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Philippe Delacote, Gwenolé Le Velly, Gabriela Simonet

CEE-M

CENTER FOR ENVIRONMENTAL ECONOMICS - MONTPELLIER

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Distinguishing potential and effective additionality to revisit the location bias of REDD+ projects

Philippe Delacote [*†‡], Gwenolé Le Velly [§¶], Gabriela Simonet [§‖]

Abstract

Since the beginning of the REDD+ mechanism, hundreds of projects have emerged around the globe. Much attention has been given to REDD+ projects in the literature, but the conditions under which they are likely to be effective are still not well known. In particular, the location bias concept states that projects are more likely to be implemented in remote areas, where development pressure is low, and hence questions their additionality. In this article, we revisit this concept, trying to assess the process of REDD+ projects implementation and its influence on project additionality. First, a simple theoretical model shows that project implementation is influenced by the type of project proponent, which appears to be a good proxy for its objectives, whether oriented toward environmental impacts, development impacts, or external funding. Our results suggest that (1) the project proponents objective and local institutions may lead the project proponent to select a community with low development potential, and (2) the selection of a low-development potential, which is frequently presented as a location bias, does not necessarily preclude additionality. Those predictions are empirically tested on a sample of six REDD+ projects in Brazil. We propose an empirical analysis of the location choices and estimate additionality in the first years of implementation using impact evaluation techniques. The results confirm the predictions of the model.

Keywords: Additionality, Conservation policy, Deforestation, Impact evaluation, REDD+, Spatial analysis.

JEL codes: Q23; Q28; Q56

[*] Université de Lorraine, AgroParisTech-INRAe, BETA. 14 rue Girardet - CS 14216 54042 Nancy cedex, France

[†] Climate Economics Chair. Palais Brongniart, 28 Place de la Bourse, 75002 Paris, France

[‡] Corresponding author: philippe.delacote@inrae.fr

[§] CEE-M, Univ Montpellier, CNRS, INRAe, Institut Agro. 2 Place Pierre Viala, 34060 Montpellier, France

[¶] Corresponding author: gwenole.le-velly@supagro.fr

[‖] CIFOR. Jalan CIFOR Situ Gede, Sindang Barang, Bogor (Barat) 16115, Indonesia

Abbreviations

CCB: Climate, Communities and Biodiversity

CDM: Clean Development Mechanism

COP: Conference of the Parties

CO2: Carbon Dioxide

DID: Difference-In-Difference

IBGE: Instituto Brasileiro de Geografia e Estatistica

IUCN: International Union for Conservation of Nature

NDCc: Nationally Determined Contributions

NGOs: Non-Governmental Organizations

PDD: Project Design Documents

REDD: Reducing Emissions from Deforestation and Forest Degradation

UNFCC: United Nations Framework Convention on Climate Change

VCS: Verified Carbon Standard

1 Introduction

REDD+ is an international mechanism aimed at compensating developing countries for their participation in the global effort to mitigate climate change through the reduction of deforestation and forest degradation, as well as the conservation and enhancement of their forest carbon stocks. At the local level, REDD+ has resulted in hundreds of REDD+ projects, frequently taking the form of Payment for Ecosystem Services. Effectiveness of REDD+ projects is generally assessed through the concept of additionality, which can be defined as the avoided deforestation attributable to the project (Engel et al., 2008; Wunder, 2015).

Some of these projects are financed through the sale of carbon credits, which are assumed to remunerate their additionality. Additionality is estimated here based on a comparison between the actual deforestation in the area under conservation and a baseline level of deforestation which corresponds to a counter-factual situation without project implementation determined using an accepted business-as-usual scenario. If the baseline scenario is accurately estimated, it is possible to compute the additionality of the projects which, as explained by Persson and Alpízar (2013), is determined by the share of area enrolled that would not meet program requirements, e.g., forest conservation, without program implementation.

The literature underlines that PES effectiveness is strongly heterogeneous (Ezzine-de Blas et al., 2016; Ruggiero et al., 2019; Chervier and Costedoat, 2017). To the best of our knowledge, most of the theoretical work on REDD+ (more broadly payment of environmental services) effectiveness uses contract theory tools to assess the impact of information on REDD+ effectiveness (Groom and Palmer, 2010; Delacote et al., 2014; Chiroleu-Assouline et al., 2018; Salas et al., 2018).[1]. Further, a strong body of empirical literature assesses that avoided deforestation projects and other policies are affected by a location bias (Joppa and Pfaff, 2009; Pfaff et al., 2015; Pfaff and Robalino, 2012; Sims, 2014): they tend to be implemented in remote areas, where development pressures are low and thus where forests are not threatened; thus they tend to provide low additionality. In this article, we contribute to this literature in two directions: we first wonder which factors determine the implementation of REDD+ projects, and second how those choices influence their additionality. We introduce a distinction between potential and effective additionality, to explain that projects

[1]Households/community models are also used to assess leakage (Delacote and Angelsen, 2015; Delacote et al., 2016)

implemented in remote areas may nevertheless be effective, because their implementation is less exposed. Using both an empirical and a theoretical analysis, we build a theory of change based on the choice of a location, the type of certification scheme and the potential/effective additionality of REDD+ projects.

First, our simple theoretical model studies the implementation strategy of the project proponent (hereafter Pp), which consists of an effort allocation, the choice of a community and a certification scheme. Two main characteristics are considered to influence those choices: first, the Pp may have mixed objectives, balancing between an environmental one (our indicator of additionality, i.e avoided deforestation) and local livelihood improvements; second, local characteristics influence the project outcome. In our simple model, local characteristics considered are the development potential of the area (our indicator of potential additionality) and local institutions that influence the enforcement capacity of the Pp (i.e characteristics that may lead actual additionality to differ from its potential). Our theoretical results show that project proponents face a trade-off between targeting more threatened forests and an efficient allocation of scarce resources. In some cases, given the difficulty to enforce conservation in areas characterised by high development pressure, it can be optimal for the project proponent to implement a project in less threatened forests. This strategy can even lead to higher additionally and maximise funding from the carbon market. This result brings important additional results to the literature on location biases, which generally considers that implementing conservation policies in remote areas implies low additionality.

Second, in order to test the predictions of our theoretical model, we empirically study the characteristics of six REDD+ projects located in Brazil, using an original database, and estimate their additionality in the short-run using impact evaluation methodologies as recommended in the recent literature about forest conservation policy instruments (Miteva et al., 2012; Baylis et al., 2016). The six projects studied are heterogeneous regarding the type of project proponents and the choice of a certification scheme. We consider two types of actors: Non-Governmental Organisations (NGOs) and private-for-profit organisations; and two types of standards for certification: the Verified Carbon Standard (VCS), which focuses on the carbon dimension of the projects, and the Climate, Communities and Biodiversity (CCB) Alliance standard, which addresses the non-carbon impacts of the projects. Our results show that the choice of location and additionality are heterogeneous from one type of project to another and are likely to be influenced by the type of project proponent and the choice of a certification scheme. Moreover, we show that proponents who choose to target areas that are structurally threatened by deforestation may fail to achieve additionality, while the ones who favour less endangered forests may implement additional projects which confirms the findings of our theoretical model.

