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RESEARCH ARTICLE

Distinguishing potential and effective additionality of forest conservation interventions

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Abstract
The additionality of forest conservation interventions is frequently questioned. In particular, they are often considered to be located in places where forests are not threatened, which points to the existence of location biases. Revisiting this location bias concept, we conceptually distinguish potential and effective additionality and theoretically consider how the objectives of the implementer affect the siting choice of the forest conservation interventions and their additionality. Our theoretical intuition is that the choices of the implementers are influenced by the quality of institutions. Our results show that (1) the implementer's objective and local institutions may lead the implementer to select a site with low development potential and low forest threat, and (2) the selection of a site with low development potential, which is frequently presented as a location bias, does not necessarily preclude additionality.

Keywords: additionality; conservation; deforestation

JEL classification: Q23; Q28; Q56

1. Introduction

While the conservation of tropical ecosystems is an indisputable objective, the effectiveness of forest conservation interventions has frequently been questioned. Since the emergence of forest conservation interventions in carbon markets, effectiveness is generally assessed through the concept of additionality, i.e., avoided deforestation attributable to the intervention (Engel *et al.*, 2008; Wunder, 2015). In other words, additionality refers to the causal effect of conservation interventions, estimated through the comparison of the actual deforestation level in the area under conservation and a counter-factual situation without intervention, determined using an accepted business-as-usual scenario. The literature underlines that the effectiveness of forest conservation interventions is strongly heterogeneous (Ezzine-de-Blas *et al.*, 2016; Chervier and Costedoat, 2017; Ruggiero *et al.*, 2019; West *et al.*, 2020). Among the many factors that are likely to influence effectiveness, a strong body of empirical literature assesses that forest conservation interventions are affected by a location bias (Joppa and Pfaff, 2009; Pfaff and Robalino, 2012; Sims, 2014; Pfaff *et al.*, 2015): they tend to be implemented in remote areas, where development pressures are low and where forests are not threatened; thus they tend to provide low additionality.

Forest conservation interventions may be of various types – such as payment for ecosystem services, protected areas, community-based or jurisdictional approaches – with different implementers, different scales and different objectives. In particular, some of them put a strong emphasis on development issues or have a more exclusive focus on forest conservation. Indeed, forest conservation objectives frequently come along with development ones (reducing rural poverty, improving livelihoods). It has been shown that such a combination of objectives is likely to influence interventions implementation (Delacote *et al.*, 2014). Focusing on interventions in the Brazilian Amazon, Delacote *et al.* (2022) empirically show that implementers exclusively focusing on the forest conservation objective tend to locate REDD+ projects in areas where deforestation pressures related to development opportunities are lower. However, their empirical analysis suggests that, despite this location bias, those projects achieve additionality. Moreover, they do not find evidence that projects combining avoided deforestation and development objectives achieve any additionality. The paper thus opens questions about how sites' characteristics influence the selection of projects and their outcome. To the best of our knowledge, this process leading to the selection of sites where interventions are implemented has never been investigated theoretically.

In this paper, we contribute to this literature in two directions. Taking into account a wide range of forest conservation interventions over the conservation/development spectrum, we address (1) which factors determine siting choices, and (2) how those factors and the siting choice influence their additionality. A key conceptual distinction is introduced, between potential and effective additionality, to explain that interventions implemented in remote areas may nevertheless be effective, because they are less exposed to development pressure.

A simple theoretical framework is considered, focusing on cases with conservation–development trade-offs within a context of complete information: the implementation strategy of an implementer[1] consists of an effort allocation and the choice of a site. Two main characteristics are considered to influence those choices: first, the implementer may have mixed objectives, balancing between forest conservation, which is our indicator of additionality, and local livelihood improvements; second, local characteristics influence the intervention outcome: the development potential of the area – which is our indicator of potential additionality – and local institutions that influence the enforcement capacity of the implementer, i.e., characteristics that may lead actual additionality to differ from its potential. Hence, both the development potential and local institutions will influence the intervention implementation and outcome.

Although abstracting from important concerns around forest conservation interventions, such as leakage and permanence issues, our theoretical results underline an interesting dilemma: areas with high development potential are those with the highest risk of deforestation, thus also the largest potential additionality. However, if institutions are weak, conservation efforts will be less effective in these areas. Then, should the implementer try to save a more threatened forest, with also a higher risk of failure, or play

[1]As noted by Delacote *et al.* (2022), forest conservation interventions may be implemented by various types of institutions: governments, NGOs, private firms. For that matter, we use the term implementer instead of policy maker.

safer and focus on a forest under lower deforestation risk? This trade-off brings important additional results to the literature on location biases, which generally considers that implementing conservation policies in remote areas implies low additionality.

In section 2, the literature on conservation–development trade-offs, siting choices, and effectiveness of forest conservation interventions is presented. Section 3 presents our theoretical model. Section 4 discusses possible model extensions and section 5 concludes.

2. Literature review

In this selected literature review, three key features of our model are considered: conservation–development trade-offs in forest conservation, the siting choice of forest conservation interventions, and the effectiveness of forest conservation. Since forest conservation interventions encompass a wide variety of types, such as REDD+ projects or protected areas, our aim is to take a look at those topics for diverse types.

2.1 Conservation–development trade-offs in forest conservation

What is certainly the major question behind the fight against tropical deforestation is the following: can forest conservation and local rural development be compatible? The combination of conservation and development objectives has been investigated for various types of interventions: REDD+ projects (e.g., Delacote *et al.*, 2022), payment for ecosystem services (e.g., Bulte *et al.*, 2008) or protected areas (e.g., Amin *et al.*, 2019).

