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EFFECTIVENESS OF CERTIFICATION AND LAND TENURE INTERVENTIONS TO CONSERVE FORESTS

Protocol

Nathalie Doswald, Sasha Murat, Martin Prowse

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List of authors

The authors of this protocol for a systematic review on the effectiveness of certification and land tenure interventions to conserve forests are (in alphabetical order of surnames:

Full name	Affiliation
Nathalie Doswald	*Asesoramiento Ambiental Estratégico* (AAE)
Sasha Murat	*Asesoramiento Ambiental Estratégico* (AAE)
Martin Prowse	Independent Evaluation Unit, Green Climate Fund

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ABBREVIATIONS

CF	Community forestry
CI	Confidence interval
DID	Difference-in-differences
EGM	Evidence gap map
FSC	Forest stewardship council
IPWRA	Inverse probability weighted regression adjustment
JFM	Joint forest management
NGO	Non-governmental organization
PFM	Participatory forest management
PELIS	Plantation Establishment and Livelihood Improvement Scheme
PSM	Propensity score matching
RCT	Randomized controlled trial
SE	Standard error
SD	Standard deviation
tC/ha	Tons of carbon per hectare

A. Abstract

This protocol outlines the methodology for a systematic review and meta-analysis that evaluates the effects of two key forest policy instruments – land tenure reforms and environmental certification – on three key outcome domains in developing countries: forest cover, livelihoods, and climate change mitigation. The protocol focuses on specific saturated cells within the body of literature identified in the companion evidence gap map on forest conservation.

Only studies employing Tier 1 methodologies, experimental or quasi-experimental designs capable of estimating attributable impacts are included. Quantitative data will be extracted to calculate standardized effect sizes and their standard error. A random-effects meta-analysis model will be applied, alongside heterogeneity and publication bias tests where applicable. Qualitative data is assessed to provide indications of key transmission mechanisms as well as context. This protocol establishes a rigorous and transparent framework for synthesizing the most updated available evidence on how these two forest policy instruments contribute to conservation, climate and development goals.

B. Background and rationale

Our companion evidence gap map (EGM) on the effectiveness of forest conservation interventions in developing countries was undertaken to understand the current landscape of evidence on the topic (Bertzky et al., 2024b). Understanding the effectiveness of forest conservation interventions is important to ensure that efforts to protect and restore forest ecosystems achieve their intended outcomes. Forests provide vital ecological services, such as carbon sequestration, biodiversity preservation, and water regulation, that support both environmental health and human well-being (Secretariat of the Convention on Biological Diversity, 2024). By evaluating what works and what doesn't, conservationists, policymakers, and stakeholders can make informed decisions, allocate resources efficiently, and adapt strategies to local contexts. This evidence-based approach helps avoid unintended consequences, improves accountability, and increases the likelihood of long-term success in safeguarding forests against threats like deforestation, climate change, and habitat degradation.

The EGM is based on a theory of change (ToC) (Bertzky et al., 2024b), with interventions classified as regulatory instruments, economic instruments, informative instruments and voluntary instruments. Outcomes are classified as direct environmental benefits, indirect resource effects, socio-economic effects and impacts. A ToC supported the creation of this intervention/outcome framework (Bertzky et al., 2024b)

The EGM reveals that the evidence base is mainly concentrated on regulatory instruments as a means to avoid deforestation, especially the effectiveness of protected areas (e.g. Ma et al., 2020; Busch & Ferretti-Gallon, 2023). Other forest policy interventions with a substantial evidence base include forest law reforms such as giving communities land tenure to undertake forest management activities (Wehkamp et al., 2018). In terms of economic instruments, the most studied intervention has been payment for ecosystem services (e.g. Snilsveit et al., 2019; Börner et al., 2020; Busch & Ferretti-Gallon, 2023), followed by forest certification (e.g. Di Girolami et al., 2023). In terms of outcome areas, the bulk of the evidence lies in the outcomes of forest cover for direct environmental benefits, livelihoods in terms of socio-economic effects and greenhouse gas mitigation in terms of impacts.