In Section 2, the REDD+ mechanism and the different certification standards are presented. Sections 3 and 4 respectively present our empirical analysis and the theoretical model. Section 5 concludes and proposes recommendations for the implementation of REDD+ projects.

2 Context

2.1 The REDD+ mechanism

Annual emissions from tropical deforestation and degradation are estimated at around 7-14 percent of global carbon dioxide (CO2) emissions (Harris et al., 2012; Grace et al., 2014; Le Quéré et al., 2015), making tropical forests a key issue for global climate change mitigation. Over the last two decades, tropical forests gradually became a central element of the United Nations Framework Convention on Climate Change (UNFCCC) strategy for climate change mitigation. Afforestation and reforestation projects were included in the Clean Development Mechanism (CDM) of the Kyoto Protocol signed in 1997 and a mechanism aimed at Reducing Emissions from Deforestation and forest Degradation, known as RED, was established during the 11th Conference of the Parties (COP) that took place in Montreal in 2005. The core idea of this mechanism was to offer financial rewards to developing countries in exchange for emissions reductions achieved through decreased deforestation. The mechanism was later expanded to include provisions addressing forest degradation, along with conservation, the sustainable management of forests, and the enhancement of forest carbon stocks, and renamed REDD+ accordingly. The Paris Agreement, which entered into force in November 2016, recognises the role of forests as carbon sinks and emphasises, in its Article 5, the necessity for implementing REDD+. Article 4 of the Paris Agreement requires that UNFCCC Parties prepare Nationally Determined Contributions (NDCs) that detail their national mitigation strategy to contribute to the global objective of keeping global temperature rise below 2.0-1.5°C above pre-industrial levels. A majority of tropical countries have included forestry, land use, and land-use change in their NDCs (Richards et al., 2015).

Although REDD+ was initially proposed as a national mechanism, pilot activities were encouraged during COP 13 in Bali (Pistorius, 2012). As of September 2018, over 400 REDD+ projects were being implemented across the tropics (Simonet et al., 2018a). Among the various sources of funding used by REDD+ projects proponents, 69 percent of the projects plan to sell carbon credits (Simonet et al., 2015). In 2015, REDD+ projects (including tree-planting and improved forest management) generated 18 percent (or 15 megatons of CO2 equivalent) of the total volume of offsets transacted in the voluntary carbon markets (Hamrick and Goldstein, 2016).

Since its creation in 2005, the REDD+ mechanism has generated much academic debate. On the one hand, REDD+ has been presented as a promising tool, capable of channelling substantial funding to forest conservation, notably through carbon markets, and of delivering multiple benefits, by combining climate change mitigation, biodiversity conservation and poverty alleviation. On the other hand, REDD+ has raised considerable criticism, in particular as regards its environmental and social impacts. The environmental effectiveness of the mechanism has been questioned for several reasons. Among those critics, the additionality of REDD+ projects, which corresponds to the environmental benefits that would not have happened without a project, have especially been questioned, notably due to the difficulty in establishing accurate baseline scenarios of future deforestation (Seyller et al., 2016). In addition to this environmental issue, concern has been expressed by many academics and organisations defending human rights about the potential negative social impacts of REDD+ (Lund et al., 2017), which is feared to generate, among others, tenure conflicts, displacements of people for conservation reasons or 'green-grabbing', which is defined as the "the appropriation of land and resources for environmental ends" (Fairhead et al., 2012).

2.2 Certification standards

To prevent the potential negative environmental and social impacts of REDD+, the UNFCCC Cancun Agreement established seven safeguards (Decision 1, CP.16). In the voluntary carbon markets, although there is no legal authority which controls and certifies carbon credits, several certification schemes emerged as an answer to the fear expressed by buyers that REDD+ carbon credits could be associated with a lack of additionality or negative social impacts (Seyller et al., 2016). In 2014, half of REDD+ projects were certified by one of the standards of the voluntary market (Simonet et al., 2015). Data provided by Simonet et al. (2018a) indicates that 40 percent of REDD+ projects certified or in the process of certification are using the Verified Carbon Standard (VCS), which is the most commonly used voluntary market standards (Hamrick and Goldstein, 2016). The VCS validates carbon monitoring methodologies proposed by project proponents and applies the same methodological principles as the CDM. Project proponents seeking VCS certification must submit a Project Design Document that describes the methodology used to estimate the emissions reductions or carbon sequestration generated by the project.

To answer buyers' concerns regarding the potential negative impacts of REDD+ projects on biodiversity or local people, projects proponents often combine the VCS certification with a certification by the Climate, Community and Biodiversity (CCB) Alliance standard, which focuses on the non-carbon benefits of the projects. Goldstein (2015) reports than three-quarters of the VCS forestry credits transacted in 2014 were also certified by the CCB.

Under the umbrella of REDD+ projects, a vast heterogeneity of projects can be found, notably in terms of project type, location, proponents or funding sources (Simonet et al., 2015). Given this heterogeneity among projects, it seems crucial when questioning the additionality of REDD+ projects to wonder, not only if REDD+ projects generate additionality, but which types of projects in particular generate additionality.

Some authors already highlighted the link between the national REDD+ strategy and the type of REDD+ projects implemented in a country, and its position on the forest transition curve (Angelsen and Rudel, 2013; Simonet and Wolfersberger, 2013). Others showed that the location of REDD+ projects can be explained by the presence of protected areas (Lin et al., 2012), as well as the baseline CO2 emissions, the forest carbon stock, the number of threatened species, the quality of governance and the region, with a bias toward Latin America (Cerbu et al., 2011).

Other less explored sources of heterogeneity concern the type of project proponent and the certification scheme adopted. Regarding project proponents, the large majority of REDD+ projects is implemented by the private sector, either by non-for-profit organisations such as NGOs that see REDD+ projects as a new source of financing for forest conservation projects, or by for-profit carbon companies that seek to start capital-generating projects focused on carbon. Public sector and research institutes represent less than 20 percent of the proponents (Simonet et al., 2015). The certification process is also very heterogeneous as some certification schemes address only carbon issues and others rather focus on the social and biodiversity impacts of the projects.

In the rest of the paper, we focus on projects of avoided deforestation, which represent around half of REDD+ projects worldwide (Simonet et al., 2015).

3 Modeling project implementation and additionality

In this theoretical section, we consider a project proponent (Pp) aiming to implement a REDD+ project in a community she has to select.[2]

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

3.1 Project proponent

A project proponent (Pp) aims to implement an avoided deforestation project. The project objective encompasses three components: (1) *environmental additionality*: a weight α is given to the project outcome in terms of avoided deforestation AD; (2) *development additionality*: a weight β is given to the development impacts Δ of the project; (3) *carbon credits*: a weight $(1 - \alpha - \beta)$ is given to financial aspects, approximated by the amount of money received from selling REDD+ credit on voluntary carbon markets.

For that purpose, the Pp chooses: (1) a *community* with characteristics b, that represent the community development potential (that we call community type); (2) an *effort allocation* e between environmental and development objectives; a *certification scheme* m.

As shown in Simonet et al. (2016), carbon credit sold on voluntary carbon markets may take into account co-benefits of REDD+ projects, such as biodiversity conservation or livelihood improvement. Indeed the Pp can choose a certification scheme that only acknowledge the reduction of carbon emissions provided by the project; or to choose a certification scheme that also certifies the development impacts of the project.