Groom and Palmer (2010) assess how the combination of conservation and poverty alleviation objectives influence the cost-effectiveness of payment for ecosystem services (PES). They show that PES mechanisms may not be the most cost-effective instrument compared to more indirect approaches (e.g., subsidies to capital). Delacote *et al.* (2014) show how the implementer's objective impacts the implementation of REDD+ projects, depending on the type of information that is available on opportunity costs. External private interest may also capture the benefits from forest resources, leading to conflicts with local communities. Engel and Palmer (2008) show under what conditions PES mechanisms may help resolve those conflicts. Duchelle *et al.* (2018) emphasizes that local participation is key to enhancing REDD+ outcomes, which suggests that local communities have to derive benefit from their participation. Pham *et al.* (2023) shows that a payment for forest environmental services increases households' livelihood quality in several dimensions (income, job satisfaction, expenditures).

Keles *et al.* (2020) and Qin *et al.* (2019) show that economic pressures are a good predictor of the degazettement and downsizing of protected areas, which suggests strong trade-offs between economic development and forest conservation. Community forest management (CFM) may also be a type of intervention potentially combining conservation and poverty alleviation issues. For example, Oldekop *et al.* (2019) show that win-win outcomes in terms of conservation and poverty alleviation have been achieved in the context of community-based management in Nepal. Similar types of results, where conservation does not come at the expense of livelihoods, is found by Mazunda and Shively (2015) in Malawi. In an experimental setting, it has also been shown that intrinsic motivation to poverty reduction of forest-dwelling community members may enhance participation and in turn increase their intrinsic motivation for forest conservation (Palmer *et al.*, 2020). Those links between deforestation and poverty alleviation are further discussed in Boltz *et al.* (2024).

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2.2 Siting choices of forest conservation interventions

The conservation science literature considers the siting choice of protected areas, taking into account factors of threats and benefits, such as biodiversity patterns and processes (e.g., Visconti *et al*., 2010). Bringing some economics into the process, Newburn *et al.* (2005) and Newburn *et al.* (2006) consider the site selection process, where factors of interest are biological benefits of conservation, land costs, and threats to land-use change. They underline a positive link between threats to land-use conversion and protection cost,[2] hence distinguishing high-vulnerability/ suitable land quality/expensive land and low-vulnerability/low cost/ poor quality land. Albers *et al.* (2023) underline the importance of jointly considering anthropogenic threats, species richness, and enforcement.

The siting of forest conservation interventions is likely to have strong influence on their implementation and effectiveness. The effectiveness of protected areas has been shown to depend on an optimal location, taking into account distance between forest patches (Albers *et al*., 2020b).[3]

Those links between economic threat to ecosystems and conservation costs lead to the mostly empirical location bias concept (Joppa and Pfaff, 2009; Pfaff and Robalino, 2012; Sims, 2014; Pfaff *et al*., 2015), according to which protected areas are implemented in most remote areas, where forests are less threatened. This concept suggests that strong trade-offs take place between forest conservation and rural development: effective forest conservation would imply strong constraints on local development; conversely, implementing effective protected areas is challenged in places with high economic pressure. Hence, conservation is implemented further away from the most active areas. In a spatially explicit setting applied to marine protected areas, Albers *et al.* (2020b) also considers this point, linking the siting choice of protected areas to enforcement effort and response of fishermen.

This question of the siting choice appears to be less investigated in REDD+ projects. At the macro level, Cerbu *et al.* (2011) assess which countries' characteristics better explain early REDD actions, emphasizing a strong bias toward South America and against Africa. Lin *et al.* (2014) identifies potential areas for REDD+ projects, mapping both forest carbon, deforestation risk and opportunity costs. For Pasgaard and Mertz (2016), the location of REDD+ interventions can be explained by previous engagements of the project implementers. More recently, Delacote *et al.* (2022) assess this choice for six REDD+ projects in the Brazilian Amazon. They show that projects combining conservation and development objectives are more likely to be implemented in areas with stronger opportunity costs, while projects focusing on the conservation objective are more likely to be implemented in more remote areas.

2.3 Effectiveness and additionality

Both theoretical and empirical work focuses on the effectiveness of forest conservation interventions (Engel *et al*., 2008; Alix-Garcia and Wolff, 2014).

From a theoretical standpoint, contract theory has been used to assess factors influencing the effectiveness of REDD+ projects. Chiroleu-Assouline *et al.* (2018) and Salas

[2]Sacre *et al.* (2019), however, shows that the links between threat and conservation costs are complex and not always linear.

[3]The analysis of siting choices and their impact on outcomes has also been investigated for marine protected areas (e.g., Albers *et al*., 2020a).

et al. (2018), among others, focus on asymmetric information on opportunity costs of deforestation, analyzing how those asymmetries affect the efficiency of REDD+ policies. Other papers (Albers and Robinson, 2013; Delacote and Angelsen, 2015; Delacote *et al.*, 2016) assess how project implementation produces some spatial or sectoral displacement of activities, leading to leakage of deforestation and forest degradation. Another branch of the literature analyzes the effectiveness of collective PES (see Hayes *et al.*, 2019; Segerson, 2022 for reviews and Nguyen *et al.*, 2022 for case studies).

Empirical assessment of the effectiveness of PES (especially REDD+) has been widely performed for the past few years. A first systematic review (Samii *et al.*, 2014) suggests that projects tend to fail to achieve the common objective of forest conservation and poverty alleviation. Duchelle *et al.* (2018) noted that few studies were focusing on the carbon outcomes of REDD+ projects at the time. Since then, the additionality of REDD+ projects has been widely questioned and challenged. Evaluating 40 REDD+ projects in nine countries, Guizar-Coutiño *et al.* (2022) underlines the relatively low levels of deforestation reduction achieved by those projects. West *et al.* (2020) considers that the over-estimation of emission reductions from Brazilian REDD+ projects is related to the over-estimation of the crediting baseline compared to their own control. West *et al.* (2023) also notice this lack of additionality in REDD+ projects, attributed to inaccurate baselines by carbon credit organisms. Montoya-Zumaeta *et al.* (2021) evaluate the impact of six Peruvian incentive-based conservation projects and find sub-optimal environmental outcomes. A meta-analysis of the effectiveness of forest conservation interventions is currently being performed (Chabé-Ferret *et al.*, 2024), and is being updated as new results are published in peer-reviewed journals. So far, the project underlines the heterogeneous additionality of forest conservation programs. However, Wunder *et al.* (2020) argue that PES can be as effective as other types of interventions, but issues of self-selection, inadequate targeting and poor enforcement can undermine the effectiveness of those schemes.