Our companion EGM highlights the landscape of evidence across interventions (rows) and outcomes (columns). In this way, the EGM shows where the evidence is located but does not on its own tell us whether these interventions are effective and, if so, under what conditions. Recently, these questions have been investigated for specific intervention types, specifically protected areas and for payment for ecosystem services in three systematic reviews (Snilsveit et al., 2019; Ma et al., 2020; Busch & Ferretti-Gallon, 2023).

C. WHY THIS REVIEW IS IMPORTANT

Conducting this review is important to gain a clearer understanding of the impacts of specific conservation policies on forest cover, particularly in a context where empirical evidence has grown substantially in both volume and complexity in recent years. A rigorous quantitative meta-analysis makes it possible to identify consistent patterns across studies and to assess the comparative effectiveness of different interventions.

While there are relevant precedents, this review incorporates studies published between 1990 and 2024, including recent publications to allow us to examine a period during which new methodologies have been developed and more detailed data on conservation outcomes have become available. Busch and Ferretti-Gallon (2017, 2023) conducted a widely cited meta-analysis of over one hundred econometric studies on deforestation. However, their work focused primarily on the sign and significance of coefficients related to multiple drivers of deforestation, without calculating standardized effect sizes or applying statistical models to quantitatively synthesize the findings.

This review builds on recent efforts to synthesize causal evidence on forest conservation policies, notably systematic reviews focused on the effectiveness of protected areas and payment for ecosystem services (e.g. Snilsveit et al., 2019; Ma et al., 2020). While those reviews provide important insights into specific intervention types, they do not cover land tenure reforms or environmental certification in detail. This review fills that gap by focusing specifically on those two instruments, providing a comparative and updated assessment of their effects on forest cover, livelihoods, and climate change mitigation in developing countries.

This systematic review adds value in several ways. First, it updates the body of evidence by including recent studies that were not considered in previous analyses. Second, it doesn't replicate recent systematic reviews but adds value by focusing on specific key conservation interventions in developing countries, land tenure reforms and environmental certification, thus allowing for a precise and comparative evaluation of their effectiveness. Finally, it applies advanced methods of quantitative synthesis, including random-effects meta-analysis models and Egger's test for publication bias, as well as the calculation of standardized effect sizes (such as Cohen's "d" and Hedges' "g"), which enhance the comparability and robustness of the results.

Overall, this review not only updates existing knowledge but also deepens it through a more targeted and methodologically rigorous approach, contributing new insights into the policies which are most effective in curbing deforestation and under what conditions.

D. 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.

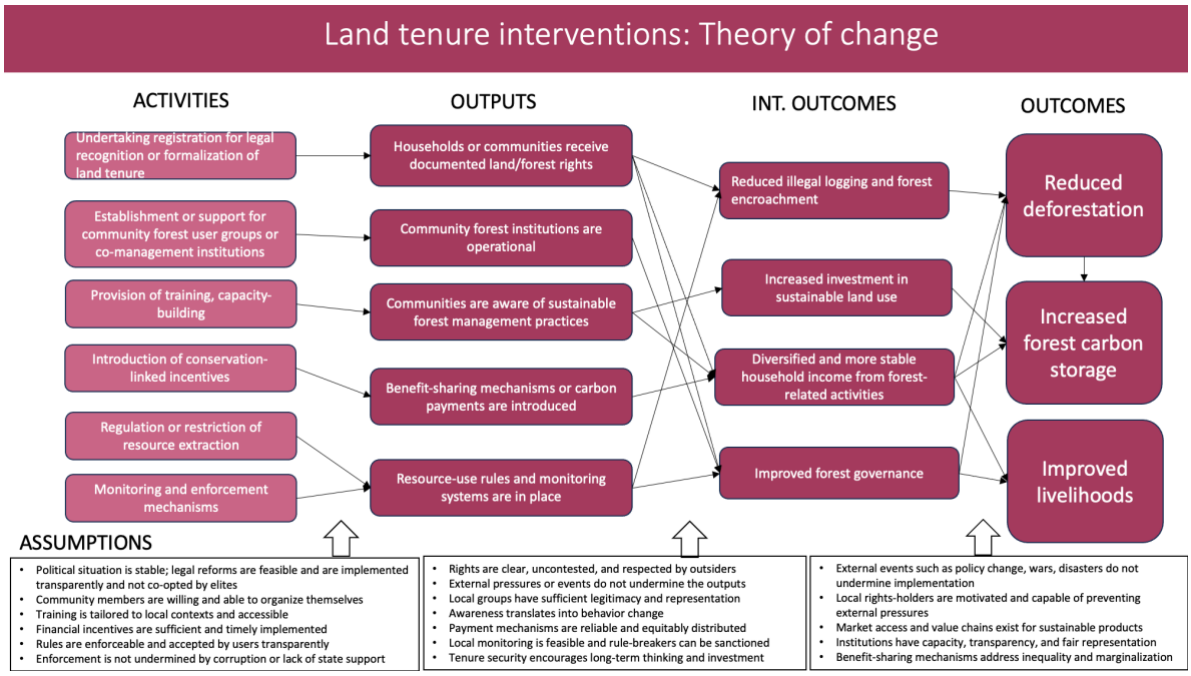
Land tenure reforms seek to clarify and secure rights over land and forest resources, aiming to reduce conflicts, incentivize sustainable land management, and improve long-term stewardship.