The certification scheme $m(p_c, p_u)$ thus combines an expected carbon price p_c and an expected premium related to livelihood improvement p_u. $p_c AD(b, e)$ is the amount of money received from

[2] Assuming a single Pp implicitly implies that there is not competition or strategic interactions between several potential of project proponents. In our case of interest, this can illustrate the fact that potential locations where projects can be implemented are numerous enough.

selling REDD+ credits on voluntary markets under certification m. $p_u \Delta(b, e)$ represents the payment related to livelihoods additionality under certification m. [3]

In order to have interior solutions, we consider that utility from environmental additionality (E), utility from livelihood additionality (L) and utility from carbon credits (F) are all increasing and concave.[4]

The project with community type b, effort allocation e and certification m provides the following utility to the Pp:

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

3.2 The community

3.2.1 Business-as-usual case

We consider a continuum of potential REDD+ communities where the project could be implemented. Each community is represented by a potential benefit b for each unit of deforestation d, that we call community type. We assume convex costs of deforestation, including non-market benefits from forest conservation, with a quadratic specification. The community chooses its level of deforestation to maximises its livelihood:

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

Under no intervention, the community optimal level of deforestation is: $\overline{d} = b$. The level of development is: $\overline{u} = \frac{b^2}{2}$. Those levels are considered as the business-as-usual scenario.

3.2.2 Community's reaction to the REDD+ project

The Pp allocates her effort between reducing deforestation (e) and improving livelihood in the community ($1 - e$). We focus on a case in which effort for reducing deforestation and effort for improving livelihood are not complementary, meaning that we focus on environment-development trade-offs situations. Indeed our main interest here is to consider how development pressure and

[3]If the certification scheme only considers the avoided deforestation output, with no importance given to livelihoods as a co-benefit, we simply have $p_u = 0$.

[4]Functional forms for the numerical illustrations are given in appendix A.

community selection affect project additionality. Note however that the project aims to achieve both environmental and development objectives here.

Yet, there are situations in which development and environmental objectives can be targeted jointly with no adverse effects. This might be the case if effort allocated to development objectives create economic opportunities outside the agricultural sector (e.g: eco-tourism). 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. An interesting model could be set here, providing insights for future research.

Coming back to our case of environment-development trade offs, economic pressures related to the community development potential b may reduce the effectiveness of effort allocated to forest conservation. Indeed forest conservation implies increasing the cost of deforestation for the community, which can be in conflict with its private economic interests. Thus private interests may try to overcome the effort made to decrease deforestation. In contrast, economic pressures are likely to increase the effectiveness of effort allocated to improving livelihoods, as both Pp and community objectives are in line. Overall, we introduce $\delta(b) \in [0,1]$ which is an indicator of effort effectiveness allocated to forest conservation, compared to effort allocated to livelihood improvement: when $\delta(b) = 1$, effort is equally efficient for environmental and livelihood objectives; when $\delta(b) < 1$, effort allocated to the environmental objective is relatively less efficient than effort allocated to the development objective. It is totally ineffective for $\delta(b) = 0$.

Larger marginal benefit b from deforestation makes more difficult the implementation of an efficient environmental effort e, as private interests to overcome the project environmental objective are stronger: $\delta'(b) \leq 0$. In some communities, private interests cannot influence the effectiveness of environmental effort $\delta'(b) = 0$; while in others, they strongly and negatively influence it.

Depending on the selected community, some characteristics may influence the effectiveness of effort allocated to the environmental objective ($\delta(b)$), and how the development potential influences this effort effectiveness δ'_b. In some communities, monitoring may be very costly, and enforcement more difficult, which reduce the effectiveness of the conservation effort and reinforce the negative impact of the development potential on this effectiveness. As a matter of simplicity, we call those characteristics "institutional quality". Larger $\delta(b)$ and small δ'_b relate to more reliable institutions and good environmental enforcement. [5] Of course, characteristics influencing the effort effectiveness are complex. Further, institutional quality has many more influences than just on effort effectiveness. Overall, summarising a community by only two related characteristics is quite reductive; nevertheless, as we will show, it allows us to underline the trade off existing between potential additionality and effective additionality.

Effort allocated to the environmental objective increases the cost of deforestation for the community (equivalently increases the benefit from forest conservation), becoming: $\frac{(1+\delta(b)e)d_i^2}{2}$. Effort allocated to development improvement increases the net benefit from the community's activities: $(1+(1-\delta(b)e))(bd-\frac{(1+\delta(b)e)d_i^2}{2})$.

The community's objective becomes:

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

The community's reaction to the REDD+ project is:

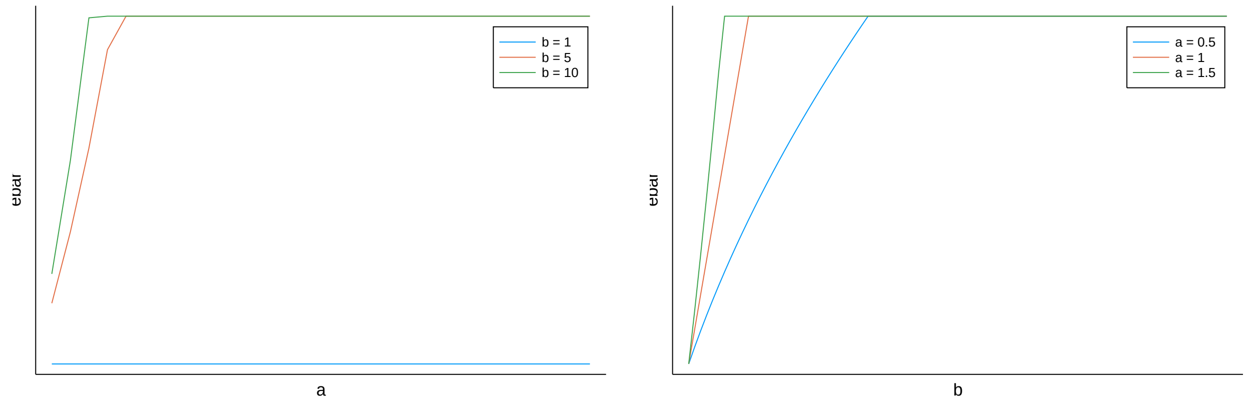
$$d^*(b,e) = \frac{b}{(1+\delta(b)e)} \tag{4}$$

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

Project participation being voluntary, the community accepts to participate if and only if it is better off, which implies the following participation constraint: $e \leq \frac{1}{2\delta(b)} \equiv \overline{e}$. This means that effort allocation to livelihood improvement has to be large enough to make the community better off. Given our hypothesis on $\delta(b)$, it is straightforward that $\overline{e} \in [0,1]$. Sensitivity to parameters b and a for our numerical example is given in figure 1.