The effectiveness of protected areas has also been widely investigated. Most recently, Duncanson *et al.* (2023) has shown that protected areas were globally effective as a climate mitigation tool. Focusing on the Brazilian Amazon, Amin *et al.* (2019) shows that integral protected areas and indigenous lands do reduce deforestation. In contrast, they do not find evidence of deforestation reduction in sustainable use areas. This result suggests that strong protection can be effective, while the combination of conservation and development objectives may be difficult to achieve. Keles *et al.* (2023) find similar results when it comes to the degazettement and downsizing of protected areas in the Brazilian Amazon: protected areas may be withdrawn in remote or high economic pressure areas, and they can be effective or ineffective before their withdrawal. It is shown that reducing forest protection increases deforestation in cases where (1) development pressure is high, and (2) protection was effective.

The literature on community-based forest management is scarcer when it comes to deforestation outcomes. Yet, Oldekop *et al.* (2019) show that, in the Nepalese context, the impact of CFM on deforestation decreases when poverty baseline levels are higher, and increases with the length and size of forest management. Deforestation has also been found by Mazunda and Shively (2015) to be lower due to CFM in Malawi.

Generally, papers underline the heterogeneity of impacts (Ezzine-de-Blas *et al.*, 2016; Chervier and Costedoat, 2017; Ruggiero *et al.*, 2019), which suggests that the sources of this failure and success should be more carefully investigated (Börner *et al.*, 2017). Among empirical studies, Delacote *et al.* (2022) is the one to which our theoretical

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analysis strongly relates. The paper shows that the additionality of REDD+ projects in Brazil strongly depends on the objective of the project implementer and the siting of the project: projects combining environment and development objectives were found ineffective, while one project with a strong focus on forest conservation was additional.

Our modeling approach in the next section comes at the intersection of those three sides of the literature: we show that the siting of forest conservation intervention can be the result of conservation/development trade-offs, and that what is generally considered a location bias does not necessarily lead to lack of additionality.

3. Modeling intervention implementation and additionality

We consider an implementer aiming to set a forest conservation intervention in a site she has to select. Assuming a single implementer implicitly suggests that potential sites are abundant enough, implying no competition nor strategic interactions between implementers. Thus they can select sites independently. Information about the targeted site characteristics (mainly opportunity costs of the community living onsite) is frequently mentioned as a key element and has been investigated in the literature. As a matter of simplicity, we thus assume complete information here.

The implementer is presented first. Then the reaction of the site community to the intervention is described. Finally, we show how the implementer's objectives may influence the implementation and its outcome.

3.1 The implementer of the forest conservation intervention

Our aim is to describe a wide range of possible forest conservation interventions over the conservation/development spectrum. For that purpose, we consider that the implementer's objective may encompass two components:

1. *Conservation additionality*: a weight α is given to the intervention outcome in terms of avoided deforestation AD;
2. *Development impacts*: a weight β is given to the livelihoods improvements Δ of the intervention.

Two choices made by the implementer are considered: (1) *site selection:* a site is chosen on its development potential b, that is also an indicator of threat on forests; and (2) *effort allocation*: between conservation (e) and development objectives ($1 - e$).

Several modeling choices have been made to take into account the wide variety of interventions. First, the weight given to conservation and development objectives can describe a large spectrum of conservation/development objectives.

Second, conservation interventions may consist of direct PES to households,[4] but they can also consist of constraints put on access to land (guards and control) or direct investment or measures (e.g., providing advice on agricultural techniques, improving agricultural resilience, creating new economic opportunities) that contribute to development. In order to take into account this wide variety, the implementer's intervention is modeled as an effort-allocation model: effort e is allocated to conservation, while effort $(1 - e)$ is allocated to poverty alleviation.

[4]As noticed by Wunder *et al.* (2020) in their evaluation of more than 200 REDD+ projects, PES mechanisms tend to be underutilized.

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In order to have interior solutions, we consider that the implementer's utility from conservation additionality (E) and from development impacts (L) are increasing and concave.[5]

The intervention with site type b and effort allocation e provides the following payoff to the implementer:

$$v(b, e) = \alpha E(AD(b, e)) + \beta L(\Delta(b, e)). \tag{1}$$

3.2 Site and community

3.2.1 Business-as-usual case

We consider a continuum of potential sites where the intervention could be implemented. Each site is represented by a potential benefit b for each unit of deforestation d, which can be considered as an indicator of opportunity costs for the agents living onsite. This simplification states that deforestation leads to short-term economic development. In the long run, the accumulation of deforestation may become detrimental to development, for instance when the loss of ecosystem services puts agricultural activities at risk. This negative feedback has been investigated in a forest transition setting, including REDD+, by Ollivier (2012).

We assume convex costs of deforestation, including non-market benefits from forest conservation, with a quadratic specification. The site community chooses its level of deforestation to maximize its livelihood:

$$\max_d u = bd - \frac{d^2}{2}. \tag{2}$$

Under no intervention, the optimal level of deforestation is: $\overline{d} = b$. The level of development is $\overline{u} = b^2/2$. Those levels are considered to be the business-as-usual scenario. This baseline is considered common knowledge and with no uncertainty, in order to focus on our matter of interest.[6]

3.2.2 Reaction to the conservation intervention

The implementer allocates her effort between reducing deforestation (e) and improving livelihood of agents living on the site ($1 - e$). We focus on a case in which effort for reducing deforestation and effort for improving livelihoods are not complementary, meaning that we focus on environment–development trade-off situations, such as the ones described in section 2.1. Indeed our main interest is to consider how development pressure and site selection affect intervention additionality. Note, however, that the intervention can achieve both conservation and development objectives.

Conservation effort effectiveness and institutional context: conservation effort may not always have the same effectiveness, depending on the site and context where the intervention is implemented.