Environmental certification, by contrast, operates through market-based mechanisms that reward compliance with environmental and social standards.

The underlying ToC for these interventions, initially presented in the EGM, outlines the expected causal pathways from intervention to impact. This framework identifies necessary inputs and enabling conditions, immediate outputs such as the clarification of property and resource rights or the delivery of incentives, and intermediate outcomes related to behavioural change, rule compliance, and improvements in forest conditions. Final outcomes are expected to include environmental benefits, such as reduced deforestation, enhanced biodiversity conservation, erosion control, and climate change mitigation, as well as socio-economic effects, including improved livelihoods, employment opportunities, and better social conditions.

While this overarching ToC captures the general mechanisms through which forest conservation interventions are expected to operate, the specific causal pathways differ between land tenure reforms and environmental certification. In accordance with best practices for systematic reviews, a distinct ToC should therefore be outlined for each intervention type. To develop a good ToC that includes causal linkages and assumptions, the literature base needs to be sufficiently developed. This is the case of land tenure reforms (see Bertzky et al., 2024b). Figure 1 presents the ToC for land tenure change for the outcomes of reduced deforestation, increased carbon storage and improved livelihoods.

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



Source: Authors

Land tenure reforms aim to improve forest conservation outcomes by securing legal rights over land and forest resources. These reforms operate by clarifying ownership or usage rights, creating awareness and incentives for sustainable land management, and establishing forest governance mechanisms. Immediate outputs include formalized land titles, the recognition of communal rights, knowledge of sustainable practices, the establishment of participatory forest governance structures, and benefit-sharing mechanisms. These outputs are expected to lead to intermediate outcomes such

as greater investment in land stewardship, improved compliance with sustainable practices, and reduced illegal exploitation. Ultimately, these behavioural changes are anticipated to result in enhanced forest cover, mitigation of greenhouse gas emissions, and socio-economic benefits for communities through strengthened livelihoods and more secure resource access.

Compared with land tenure change, the literature surrounding the causal mechanisms for environmental certification is less well established (Bertzky et al., 2024; Di Girolami et al., 2023) and thus it is harder to develop a good ToC that includes causal linkages and assumptions. We therefore provide a descriptive ToC based on existing evidence. 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 socio-economic 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.

E. Research questions

This review will address the following primary research questions:

Land tenure

1. To what extent has land tenure been effective at reducing deforestation, improving livelihoods and increasing carbon storage in developing countries?
2. What factors influence the effectiveness of land tenure for forest conservation in developing countries?

Certification

3. To what extent has forest certification been effective at reducing deforestation, improving livelihoods and increasing carbon storage in developing countries?
4. What factors influence the effectiveness of certification for forest conservation in developing countries?

F. Inclusion/exclusion criteria

1. Types of studies

This systematic review and meta-analysis include studies employing experimental or quasi-experimental designs in which a control or comparison group is present, and one of the following holds:

- A quasi-random method of assignment has been used, and pre-treatment equivalence between groups is reported or statistically adjusted for.