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

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



Avoided deforestation from the project 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:

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

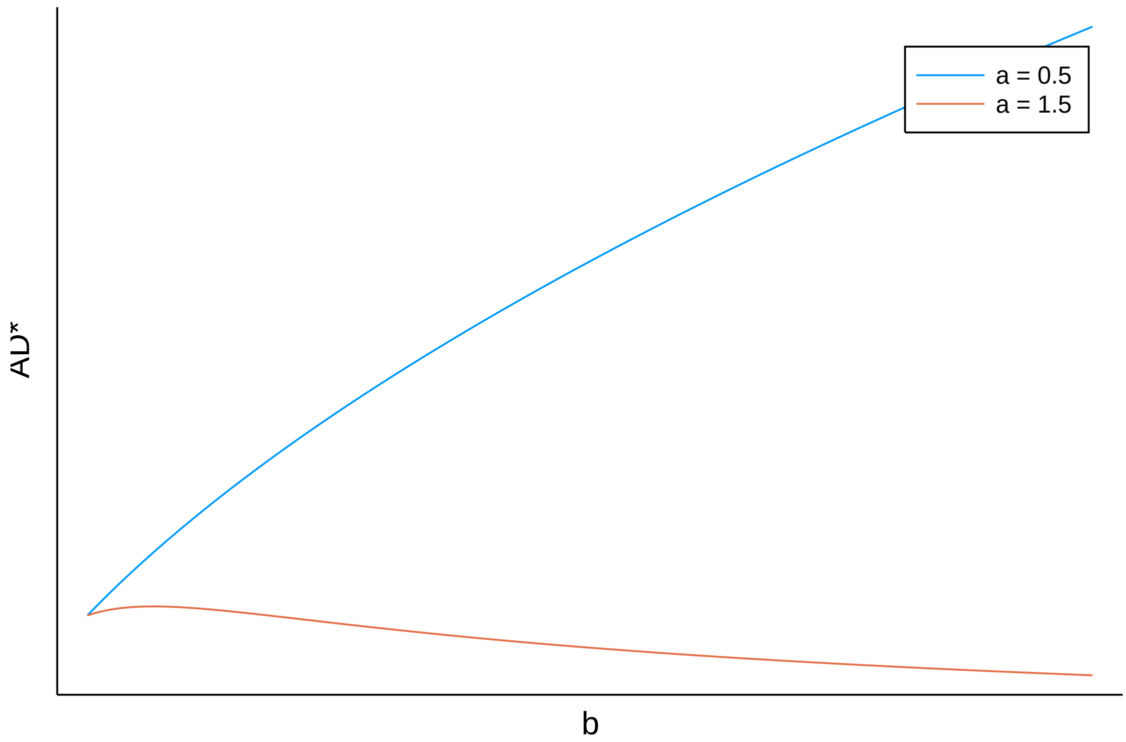
The impact of community type b on avoided deforestation is:

$$AD^{*\prime}_b = \frac{\delta(b)}{(1+\delta(b)e)} + \frac{b\delta'_b e}{(1+\delta(b)e)^2} \tag{8}$$

Equation (8) allows us to make an interesting distinction between potential and effective environmental additionality of the project. The first part of equation (8) is positive: choosing a community with large development potential b suggests high potential environmental additionality, as the BAU deforestation is large if no project is implemented. The second part of the equation is negative: deforestation in a community with strong development potential is more difficult to contain, when local institutions are poorer. In a case where institutions work perfectly, meaning $\delta(b) = 1$ and $\delta'_b = 0$, then potential environmental additionality equals effective additionality.

Result 1 : *If the development potential b has low impact on the environmental efficiency of the project (δ_b' close enough to 0), effective environmental additionality is close to its potential, meaning that selecting a community with stronger development potential b increases avoided deforestation. If the impact of development potential on environmental efficiency is large (δ_b' strongly negative), selecting a community with higher b decreases avoided deforestation. This may be the case in communities where law enforcement and monitoring is low, or where corruption is important.*

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



Development impact of the project is:

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

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

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

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

3.3 Project implementation

In order to give intuitions about more general results, we focus first on two extreme cases of Pp objectives: when the Pp focuses only on the environmental ($\alpha = 1$) or the development ($\beta = 1$) outcome. We combine them to two corner cases of local institutions: $\delta_b' = 0$ and δ_b' strongly negative.

The effort allocation follows equations (7) and (10) and is straightforward: the Pp allocates all her effort on development if it is her unique objective: $e^* = 0$ if $\beta = 1$; and the effort allocation that satisfies the community participation constraint if avoided deforestation is her unique objective: $e^* = \bar{e}$ if $\alpha = 1$.

Equations (8) and (11) describe how development potential influences the environmental and development outcome when the development potential increases. Therefore it enlightens us on the characteristics of the community to be picked by the Pp. If development is the unique objective of the Pp, she selects the community with the highest development potential whatever is the local institutional quality. However, when considering a Pp only focusing on environmental outcomes, institutions matter. If institutions are good, effort allocated to avoided deforestation is effective, private interests related to development potential have no or little influence in this effectiveness. Thus effective additionality is equivalent to potential additionality, and the Pp selects the community with the highest development potential (hence the highest potential and effective additionality). In contrast, when institutions are bad, effort allocated to avoided deforestation is ineffective and private interests related to the development potential strongly affect the effort effectiveness. It follows that the Pp selects a community with the lowest development potential in order to maximise effective additionality. The following table summarises those four cases.

Objective	Avoided Deforestation $\alpha = 1$		Development $\beta = 1$	
Institutions	Poor $\delta'_b << 0$	Good $\delta'_b = 0$	Poor $\delta'_b << 00$	Good $\delta'_b = 0$
b^*	Lowest b	Highest b	Highest b	Highest b
e^*	$\bar{e}$	$\bar{e}$	0	0

This result gives new insight on the concept of location bias, that generally assimilates projects implemented in low development area as ineffective. In contrast, we show here that it may be rational and efficient for a Pp with a focus on environmental issue to pick a community with low development potential, simply because of poor institutions that take effective additionality away from potential additionality.

Getting more general results require to consider the maximization problem presented in equation (1). The first-order conditions implicitly describe this set of choices:

$$v'_b = \alpha E' AD'_b + \beta L' \Delta'_b + (1 - \alpha - \beta) F'(p_c AD'_b + p_u \Delta'_b) = 0 \quad (12)$$

$$v'_e = \alpha E' AD'_e + \beta L' \Delta'_e + (1 - \alpha - \beta) F'(p_c AD'_e + p_u \Delta'_e) = 0 \quad (13)$$