First, we consider that economic pressures, described by the site type b, may reduce the effectiveness of effort allocated to forest conservation. Indeed, forest conservation

[5]The functional forms used for the numerical illustrations are given in appendix A.

[6]For an analysis of REDD+ projects with asymmetric information or uncertainty about baselines and opportunity costs, see Delacote *et al.* (2014) and Delacote and Simonet (2013), respectively.

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implies increasing the cost of deforestation, which can be in conflict with private economic interests (especially if opportunity costs are high), which may try to overcome the effort made to decrease deforestation.[7]

Second, other local factors can also impact the conservation effort effectiveness. In particular, factors related to institutions, mainly the ones related to ecosystem management, can influence the links between conservation effort and outcome.[8] At the national scale, institutions (democratization, rule of law) have been shown to influence the implementation of protected areas (Bareille *et al.*, 2023) and deforestation (Burgess *et al.*, 2012). At the more local level, institutions can be referred to as the capacity to enforce the ecosystem management rules. Robinson *et al.* (2015) underlines the importance of village level institutions to increase the compliance to REDD+ projects, while Albers and Robinson (2013) reviews the importance of property rights enforcement for non-timber forest products extraction. Robinson *et al.* (2019) notice that REDD+ should be implemented in areas where property rights are well-defined. Robinson *et al.* (2014) distinguish resource extraction from insiders and outsiders. In our framework, one can consider that institutions encompass the capacity both to prevent resource extraction by outsiders and to limit unsustainable extraction by insiders.

$\delta(b) \in [0, 1]$ is our indicator of this conservation effort effectiveness, relative to effort allocated to livelihood improvement: when $\delta(b) = 1$, effort is equally efficient for conservation and livelihood objectives; when $\delta(b) < 1$, effort allocated to conservation is relatively less efficient than effort allocated to development. It is totally ineffective for $\delta(b) = 0$.[9]

In our framework, both local institutions and development influence the effectiveness of effort allocated to the conservation objective ($\delta(b)$).[10] In the case of weak institutions, larger opportunity costs from deforestation b makes more difficult the implementation of an efficient conservation effort e: $\delta'_b << 0$. For example, if property rights are not well enforced, deforestation by outsiders is more difficult to contain in areas with higher development potential. In the case of strong institutions, the effectiveness of conservation effort is less sensitive to the development potential: $\delta'_b \to 0$. Thus, $\delta(b) \to 1$ and $\delta'_b \to 0$ relate to more reliable local institutions and strong conservation enforcement.[11] Effort allocated to the conservation objective increases the cost of deforestation for the community (equivalently increases the benefit from forest conservation), becoming: $(1 + \delta(b)e)d_i^2/2$. Effort allocated to development improvement increases the net benefit from the community's activities : $(1 + (1 - \delta(b)e))(bd - (1 + \delta(b)e)d_i^2/2)$.

[7] In contrast, economic pressures are likely to increase the effectiveness of effort allocated to improving livelihoods, as both implementer and community objectives are in line.

[8] Institutions can more broadly imply long-run economic benefits. We focus here on the short-run link between institutions and conservation.

[9] The case of effort that is more efficient for conservation objectives than for livelihood objectives can also be considered: $\delta(b) > 1$. For example, it would be the case for contexts where (public) authorities prioritize the environment over development, leading to an institutional setup, a, that likewise prioritizes forests. This type of situation would bring lower levels of deforestation and livelihoods (see equations (4) and (5)).

[10] Effort effectiveness may not always be decreasing in opportunity costs, for example, if better development opportunities go along with more efficient institutions. In this type of case, there is no longer a trade-off and we have qualitative results similar to those for efficient institutions.

[11] For the numerical illustration, we consider $\delta(b) = 1/b^a$. When $a = 0$, we consider that effort is equally efficient in conservation and development outcomes, which indicates strong conservation enforcement and local institutions; higher a represents worse institutional quality. See appendix A.

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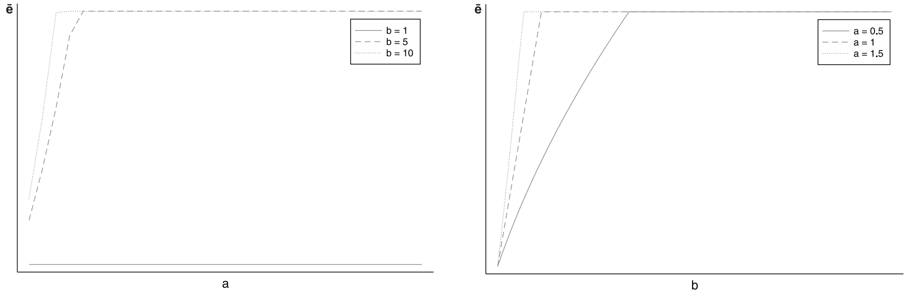

Figure 1. Influence of development potential b and institutional quality a on community's participation constraint $\bar{e}$.

Voluntary or coercive intervention: forest conservation interventions may be voluntary (e.g., REDD+ projects) or coercive (e.g., integral protected areas). If participation is voluntary, the community accepts to participate if and only if the following participation constraint is satisfied: $e \leq 1/2\delta(b) \equiv \bar{e}$, implying that effort allocated to livelihood improvement has to be large enough to make the community better off.[12]

In the case of a coercive intervention, such a participation constraint may not take place and the effort allocation can be set to $e > \bar{e}$, meaning that the intervention is implemented at the expense of the local community.[13]

Reaction to the intervention: under the forest conservation implementation, the community's objective becomes:

$$\max_{d} u = (2 - \delta(b)e)(bd - \frac{(1 + \delta(b)e)d_i^2}{2}), \tag{3}$$

leading to the following reaction:

$$d^*(b, e) = \frac{b}{(1 + \delta(b)e)} \tag{4}$$

$$u^*(b, e) = \frac{(2 - \delta(b)e)}{(1 + \delta(b)e)} \frac{b^2}{2}. \tag{5}$$

Avoided deforestation is

$$AD^*(b, e) = \bar{d}(b) - d^*(b, e) = \frac{b\delta(b)e}{(1 + \delta(b)e)}. \tag{6}$$

Avoided deforestation is unambiguously increasing in e:

$$AD^{*\prime}_e = \frac{b\delta(b)}{(1 + \delta(b)e)} > 0. \tag{7}$$

[12] Sensitivity to parameters b and a for our numerical example is given in figure 1.