- Participants or units (e.g. households, communities, forest plots) are non-randomly assigned, but potential confounding factors are controlled for using statistical methods. These include propensity score matching (PSM), inverse probability weighting (IPW), difference-in-differences (DiD), matching combined with DiD, regression discontinuity, or synthetic control methods.
- Studies using linear or mixed effects regression models that control for group differences through matching or demographic covariates are also included.

Mixed-method studies with any of the above quantitative designs are eligible. Studies of any follow-up duration are included. While purely qualitative studies and process evaluations are excluded, qualitative data embedded within Tier 1 quantitative studies, such as information on model specifications, measured variables, types of interventions, and geographical contexts, was extracted to support the structuring and interpretation of the quantitative analysis.

2. Types of participants/settings

The types of participants/settings are set out in the approach paper for the EGM on forest conservation (see Bertzky et al., 2024a). In particular:

- We refer to developing countries in this context as non-Annex I countries as defined by the Kyoto Protocol.
- The evidence review will include studies conducted at different units of observation, including households, communities, firms, districts, regions, and countries.[1]
- The review will focus on forest ecosystems targeted by a forest conservation intervention, including terrestrial forest ecosystems, mangroves, and agroforests.

3. Types of interventions

As outlined above, the systematic review will focus on two types of forest conservation interventions:

1. **Environmental certification**, particularly certification under the Forest Stewardship Council (FSC) standards.
2. **Land tenure reforms**, encompassing studies that assess the effects of various forms of recognition and strengthening of rights over forest resources. Independent variables capturing these interventions include:
   a) Indicators of tenure security, such as land tenure security or forest-friendly titling.
   b) Legal recognition of collective territories, such as indigenous lands, community forest management, or land ownership.
   c) Participation in government-led or co-managed programmes, including participatory forest management, forest co-management, joint forest management, community forestry, participation in PELIS, or differentiated concession types (concession type, type of forest zoning unit).[2]
   d) Distinctions based on management structures or arrangements, such as management type.
   e) These reforms may include formal/legal components (e.g. titling or legal recognition) or institutional arrangements (e.g. co-management or participatory governance schemes).

[1] The term "regions" can here be understood as referring to subnational units (e.g. the Brazilian Pantanal) as well as international units (e.g. the Amazon rainforest).
[2] PELIS stands for Plantation Establishment and Livelihood Improvement Scheme. It 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.

Other types of forest-related interventions identified in the EGM were not included in this meta-analysis.

4. TYPES OF OUTCOMES

This meta-analysis includes studies that report quantitative outcomes relevant to forest conservation. Outcomes are grouped into three main categories (Table 1).

Table 1. Outcome categories relevant to the forest conservation initiatives

OUTCOMES	DESCRIPTION	INDICATORS
Forest cover	These outcomes measure changes in forest extent or condition.	Percentage of forest area cleared
		Percentage of forest canopy cover
		Annual deforestation rate and annual forest cover loss
		Probability of deforestation
		Percentage of forest cover or forest cover loss
		Land conversion rate
		Forest cover change (%)
		Deforestation
		Incidence of forest fires
		Signs of anthropogenic damage (e.g. m^2/ha)
Livelihood	These outcomes reflect changes in household or community welfare.	Forest income (absolute or per adult equivalent)
		Total income
		Per capita monthly expenditure and consumption
		Malnutrition indicators (e.g. number of undernourished persons)
Mitigation	This category includes outcomes related to climate change mitigation potential.	Carbon stock

Source: Authors

Only outcomes for which sufficient statistical information is available (e.g. means, standard deviations, sample sizes, or effect sizes and standard errors) are included.

To ensure consistency and comparability in the measurement of combined effects, studies sharing the same independent variables will be grouped, guaranteeing that within each study category all variables measure exactly the same concept (e.g. annual forest cover loss, deforestation rate). This grouping will allow a robust combined analysis and facilitate the clear interpretation of the average effects obtained in the meta-analysis.

G. INFORMATION SOURCES

The primary source of information for this systematic review and meta-analysis is the set of studies identified and screened as part of our companion EGM focused on forest conservation interventions.