$$v'_m = v'_{p_c} + v'_{p_u} = 0 \quad (14)$$

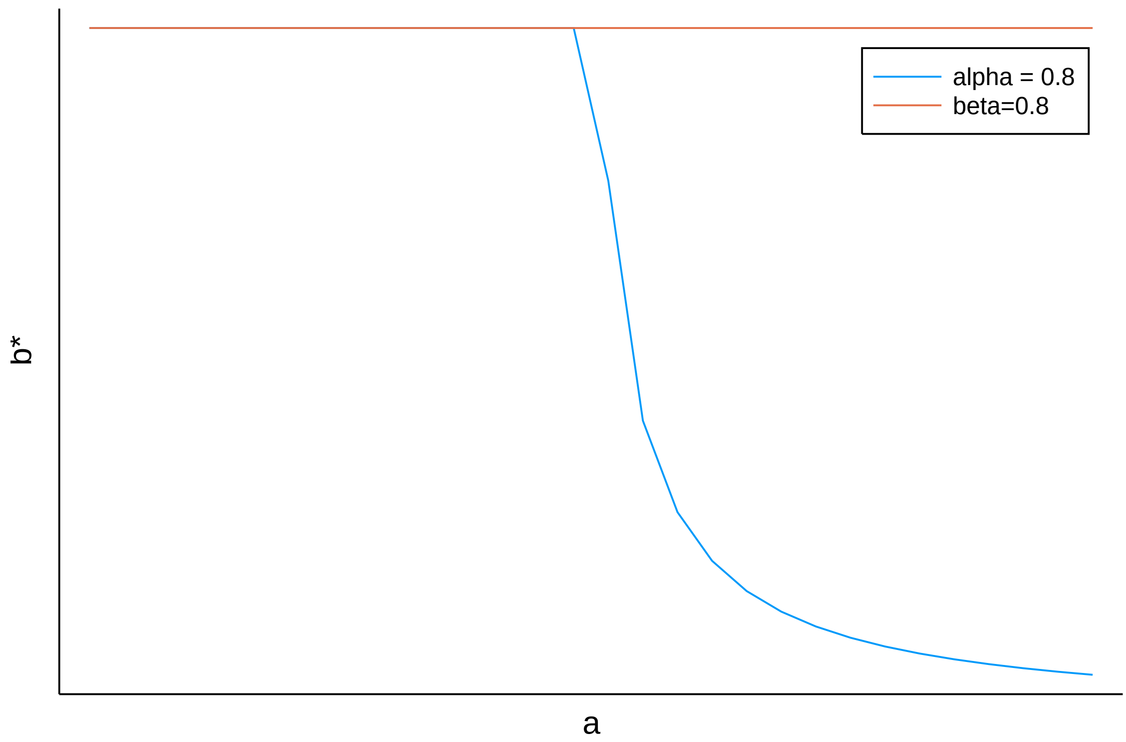
3.3.1 Community type

The choice of community type by the Pp is expressed in equation (12). The Pp 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 environmental (α) and development (β) objectives; second, on the link between development potential b and environmental effort efficiency $\delta(b)$ (as shown in result 1).

Result 2 : *When institutions are strong and when the development potential has low impact on the project environmental efficiency (δ'_b close to 0, small a), the Pp selects a community with large development potential whatever her main objective (α, β): larger b increases avoided deforestation because of larger potential additionality, and also increases the development potential because of larger marginal benefit from economic activities. When institutions are weak and when higher* *development potential is likely to strongly decrease environmental efficiency (δ'_b strongly negative, large a), the Pp selects a community with low potential benefit b if she has strong environmental objective (large α); and a community with large potential benefit b if she has strong development objective (large β).*

This result suggests that local institutions strongly affect the community choice of the Pp when she has strong preference toward her environmental objective, while they have no influence in the location choice when she puts more weight on the development objective. Furthermore, this result underlines that a Pp with strong environmental objectives may have an interest to select a community with low development potential (which is frequently considered as a location bias in the literature).

Figure 3: **Influence of institutional quality a on community choice b^*, for diverse levels of Pp objective α, β**

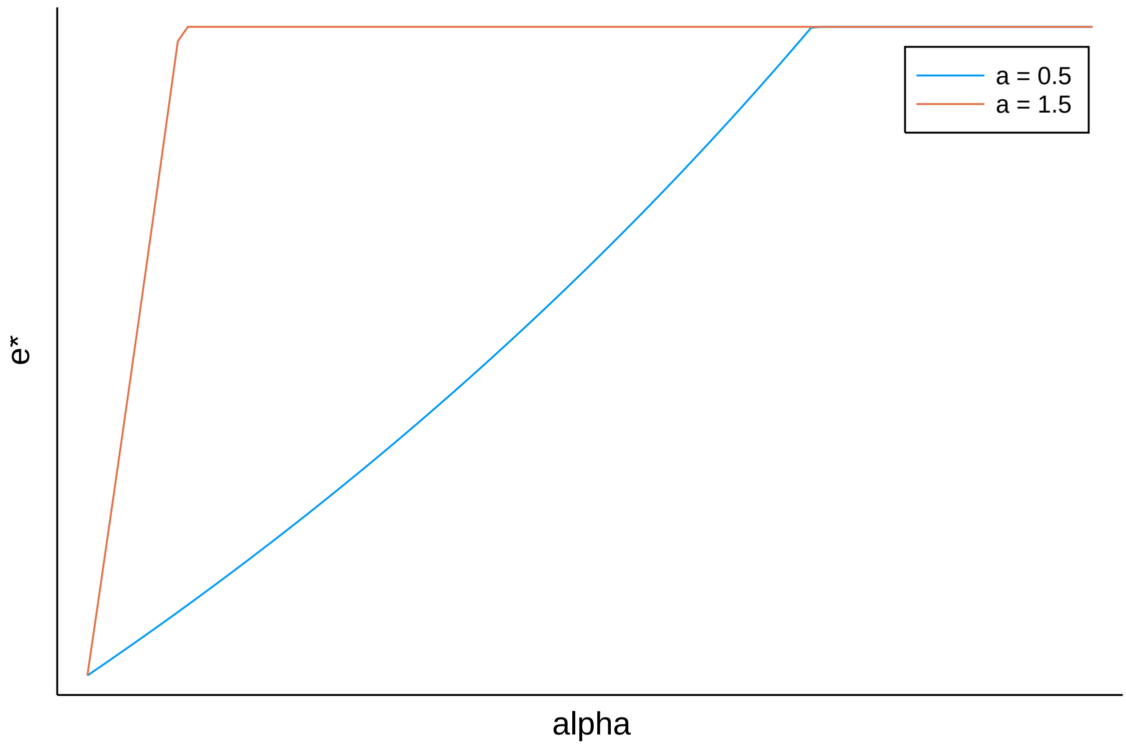


3.3.2 Effort allocation

In equation (13), the Pp allocates her effort between her environmental and development objective in order to balance marginal benefit from avoided deforestation, and marginal benefit from livelihood improvement.

Result 3 : *The Pp allocates her effort accordingly to her objectives: larger environmental 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 4: **Pp objective α and optimal effort allocation e^*, for diverse levels of institutions a**



