basin in Kenya	Kenya	Africa	Livelihood	Annual income per household
Lambini and Nguyen (2022)	Impact of community-based conservation associations on forest ecosystem services and household income: Evidence from Nzoia Basin in Kenya	Kenya	Africa	Mitigation	Carbon stock
Blackman and Villalobos (2021)	Use forests or lose them? Regulated timber extraction and tree cover loss in Mexico	Mexico	Latin America	Forest cover	Annual deforestation rate
Gelo and Koch (2014)	The Impact of common property right forestry: Evidence from Ethiopian villages	Ethiopia	Africa	Livelihood	Annual per capita expenditure
Gelo and Koch (2014)	The Impact of common property right forestry: Evidence from Ethiopian villages	Ethiopia	Africa	Livelihood	Annual income per adult
Lambrick and others (2014)	Effectiveness of community forestry in Prey Long Forest, Cambodia	Cambodia	Asia	Mitigation	Carbon stock
Bruggeman, Meyfroidt and Lambin (2018)	Impact of land-use zoning for forest protection and production on forest cover changes in Bhutan	Bhutan	Asia	Forest cover	Annual deforestation rate
Fortmann, Sohngen and Southgate (2017)	Assessing the role of group heterogeneity in community forest concessions in Guatemala's Maya Biosphere Reserve	Guatemala	Latin America	Forest cover	Annual deforestation rate

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