The EGM search strategy is detailed in the EGM report section titled "Search databases and repositories", and the full results are summarized in Table 3 of that same section, which reports a total of 4,752 records identified across multiple databases and repositories (Bertzky et al., 2024b).

For the purpose of this review, a subset of these studies was selected based on three key inclusion criteria: (i) the intervention studied is either land tenure reform or environmental certification; (ii) the study describes outcomes related to forest cover, livelihood, or climate change mitigation; and (iii) the study is categorized as Tier 1, meaning it uses experimental or quasi-experimental methods that allow for causal inference. Studies with a high likelihood of bias were retained in the EGM but excluded from the systematic review.

Applying these criteria, a final set of 24 studies was included for land tenure reforms, and 5 studies for environmental certification. This approach ensures that the analysis draws on the most methodologically robust and thematically relevant evidence available, allowing for a rigorous synthesis of the effects of these interventions on key conservation and development outcomes.

H. Data extraction and management

1. Screening, coding and abstraction

Data extraction included both study design characteristics and relevant qualitative and quantitative information required for statistical calculation. The process was conducted using standardized tools and is described in detail below.

a. Data extraction and selection of studies

Following the identification of studies in the EGM, this review retained the aforementioned 24 studies on land tenure reforms and 5 studies on environmental certification, selected based on predefined inclusion criteria.

For these studies, we extracted new data using the base information compiled for the EGM and its corresponding report as a foundation. From each selected study, both qualitative and quantitative data were extracted. This included details on study design and the statistical parameters required to conduct heterogeneity tests and a random-effects meta-analysis model, allowing for the estimation of combined effect sizes for each intervention-outcome pair.

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. 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 standard errors, 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 infeasible under the assumptions required for meta-analysis.[3]

[3] Excluded studies from quantitative synthesis for land tenure reforms: Bocci & Fortmann (2023); Gulzar et al. (2024); West (2024); Pagiola, Honey-Rosés & Freire-González (2016); Putraditama et al. (2019); Bruggeman, Meyfroidt & Lambin (2015); and Scullion et al. (2014). And/or for certification: Bocci & Fortmann (2023) and Rana & Sills (2018).

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, standard errors, or sample sizes), which made the estimation of standardized effect sizes extremely challenging. The other study, although reporting statistically significant coefficients and standard errors 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.

In some cases, the published version of the study did not contain sufficient information for effect size calculation. To address this, we sought additional data from the online publication platforms, which in some cases included supplementary tables or figures that supported the extraction of required values. After applying these exclusions, the final sample for the meta-analysis consisted of 17 studies on land tenure reforms and 3 studies on environmental certification.

2. Risk of bias assessment 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 et al., 2016, 2019), 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 exclusively selected Tier 1 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, PSM, and other quasi-experimental strategies. Tier 1 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.

I. Data analysis

1. Coding and data extraction

a. Unit of analysis issues

The unit of analysis in this meta-analysis corresponds to study-level effect sizes, which may reflect outcomes reported at the community, household, or plot level, depending on the design of each included study. When multiple observations were available within the same study, the following criteria were applied:

- Subgroup estimates: when results were reported for subgroups (e.g. by region, forest user type, or management scheme), effect sizes were coded separately for potential moderator analysis. In the main meta-analysis, the grouped effect was used when reported by the study or calculated if sufficient information was available for all groups.
- Follow-up effects over time: for studies reporting effects at multiple time points (e.g. annual impact estimates), the most recent effect was selected unless earlier results better reflected the causal effect of the intervention or allowed better comparability across studies.

- Model specification: when multiple models were reported, we prioritized those that adjusted for observable confounders (e.g. through matching, controls, or weights). If both adjusted and unadjusted models were available, the adjusted model was selected. If several adjusted models were available, the most comprehensive or clearly preferred specification was chosen.
- Significance-based inclusion criterion: in cases where studies reported multiple regression results for a given indicator (e.g. biomass), but none of the results were statistically significant, those estimates were excluded and not included in the meta-analysis

b. Coding categories

The included studies were coded based on the following key variables:

- Intervention and outcome: each study was coded according to the intervention evaluated (e.g., land tenure reform or environmental certification) and the corresponding outcome classified under one of the following categories: forest cover, livelihood, or mitigation.
- Model used: the econometric or statistical model applied in the study was recorded (e.g., linear regression, DiD, PSM, etc.).
- Dependent variable: the specific dependent variable used in each analysis was recorded (e.g. annual deforestation rate, forest income), and these were also grouped into broader thematic categories under the dependent variable type field (e.g. deforestation-related, income-related, carbon-related variables).
- Independent variable: the treatment or explanatory variable associated with the intervention was recorded (e.g. land tenure security, participation in PELIS, FSC certification).
- Variable type: it was noted whether the dependent variable was continuous or binary.
- Descriptive analysis: it was indicated whether the study included a descriptive analysis of the data prior to modelling.

In addition to the manually extracted data, some contextual variables were drawn from the previous coding conducted for the EGM, including country and region of the study, scale of intervention (individual, household, community) and other general study characteristics defined in the EGM framework.

c. Data extraction for meta-analysis

For the meta-analysis, the following variables were extracted from the included studies:

- Effect size: effect sizes were coded as reported in the studies (e.g. regression coefficients), or calculated using available data such as means and standard deviations for treatment and control groups. In some cases, grouped effect sizes were calculated when studies reported multiple outcomes within the same category and in the same direction.
- Sample size: sample sizes for treatment and control groups were recorded. In cases where disaggregated sample sizes were not reported, and the study employed matching methods, it was assumed that the sample sizes for treatment and control groups were equal, as observations were matched by design.
- Additional statistics: when available, standard deviations, standard errors, t-values, confidence intervals, or other relevant statistics were extracted to allow the computation of effect size variances.

Whenever assumptions or indirect calculations were required (e.g. estimating standard deviations from confidence intervals), the procedures used were documented explicitly.

d. Critical appraisal and risk of bias

All studies included in this meta-analysis were previously assessed and classified as Tier 1 in the EGM, meaning they use experimental or quasi-experimental designs to estimate causal and attributable impacts. These designs are considered to carry a low risk of bias and are appropriate for inclusion in this review.

In addition to the previously completed risk of bias assessment, to assess the quality of the synthesized evidence, we will evaluate the following aspects:

- Publication bias: Egger's tests will be applied to detect publication bias where possible. This test requires at least eight effect sizes to be meaningful.
- Imprecision: we will consider heterogeneity levels and downgrade the robustness of findings when I^2 exceeds 80 per cent.
- Evidence base: studies will be pooled across conceptually similar variables, and heterogeneity will be minimized by grouping outcomes by type.

Heterogeneity and bias tests will be assessed together with their associated p-values in order to evaluate the overall reliability of the combined effects.

2. Descriptive analysis

We will present tabulations of the key variables extracted from the included studies for the descriptive analysis. These will include, for example, summaries of included studies by intervention and outcome or variable summaries describing the distribution of extracted variables such as model type, variable type (continuous or binary).

This analysis will build on the descriptive tabulations and visualizations already developed for the EGM and will focus more specifically on the subset of studies evaluating land tenure reform and certification interventions. These refined summaries will allow for a clearer understanding of the scope and composition of the evidence base relevant to the meta-analysis.

3. Statistical procedures and conventions

Effect sizes were standardized using Hedges' g, calculated either from reported values of Cohen's d or through the computation of partial Cohen's d in cases where only regression coefficients and standard errors were available. In these cases, the standard deviation was reconstructed using the coefficient's standard error and the sample sizes for the treatment and control groups when reported. Finally, to obtain partial d, the coefficient was divided by the estimated pooled standard deviation.

Based on these calculations, the following statistics were derived:

- Hedges' g
- Standard error (SE) of Hedges' g
- Odds ratio (OR), log (OR), and SE (log OR)
- Z-statistic, to assess the direction and magnitude of the effect
- Precision (1/SE), used for the assessment of publication bias

A random-effects meta-analysis model was used to pool standardized effect sizes. This model was considered more appropriate than a fixed-effects model, as it assumes that the included studies estimate true effects that may vary across contexts, populations, or specific interventions, rather than a single underlying common effect.

The following additional assumptions were applied when complete information was not reported:

- For binary outcomes, the standard deviation was estimated using the square root of the variance.