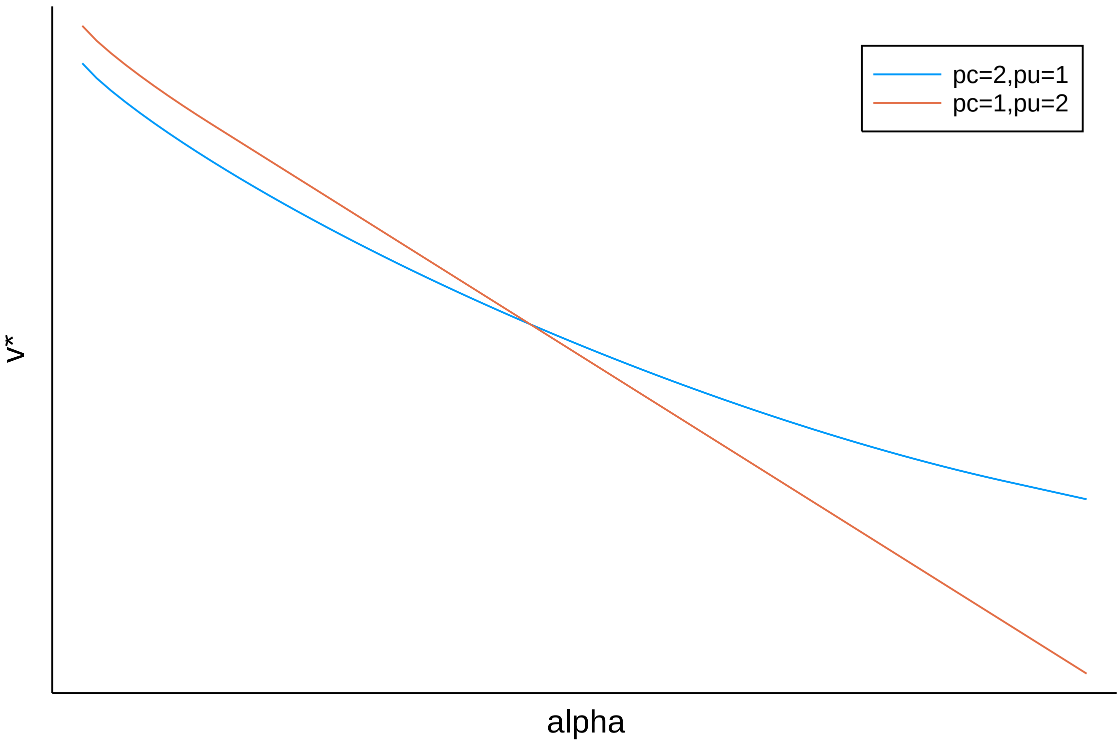
3.3.3 Certification choice

The Pp outcome is unambiguously increasing in p_c and p_u. Ideally the Pp would thus select a certification scheme with large carbon prices and livelihood premium. Yet, equation 14 underlines the trade off that may exist between certification schemes with high carbon price and low development premium, and schemes with low carbon prices but high development premium. The payoff from certification being complementary to the one from avoided deforestation and development improvement, the Pp's preference toward those two objectives will impact the type of certification chosen.

Result 4 : *A Pp with stronger preferences for avoided deforestation (high α) selects a certification scheme with higher carbon price, while a Pp with stronger preferences for livelihood improvement (high β) selects a certification scheme with higher development premium price.*

If we focus now on a Pp who essentially puts her objectives toward funding benefits (low α and β), one can easily see that she will target certifications schemes that are the most profitable. First, the prices given for avoided deforestation and the development premium are important. Second, the effectiveness of effort is crucial: if effort allocated to avoided deforestation is relatively inefficient ($\delta(b)$ close to 0, δ'_b strongly negative), two Pp strategies can be observed: selecting a low development potential b and choosing a certification scheme that prioritize the carbon outcome; or selecting a high development potential and choosing a certification scheme which gives a strong importance to the development outcome. This result will be used in the empirical section in order to give intuitions about the objective weights of the projects we investigate (see table 1).

Figure 5: **Pp objectives α and optimal payoff v^* for diverse certification schemes** p_c, p_u



In the next Section, we test how the conclusions of our model applies in the context of REDD+ projects in Brazil. We specifically look at the choice of location according to the type of project proponents and how it impacts the additionality of the projects.

4 Empirical analysis

In order to analyse how the type of project proponent and the choice of a certificate scheme can influence the implementation and the additionality of REDD+ projects, we study a sample of six REDD+ projects in Brazil.

4.1 Data and methods

4.1.1 Sample of REDD Projects in Brazil

Brazil is a key player in the field of deforestation, with deforestation generating 44 percent of the total greenhouse gases emissions (GHG) of the country (in 2012, according to data from the World Resource Institute) and because of the significant shift observed in its deforestation since

2004. Indeed, the annual deforestation rate in Brazil fell by 70 percent between 2005 and 2013 due to the implementation of command-and-control measures, the expansion of protected areas, and interventions in the soy and beef supply chains, such as the Soy Moratorium established in 2006 (Nepstad et al., 2014). In 2009, Brazil received about one billion of USD to implement REDD+ projects, mainly by Norway, through the Amazon Fund. This fund made Brazil the main recipient of REDD+ funding (Silva-Chavez et al., 2015).

Simonet et al. (2018a) built an international database of REDD+ projects around the world. This database is available online [6] and contains 454 projects located in 56 countries. As of August 2018, the database included information about 59 projects in Brazil, of which 30 are ongoing projects of avoided deforestation (REDD). However, a vast majority of these projects were not certified. Given the scope of this article, we focus on projects that relied, or will soon rely, on funding coming from the voluntary carbon markets. Therefore, we choose to focus on projects that already obtained the VCS and/or the CCB certifications. Indeed, in line with result 4, the type of certification chosen gives us information about the Pp objective weights: a project that only certifies carbon outcomes (VCS) is likely to focus more on the environmental objective; while a project relying on double certification (VCS + CCB) is expected to give more importance to livelihood outcomes (see table 1).

Moreover, we choose to focus on conservation projects instead of reforestation ones for two reasons. First, it is easier to monitor deforestation than reforestation using satellite images. Second, reforestation projects are smaller, making georeferencing complicated if not impossible. Eventually, we exclude projects that are partially overlapping with protected areas in order not to bias the estimates of additionality. A recent article by Simonet et al. (2018b) studies the impact of a REDD+ project in Brazil using similar techniques. Note that this project is not included in our sample but we improve on their work by studying six projects and providing explanation for the underlying mechanisms that leads to heterogeneous results.

Our sample is composed of 6 REDD projects that cover around 1.6 millions hectares of forests. We hypothesise that the projects that are promoted by private-for-profit organisations tend to rely more financially on the voluntary market. In line with the theoretical model presented in section 3, the income obtained from the projects is a strong objective for these actors compared to NGOs. Qualitative evidence collected during the construction of the ID-RECCO database showed us that

[6] http://www.reddprojectsdatabase.org/

NGOs rely only partially on the carbon market. As a matter of fact, most NGOs already existed and relied on other sources of funding before selling carbon credits, while many private-for-profit organisations emerged for the purpose of selling carbon credits. This hypothesis is supported by the fact that, according to the database, selling carbon credits appears as an objective of the project in around 50% of the REDD projects implemented by private for-profit organisations, against 36% for NGOs. This intuition also helps us to link our projects to their allegedly objectives, in relation to result 4 (see table 1).

The six projects are representative of a sub-sample of Brazilian REDD+ projects that are focused on reducing emissions from deforestation (or REDD, by opposition to projects focused on afforestation/reforestation, or AR), certified by at least one standard of the voluntary carbon market, and not located in a protected area under the governance of federal, regional or indigenous entities according to the database by UNEP-WCMC (2018). For comparison purposes, out of the 57 REDD+ projects identified in Brazil in 2018, 36 are oriented toward REDD versus 21 AR; 38 are certified or in the process of certification, the others will not seek to sell carbon credits but will rather rely on other funding sources (notably, in Brazil, the Amazon Fund) and only 12 are located in protected areas. Moreover, 14 have a component of direct conditional cash payments (PES-like) and two of these projects are in our sample (ie 33%). Our sample thus shows a small over-representativeness of projects including a PES component compared to the whole sample of Brazilian REDD+.