[13] Albers (2022) suggests that implementation of protected areas should better consider interactions with local people. In the context of our paper, this would lead to taking the participation constraint into account when implementing a protected area.

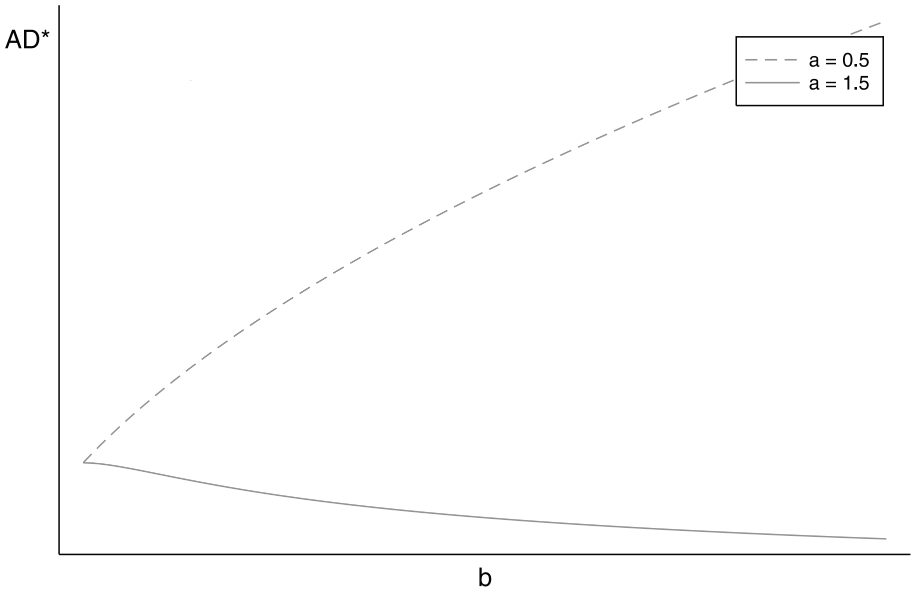

Figure 2. Influence of development potential *b* on avoided deforestation AD^*, for diverse levels of institutional quality *a*.

Potential and effective additionality: the impact of type *b* on avoided deforestation is:

$$AD^{*\prime}_b = \underbrace{\overbrace{\frac{\delta(b)}{(1+\delta(b)e)}}^{\text{Potential Additionality}} + \frac{b\delta'_b e}{(1+\delta(b)e)^2}}_{\text{Effective Additionality}}. \tag{8}$$

Result 1 : *Potential and effective additionality. Choosing a site with high development potential b suggests high potential additionality, as the baseline deforestation is large if no forest conservation intervention is implemented; the first part of equation (8) is positive.*

The level of effective additionality depends on the quality of institutions; the second part of equation (8) is negative. If institutions are strong, ($\delta(b) \to 1$, $\delta'_b \to 0$), effective additionality is close (possibly equal) to its potential. In this case, avoided deforestation is larger in communities with high development potential b. If institutions are weak, ($\delta(b) \to 0$, $\delta'_b << 0$), the difference between potential and effective additionality is larger. In that case, avoided deforestation is smaller in communities with high development potential b.

Figure 2 illustrates this result with a numerical example.

Overall this distinction between potential and effective additionality implies that baseline deforestation is not a good indicator of additionality when institutions are weak. Indeed, in that case, the level of avoided deforestation may be higher in sites where the baseline deforestation is low. It follows that site selection focusing mainly on threat to ecosystems that do not take into account socioeconomic contexts (including institutions) is likely not to achieve its conservation objectives.

Table 1. Effort allocation and site selection

Intervention type	Objective	Avoided deforestation $\alpha = 1$		Development $\beta = 1$	
	Institutions	Weak	Strong	Weak	Strong
		$\delta'_b << 0$	$\delta'_b = 0$	$\delta'_b << 00$	$\delta'_b = 0$
	b^*	Lowest b	Highest b	Highest b	Highest b
Voluntary	e^*	$\bar{e}$	$\bar{e}$	0	0
Coercive	e^*	1	1	0	0

Development impact of the intervention is

$$\Delta(b, e) = u^*(b, e) - \overline{u}(b) = \frac{b^2}{2} \frac{(1 - 2\delta(b)e)}{(1 + \delta(b)e)}. \tag{9}$$

Increasing e decreases the intervention benefits in terms of livelihoods, while selecting a site with strong development potential b increases it,

$$\Delta^{*\prime}_e = \frac{-b^2}{2} \frac{3\delta(b)}{(1 + \delta(b)e)^2} < 0 \tag{10}$$

$$\Delta^{*\prime}_b = \frac{b(1 - 2\delta(b)e)}{(1 + \delta(b)e)} - \frac{3b^2\delta'_b e}{(1 + \delta(b)e)^2} > 0. \tag{11}$$

3.3 Intervention implementation

In this section, the effort allocation and the site selection are described. First, in order to give some intuition about our results, we focus on two extreme cases of implementer objectives: when the implementer focuses only on conservation ($\alpha = 1$) or only on development ($\beta = 1$). We combine them with two corner cases of local institutions: $\delta'_b = 0$ and δ'_b strongly negative. The results are presented in table 1.

Second, we generalize those results and consider the maximization problem presented in equation (1). The first-order conditions implicitly describe this set of choices:

$$v'_b = \alpha E' AD'_b + \beta L' \Delta'_b = 0 \tag{12}$$

$$v'_e = \alpha E' AD'_e + \beta L' \Delta'_e = 0. \tag{13}$$

3.3.1 Effort allocation

Looking at table 1, effort allocation is straightforward. The implementer allocates all her effort to development if it is her unique objective: $e^* = 0$ if $\beta = 1$ (e.g., a project of community forest management with a strong poverty alleviation objective). If avoided deforestation is her unique objective and participation is voluntary (e.g., REDD+ project), the implementer selects the effort allocation that satisfies the community participation constraint if avoided: $e^* = \bar{e}$ if $\alpha = 1$. If the intervention is coercive (e.g., integral protected area), she can allocate all her effort to conservation: $e^* = 1$.