- In studies using matching methods, where sample sizes for the treatment and control groups were not reported, equal group sizes were assumed since the observations were expected to be matched by design.
- When a single study reported multiple regressions related to the same intervention and outcome, and the effects were in the same direction, a grouped effect was calculated using weighted averages based on sample size.

Studies were excluded from the quantitative synthesis if they did not report sufficient statistical information or relied on non-parametric methods that required strong assumptions to estimate effect sizes.

4. HETEROGENEITY

Heterogeneity among reported effect sizes will be assessed by calculating and reporting the Q statistic, degrees of freedom, and the I^2 statistic, which indicate the proportion of variability across studies attributable to true heterogeneity rather than chance. Forest plots will be generated to provide a visual summary of pooled effect sizes and to inspect the consistency of results across studies.

Since moderator analysis will be conducted using regressions where the unit of observation is each study, it will be ensured that the number of moderators does not exceed the total number of studies included. Importantly, categorical variables must be transformed into dummy variables for their inclusion in the model. To avoid multiple variables related to the same topic, these will be 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 will focus on theoretically relevant moderators to explain the observed heterogeneity across all intervention-outcome groups. Specifically, the year of intervention start and colonial heritage will be included in all cases. The latter is 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 allows the inclusion of additional moderators, the entity type and scale of intervention will also be considered. 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 (e.g. government, NGO, private sector, community-based organization)
Scale	Scope of the intervention: national, subnational, or community
Year of intervention start	The year in which the conservation intervention was initially implemented
Colonial heritage	Colonial background of the country, grouped by Latin or Anglo

Source: Authors

5. TREATMENT EFFECTS

The studies included in this meta-analysis rely primarily on quasi-experimental designs, such as PSM, DiD, and other matching-based strategies using administrative records, household surveys, or geospatial data. In these types of designs, attrition, understood as the dropout or loss of individual

participants between baseline and endline, is not applicable in the conventional sense, since most units of analysis are pixels, forest management units (FMUs), or aggregate-level observations (e.g., villages or communities) rather than tracked individuals over time.

Moreover, many of the included studies use matching approaches to balance treatment and control groups on observable characteristics. By design, these techniques reduce baseline imbalances and help ensure that both groups are comparable. This reduces the potential for differential outcome reporting or systematic exclusion that would bias results. For these reasons, the risk of bias due to attrition is considered low across the included studies. Outcome data will be carefully assessed to ensure consistency and availability for both treatment and control groups. Studies where outcome data were missing or incompletely reported will be excluded from the meta-analysis.

6. Publication bias

Publication bias will be assessed using Egger's test only in cases where there is a sufficient number of effect sizes (typically eight or more), in line with established guidelines. Although the test can technically be computed with fewer observations, results based on small samples are highly unreliable and may be misleading. When applicable, funnel plots may be generated to support visual inspection of potential asymmetry, although these should be interpreted with caution in cases of limited sample size.

J. Conclusion

This protocol presents the methodological design for a systematic review and meta-analysis aimed at evaluating the effects of land tenure reforms and environmental certification on forest cover, livelihoods, and mitigation outcomes in developing countries.

Data extraction will include both descriptive characteristics and statistical parameters required to estimate standardized effect sizes and analyze them using random-effects models. Results will be analyzed separately by intervention and outcome category, avoiding overgeneralization and ensuring methodological precision.

By predefining this analytical strategy, the protocol ensures a systematic and credible approach to evidence synthesis, which will help inform the design of forest policy based on robust and reliable data.

Furthermore, this review addresses a clear gap in the existing literature. While previous meta-analyses have focused on broader categories of forest interventions, this study offers a more targeted and updated synthesis. It narrows its scope to two widely used yet under-reviewed instruments and applies a robust quantitative methodology, thereby contributing critical insights into which conservation policies are most effective, and under what conditions, in developing country contexts.

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Independent Evaluation Unit
Green Climate Fund
175, Art center-daero, Yeonsu-gu
Incheon 22004, Republic of Korea
Tel. (+82) 032-458-6450
ieu@gcfund.org
https://ieu.greenclimate.fund