Our sample of projects is composed of three groups, detailed in Table 1. All the projects obtained VCS certification but only four of them obtained CCB certification. The two projects that did not obtain CCB certification are implemented by private for-profit proponents. Two projects are implemented by NGOs and they all obtained both CCB and VCS certifications. Relying on result 4, we hypothesise that the projects with both certifications have higher preferences for social benefits and livelihood improvements (high β in the theoretical model) given that they obtained a premium for development outcomes due to the CCB certification. In contrast, projects only relying on the VCS certification are assumed to focus more on the environmental objective (high α in the model).

4.1.2 Data

We georeferenced each project using the Project Design Documents (PDD) that the proponents of the projects must elaborate in order to obtain the certification. The PDDs include a map of

Table 1: List of projects

Certification	Actors	Variable	Number of projects	Result 4
CCB and VCS	Private for-profit	$CCB^{Pri} = 1$	2	Higher β, Lower α
VCS only	Private for-profit	$VCS^{Pri} = 1$	2	Higher α, Lower β
CCB and VCS	NGO's	$CCB^{Ngos} = 1$	2	Higher β, Higher α

the projects in PDF format that can be projected using a GIS software but lacks of geographic coordinates. In order to correctly locate each project, we use shape files mapping waters, urban areas and roads, provided on-line by the *Instituto Brasileiro de Geografia e Estatistica* (IBGE) and ESRI's Digital Chart of the World, and the shape file of protected areas provided by the International Union for Conservation of Nature (UNEP-WCMC, 2018). We overlap each image extracted from the PDD with some of these geographic features to locate the six projects. Once they are located, we draw the polygons that correspond to each project. We use this methodology for the six REDD projects. We build polygons that measure on average 103% of the project areas declared by project proponents in the PDDs. This ratio is heterogeneous but for all six projects, the difference between computed and declared areas is lower than 15%. For this reason, we are confident that we successfully georeferenced the six REDD projects.

In order to build a database, we use a similar procedure as Le Velly et al. (2017), combining conservation policies, gridding and forest cover. We use a gridding of 5 km x 5 km so that each cell measures 2,500 hectares. Given the size of REDD projects in Brazil, it seems relevant to consider that the decisions made by project proponents involve large forested areas. Therefore, we choose to build grids of 5km x 5km as it both seems relevant as a unit of decision for the project proponent and allows us to capture heterogeneity within the projects boundaries.

We intersect this grid with REDD projects boundaries. Therefore, each forested cell is either entirely within or outside a REDD project. Regarding forest cover and deforestation, we use data provided by PRODES[7]. PRODES is a national program that provides geographic data about deforestation and forest cover in the Legal Amazon between 2000 and 2014, based on LandSat images of 20 to 30 meter resolution. The georeferenced projects all started during this period of analysis which allows us to compute deforestation before and after implementation of the project. This procedure allows

[7] http://www.dpi.inpe.br/prodesdigital/prodes.php

us to compute yearly deforestation rates within each cell. We drop cells of less than 1000 hectares as they mainly result from polygons overlapping and may bias our results.

4.1.3 Analysing the choice of a location

In the first stage of our analysis, we study the choice of a location by project proponents according to the type of certification and the type of proponents. Note that, in this analysis, we do not study if the areas under REDD+ are different from non REDD+ areas but if, within a sample of REDD+ areas, there are differences that are correlated with the type of proponent. In Section 4.1.1, we defined three groups of projects. In order to study the difference in the choice of location for each type of REDD projects, we restrict our sample to the cells included in one of the six projects. We obtain a sample of 566 observations.

In order to study the heterogeneity between the different types of projects, we run two analyses. First, we provide descriptive statistics of our sample of grid cells i in order to study the distribution of a vector X_i of six variables including geographic characteristics that are structural determinants of deforestation (Kaimowitz and Angelsen, 1998; Pfaff, 1999; Robalino and Pfaff, 2013) such as distances to the closest waters, main roads[8] and localities in hundreds of kilometers, as well as slope in percent rise. We also include two measures of deforestation before the implementation of the REDD projects. The first one is the average yearly deforestation rate between 2006 and the first year of implementation of the project within the cell i. The second variable measures the average yearly deforestation rate for this same period before the implementation of the project but in the direct neighbouring cells. Details about the sources of the data can be found in Appendix B.

For all measures of deforestation, we compute the average yearly deforestation rates ex-ante in grid cells i according to the following equation where t is the first year of implementation of the project:

$$DefRate_i = 1 - (Cover_{i,t-1}/Cover_{i,2006})^{\frac{1}{t-1-2006}} \tag{15}$$

For each variable in X_i, we provide the median, the minimum and maximal values and the first and last decile. Those statistics allow us to analyse the heterogeneity of the grid cells for each type of projects. As a matter of fact, for distances or deforestation measures, the median values might

[8]Note that the data we use do not include secondary roads and tracks into the forests.

be of lesser interest than the first and last decile in order to assess if those areas are likely to be deforested.

Second, We also run a multinomial logit in order to estimate how each of the variables included in X_i influences the probability that the grid cell i is located within the boundary of a project of the different types presented in Table 1. Based on the results of our estimation, we derive the marginal effect of each variable at mean values of other variables.

4.1.4 Estimating additionality

In the second stage of the analysis, we estimate the additionality of each of the six projects separately. Remember that there are two projects per type of proponent. The additionality is here defined as the avoided deforestation that can be directly attributed to the the project. It cannot be estimated only by comparing enrolled and non-enrolled areas. As a matter of fact, there are factors, called confounding variables, influencing both deforestation and the enrolment in a REDD project, making simple comparisons biased. To estimate the additionality, we rely on impact evaluation methodologies, and more specifically matching methods, in order to estimate the Average Treatment Effect on the Treated. In line with this literature, we define the areas enrolled in the REDD projects as treated areas and build a counterfactual using a control group of non-enrolled areas.

In order to build a relevant counterfactual, we use difference-in-difference (DID) matching (Chabé-Ferret and Subervie, 2013; Chabé-Ferret, 2015). Contrary to simple matching, DID-Matching introduces a control on time-unvarying unobservable confounding factors. The objective of this procedure is to select a group of observations that are as similar as possible to the treated areas and only differ regarding the treatment. For each REDD project we consider as treated the cells that are located within the polygon of the project and build a control group of observations that are outside the boundary of a REDD project.