This intuition is generalized in equation (13): the implementer allocates her effort between her conservation and development objectives in order to balance marginal benefit from avoided deforestation and marginal benefit from livelihood improvement.

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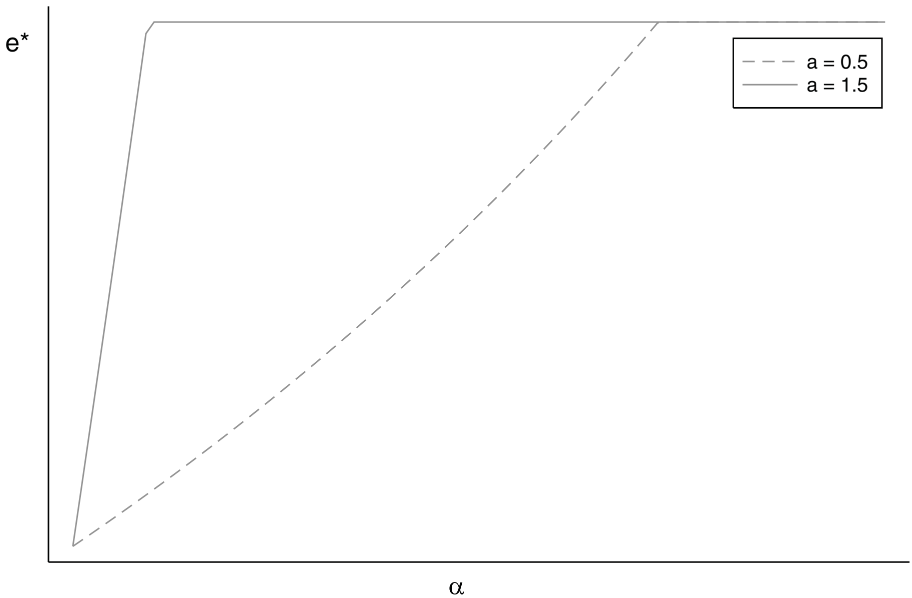

Figure 3. Implementer objective α and optimal effort allocation e^*, for diverse levels of institutions a.

Result 2 : *The implementer allocates her effort according to her objectives: larger conservation objective (α) implies larger effort allocated to avoided deforestation (larger e); while larger development objective (β) implies larger effort allocated to improving livelihoods (smaller e). Figure 3 illustrates this result with a numerical example.*

3.3.2 Site selection

The trade-off behind site selection is described in table 1. If development is the unique objective of the implementer ($\beta = 1$), she selects the site with the highest development potential whatever is the local institutional quality. In contrast, when considering an implementer only focusing on conservation outcomes ($\alpha = 1$), institutions matter and the difference between potential and effective additionality described in result 1 is crucial. If institutions are strong and effort allocated to conservation is effective, then effective additionality is close to potential additionality and the implementer selects the site with the highest development potential (hence the highest potential and effective additionality). If institutions are weak, the effectiveness of effort allocated to conservation is strongly negatively affected by the development potential. The implementer then selects a site with the lowest development potential in order to maximize effective additionality.

This intuition is generalized in equation (12). The implementer balances the trade-off between the impact of the development potential on avoided deforestation, and the impact on livelihoods. This trade-off depends on two interconnected factors: first, on the relative weight between conservation (α) and development (β) objectives; and second, on the link between development potential b and conservation effort effectiveness $\delta(b)$ (as shown in result 1).

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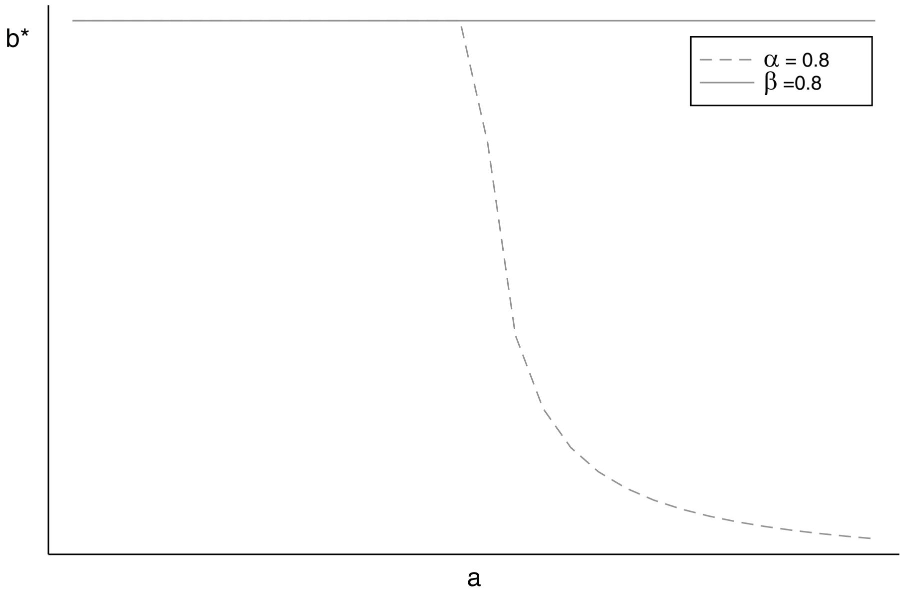

Figure 4. Influence of institutional quality a on site choice b^*, for diverse levels of implementer objective α, β.

Result 3 :

- ***Development first:*** *a development-first implementer (high β) selects a site with high development potential b, whatever is the level of local institutions.*
- ***Conservation first:*** *a conservation-first implementer (high α) selects a site*
  - *with high development potential b, if local institutions are strong ($\delta'_b \rightarrow 0$, small a)*
    $\rightarrow$ the best strategy is to target places where potential additionality is high and close to effective additionality.
  - *with low development potential b, if local institutions are weak ($\delta'_b << 0$, small a)*
    $\rightarrow$ the best strategy is to target places where potential additionality is lower, but effective additionality easier to achieve.

Figure 4 illustrates this result with a numerical example.

Institutions are shown to strongly affect the site choice of the implementer if she gives strong importance to the conservation objective. If they are strong, the implementer can be ambitious about the intervention outcome, and target sites where development pressure is high; if they are weak, it is preferable for the implementer to focus on sites where development pressure is lower, in order to more easily capture conservation benefits.

This result underlines that an implementer with strong conservation objectives may have an interest in selecting a site with low development potential, which is frequently considered as a location bias in the literature. Hence it gives new insight into this concept, which generally considers that interventions implemented in remote areas are ineffective. In our framework, an implementer with a focus on conservation may pick a site with low development potential, in a remote area, simply because weak institutions reduce the effectiveness of conservation effort.

4. Discussion: permanence, uncertainty and leakage

Our simple model abstracts from some important issues behind forest conservation interventions. Those blind spots are briefly discussed in this section, in order to give insights for possible extensions of the model.

Conservation–development synergies and permanence issues: Our model focuses on situations implying conservation–development trade-offs, which are often described in the literature. However, another approach is to find situations and implementations in which development and conservation objectives can be targeted jointly. This point is particularly important when addressing the issue of permanence. Indeed, if conservation is done at the expense of local development, it is likely that avoided deforestation will not last when the intervention ends. As shown by Carrilho *et al.* (2022), post-project permanence is a challenging issue, even when win-win outcomes are achieved in the short run. Long-term win-win outcomes might be achieved if effort allocated to development objectives creates economic opportunities outside the agricultural sector (e.g., eco-tourism, transformation of raw commodities). In this case, effort to reduce deforestation would create a reallocation of labor from agriculture to those new activities, creating complementarity between effort allocated to forest conservation and effort allocated to development objectives.

In the context of our paper, seeking win-win outcomes can have an influence on the site selection. One could expect that implementers combining conservation and development objectives would select sites where the potential synergies are the strongest. In contrast, implementers focusing only on environmental objectives would select sites regardless of their potential win-win outcomes, and would only focus on their conservation outcome.

Overall, finding effective ways to combine conservation and poverty alleviation is a major challenge, which requires further theoretical and empirical research, in line with permanence and long-term effects.

Imperfect information and uncertainty: In this paper, complete information and lack of uncertainty are assumed on several aspects: baseline scenario, opportunity costs of deforestation. In reality, all those variables experience a high level of variability and uncertainty. For example, West *et al.* (2023) shows that the baselines used by carbon credit certifiers are over-estimated, which produces an over-estimation of avoided deforestation, and an over-allocation of carbon credits. One would expect that such uncertainties also impact the site choice by the implementers, but also the effort allocation (Delacote *et al.*, 2014).

Introducing such uncertainties in our framework would imply new foundations of the implementer payoff, which would depend on measurement errors. Does the implementer care about measurement errors? If we consider that the implementer has strong aversion for measurement errors, one would expect her to select sites where baselines and opportunity costs are better known, and where outcomes are less risky.

Leakage: The paper focuses on additionality, putting aside leakage, another important outcome determining the success or failure of a forest conservation intervention (Filewod and McCarney, 2023). As shown in Delacote *et al.* (2016), leakage strongly depends on the implementation. Hence, leakage is likely to be influenced by site characteristics and allocation of effort.

An extension of our model including leakage is presented in appendix B. Two channels of leakage are distinguished: (1) the AD channel in which larger avoided deforestation increases displacement of deforestation; and (2) the D channel in which larger local livelihood improvement decreases the incentive to displace deforestation. If the AD channel is more important than the D, one could expect a higher effort allocated to livelihoods: leakage is strongly reduced by the D channel, hence improving livelihoods indirectly increases avoided deforestation. Site selection is also impacted by this introduction of leakage, and depends on institutional quality: if institutions are strong, the AD and the D channels play in the same direction, meaning that choosing a high-b site increases avoided deforestation. In contrast, if institutions are weak, the two channels play in opposite directions: a large AD channel (low D channel) pushes the siting selection toward lower development potential.

Although this simple extension brings some insights about the intervention implementation, further analysis would be required to investigate those connections more deeply.

5. Conclusion

Following the data revolution of remote sensing and the methodological uptake of impact evaluation, the empirical literature has been growing over the past years to assess the effectiveness of forest conservation interventions. An important part of this literature focuses on a global analysis of forest conservation effectiveness: most recently (West *et al.*, 2023) for REDD+ projects and (Duncanson *et al.*, 2023) for protected areas. Those global analyses are very important, but as noticed by Chabé-Ferret *et al.* (2024), a wide variety of outcomes is also observed. Understanding the sources of those heterogeneities, and the barriers and levers to effectiveness, are key issues, in complement to those global analyses. In this regard, an important role of theory is to underline mechanisms behind those heterogeneous impacts, which can help to target empirical work and data gathering, and predict possible results. The aim of this paper is to describe potential mechanisms related to site selection, intervention implementation and outcomes in a conservation/development framework.

Forest conservation interventions frequently combine environmental and development objectives and have heterogeneous impacts. How sites and communities are selected by implementers, and how this choice affects the interventions' outcome, has been overlooked in the literature.

In this paper, we theoretically study how the objectives of the implementer (conservation and development) and local siting characteristics (opportunity costs and institutions) influence implementation and additionality. Doing so, we revisit the location bias concept, by distinguishing potential and effective additionality. Areas with strong development potential have high potential additionality: if the intervention is effective, large

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avoided deforestation can be achieved. But the effectiveness of effort may be challenged by local institutions, leading to lower effective additionality.

Our results show that the implementer preferences strongly affect site selection and thus the intervention additionality. This theoretical result supports the empirical evidence found by Delacote *et al.* (2022), where it is shown that REDD+ projects focusing exclusively on carbon tend to pick communities with lower opportunity costs but are more additional than projects focusing both on carbon and development targets. It also support the evidence found by Amin *et al.* (2019) who show that integral protected areas (hence with stronger focus on conservation) bring higher deforestation reduction than multiple-use protected areas (hence combining conservation and development objectives).

Our theoretical intuition is that the choices of the implementers are influenced by the quality of institutions; i.e, siting characteristics that favor (or prevent) the effectiveness of effort to reduce deforestation, such as property rights, potential to prevent invasion by outsiders, or capacity to enforce forest management rules. In a context of weak institutions, it can be difficult to enforce conservation activities in areas with high development potential. In that case, potential additionality is large in areas with high development potential, but effective additionality is low because of this impact of institutions on the effectiveness of conservation effort.

Our results have implications for implementers of forest conservation interventions and for their evaluation. A first direct implication of our results is that implementers should have a good ex-ante knowledge of institutional contexts in order to make an enlightened selection of sites where their interventions will be implemented. Such inquiries can represent additional implementation costs, but can have an impact on the intervention outcomes. Second, given this distinction between potential and effective additionality, and the trade-off implied by institutional quality, our results suggest that, in the absence of robust local institutions, implementers with strong environmental objectives should cherry-pick some easy wins, i.e., focus on areas with higher effective additionality, even though they have lower potential additionality. Third, we also show that the combination of conservation and development objectives can be done at the expense of avoided deforestation. This result sheds light on the necessity to have strong scientific-based ex-post evaluation of REDD+ projects with double certification (carbon and co-benefits) and of multiple-use protected areas, in order to have reliable indicators of their additionality. Fourth, in terms of ex-post evaluation, our results suggest that indicators of local institutions (quality and clarity of property rights, enforcement of forest management rules) could be relevant moderators when looking at impact heterogeneity and should be used for matching treated and control groups in order to take into account this impact of institutions on the effectiveness of conservation effort. Gathering local data on such types of indicators could therefore be required.

Overall, by distinguishing potential and effective additionality, our work underlines an important feature: location biases, often identified in the literature, are not independent of the implementer type and objectives. Furthermore, the existence of a location bias, frequently represented by implementing conservation interventions in remote areas, does not necessarily imply a lack of additionality. In contrast, choosing a site with high development potential may lead to a low level (if any) of additionality. Our analysis provides innovative theoretical insights regarding the mechanisms that lead to site selection and additionality of forest conservation interventions. We show how the incentives behind conservation can lead to target areas with lower development potential and that the quality of governance can impact the behavior of the implementers. This insight provides a complementary perspective to Wunder *et al.* (2020) which suggest that PES schemes should be implemented in high-threat areas, but also in areas with strong land tenure (which can be associated to strong local institutions). Our complementary argument is that in situations in which strong land tenure is difficult to implement, it can be worthy to pick less-threatened areas in order to get some kind of additionality.

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Appendix A: Value of the functions and parameters used for the numerical illustration

Table A1. Functions

Function	
$E(AD(b, e))$	$log(AD(b, e))$
$L(\Delta(b, e))$	$log(\Delta(b, e))$
$\delta(b)$	$\frac{1}{b^a}$

Table A2. Parameters

Variable	Figure 2	Figure 3		Figure 4	
b	$\in [1, 10]$		b^*		
e	0.5		e^*		
a	(0.5, 1.5)	$\in [0.1, 3]$		0.5	1.5
α	n.a	0.8	0.2	[0, 1]	
β	n.a	0.2	0.8	[1, 0]	
b^*	n.a	[10, 1.58]	[10, 10]	10	[10, 1.58]
e^*	n.a	[0.45, 1]	[0.09, 1]	[0, 1]	[0, 1]
v^*	n.a	[1.24, −1.05]	[2.87, 2.20]	[3, 91, 0.87]	[3, 91, −0.63]
$\bar{e}$	[0.5, 1]	[0.63, 1]	[0.63, 1]	1	1

.

Appendix B: A simple model extension with leakage

In our main model, leakage is not considered, neither by the implementer, nor by the certification standard. An extension of the model would consist of introducing a leakage measure depending on both direct avoided deforestation and livelihood improvements: $L(AD(b, e), \Delta(b, e))$; where one could expect: $L'_{AD} = \partial L/\partial AD > 0$ and $L'_{\Delta} = \partial L/\partial \Delta < 0$. Indeed, if the intervention induces a larger amount of avoided deforestation, one could expect that the displacement risk is higher because of stronger constraints on the land use; similarly, if the intervention induces larger livelihood improvements, one could expect that agents do not have the incentive to displace their deforestation activities.

If the implementer explicitly considers leakage in her objective function, her value function becomes:

$$v(b, e, m) = \alpha E(AD(b, e) - L(AD(b, e), \Delta(b, e)) + \beta L(\Delta(b, e)) \tag{B.1}$$

Equations (B.2) and (B.3) become:

$$v'_b = \alpha E'(AD'_b \overbrace{-L'_{AD}AD'_b}^{>0\ or<0} \overbrace{-L'_{\Delta}\Delta'_b}^{>0}) + \beta L'\Delta'_b = 0 \tag{B.2}$$

$$v'_e = \alpha E'(AD'_e \underbrace{-L'_{AD}AD'_e}_{<0} \underbrace{-L'_{\Delta}\Delta'_e}_{>0}) + \beta L'\Delta'_e = 0 \tag{B.3}$$

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Comparing those equations allows to assess the effect of taking leakage into account when implementing the intervention. The two leakage channels described before are crucial. If we consider an implementer with a strong preference for avoided deforestation (high α), taking leakage into account implies:

- higher (resp. lower) effort e if L'_{AD} is small (resp. large) and L'_{Δ} is large (resp. small)
- if institutions are strong, higher b
- if institutions are weak, higher b if L'_{AD} is small (resp. large) and L'_{Δ} is large (resp. small)

Overall one can see here that taking leakage into account can exacerbate or temperate the trade off described in the simpler version of the model, but does not modify the qualitative results.

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