We use covariate matching based on the Mahalanobis distance with Abadie and Imbens (2011)'s correction. In order to check the robustness of our results, we display for each project the results of the matching procedure using the three and five nearest neighbours. We use the weights generated by the matching procedure in order to compute the impact of the program on the difference in average yearly deforestation rates before and after the project implementation. Therefore, we wonder if deforestation rates decreased or increased more in areas within the boundary of the REDD projects using the matched control group as a counterfactual situation. For deforestation rates before the project, we consider the difference between 2006 and the first year of implementation of the project in order to have at least three years of implementation for each project. Our outcome variable is defined as:

$$DID_i = (1 - (Cover_{i,2015}/Cover_{i,t})^{\frac{1}{2015-t}}) - (1 - (Cover_{i,t-1}/Cover_{i,2006})^{\frac{1}{t-1-2006}}) \quad (16)$$

We define our control group as all the cells located within a distance of 15 to 100km around each project. In order to obtain a valid estimation of the impact, the Stable Unit of Treatment Value Assumption (SUTVA) must hold. This hypothesis requires that the outcome of an observation, here deforestation, is only influenced by its own status regarding the treatment. In our case, it means that the project does not impact deforestation in the control group. For this reason, we consider that the direct buffer of 15km around the projects (approximately the three cells the closest to the project) is likely to be influenced by the project through leakage for instance (Alix-Garcia et al., 2012) so we exclude this buffer from our control group. This is similar to the analysis by Arriagada et al. (2012) of Costa Rica's PES who excluded from the control group the areas that were contiguous from the PES farms. If we do not exclude the neighboring cells, the SUTVA hypothesis would not hold and the estimation might be biased. However, in order to identify the impact of the projects, the choice of the control and treated groups must take into account unobservable confounding factors that affect both deforestation and the location of the REDD projects. By restricting our control group to the cells that are located no further than 100km from the REDD project, we hope to balance unobservable covariates such as agro-ecological conditions. We also exclude protected areas and/or other REDD projects from the control group since they can influence deforestation.

We introduce seven variables in the matching procedure: the six variables from X_i described and the area forested in 2006 in hundreds of hectares. This procedure allows us to build a relevant control group for each of the six REDD projects.

One of the key assumptions of DID-matching is the conditional parallel trend. This assumption states that, once controlled for observable confounding factors through the matching procedure, there are no significant differences between the two groups in terms of deforestation rates before the implementation of the program. In order to test for the validity of our matching procedure, we run placebo tests for each estimation using as an outcome variable the difference in average yearly deforestation rates between 2006 and the beginning or the project compared with average yearly deforestation rates between 2003 and 2005. Here again, we choose 2003 in order to average deforestation rates over three years. Our outcome variable for placebo testes is defined as:

$$DID_i = (1 - (Cover_{i,t}/Cover_{i,2006})^{\frac{1}{t-2006}}) - (1 - (Cover_{i,2005}/Cover_{i,2003})^{\frac{1}{3}}) \quad (17)$$

Therefore, we estimate the impact of the REDD projects on the increase of deforestation rates in the few years before its implementation compared to the period between 2003 and 2005. If the conditional parallel trend assumption holds, there should be no statistically significant differences between treated and control group after weighting.

4.2 Results

4.2.1 Choice of a location

Table 8 to 13 in the Appendix presents the descriptive statistics as explained in Section 4.1.3. According to those statistics, NGOs and private-for-profit organisations with higher social preferences, i.e. with both VCS and CCB certification, seem to focus on more threatened forests than private-for-profit organisations with a carbon objective only. As a a matter of fact, looking at Table 11 and 12, the most threatened forests for the private-for-profit organisations with only VCS certification have experienced lower levels of deforestation in the past than others. Moreover, according to Table 9, those projects are located further away from the urban areas and, according to Table 8, they are located further from the roads than the projects led by private-for-profit organisations with both certification. Those results show that the proponents with lower social objective and higher environmental objective tend to be located in areas where deforestation pressures related to development opportunities are lower. This result is in line our result 2, in the case where local institutions have a strong and negative influence on the effectiveness of environmental effort.
The results of the multinomial logit are displayed in Table 2. Here, we do not find statistically significant results regarding the choice made by the projects proponents with only VCS certification which is probably due to the fact that there are fewer grid cells for those projects. However, by comparing Column (1) and (3), one can study the choices made by private-for profits organisations,

that relies more on the carbon market and puts more emphasis on financial objectives, and NGOs. NGOs tend to enrol areas in REDD projects where the pressure to deforest seems higher. However, these areas are more remote from the roads and the waters than the areas enrolled by private-for-profit organisations with a double certification.

Therefore an important result is that the location bias frequently identified in the literature crucially depends on the project managers' type. Given the location of the project, one could hypothesise that the projects with only VCS certification are less likely to have an impact on deforestation since those areas are further from roads and urban areas and have experienced lower deforestation rates in the past. However, given the results of the theoretical model presented in Section 3, which distinguishes potential and effective additionality, we understand that the impact of the project will depend on the choice of the effort by the project proponent and the effort efficiency. The results regarding additionality of the six projects give us some insights regarding how the choice of location can influence the impact of a project.

Table 2: Impact of location characteristics on the type of REDD proponents (marginal effects)

Variable	Pr(Priv. for profit Both certification =1)	Pr(Priv. for profit VCS only =1)	Pr(NGO Both certification =1)
Distance to waters	-0.1526***	0.0001	0.1525***
	(0.0541)	(0.0006)	(0.0541)
Distance to roads	-0.1583***	-0.0021	0.1603***
	(0.0590)	(0.0030)	(0.0591)
Distance to closest urban area	-0.0305	0.0083	0.0222
	(0.0340)	(0.0119)	(0.0353)
Slope	-0.0396**	0.0002	0.0394***
	(0.0166)	(0.0004)	(0.0166)
Av. yearly def. rates in neighbouring cells ex-ante	-6.6696***	-0.1081	6.7777***
	(2.4001)	(0.1861)	(2.4061)
Av. yearly def. rates ex-ante	-0.5079	-0.1193	0.6272
	(1.7533)	(0.1165)	(1.7570)
Number of observations	566		
Pseudo-R^2	0.4758		

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.2.2 Additionality

Table 3 and 4 displays the results regarding the additionally of the projects estimated using the methodology presented in Section 4.1.4. Remember that there are two projects per type of proponent. Each Table displays the number of treated observations for each project and the results before and after matching for the impact estimation and the placebo tests. As a comparison, the yearly deforestation rate in the Brazilian Amazon over the period 2010-2015 is around 0.1%, according the FAO's Global Forest Resource Assessment (MacDicken et al., 2015). Our results do not always allow to conclude about the additionality of each type of projects. However, the results tend to show that the projects implemented by proponents with only VCS certification decrease deforestation. Those results remain stable and statistically significant with three and five nearest neighbours matching for one project and with five nearest neighbours matching for the other. According to our placebo tests, the parallel trend assumption is not always verified but, when it is not, the difference between the treated and the matched sample remains very small. However, as will be explained below, the results regarding Columns (7) and (8) should be interpreted with caution as the estimates are likely to be biased.

Table 3: Additionality of the projects using three nearest neighbour matching

	(1)	(2)	(3)	(4)	(5)	(6)
	Priv. for profit Both certification		Priv. for profit Both certification		Priv. for profit VCS only	
Treated observations	72		47		13	
	Unmatched	Matched	Unmatched	Matched	Unmatched	Matched
Treated group	-0.0018	0.0001	**-0.0005**	-0.0005	0.0001	0.0001
Control group	0.0000	-0.0000	**-0.0059**	-0.0011	-0.0070	0.0040
Difference	-0.0019	0.0001	**0.0054****	0.0005	0.0071	-0.0039
Standard-Error	0.0019	0.0003	**0.0023**	0.0005	0.0074	0.0030
p-value	0.321	0.772	**0.022**	0.352	0.341	0.189
Placebo Treated group	**0.0004**	0.0005	**-0.0006**	-0.0006	-0.0004	-0.0004
Placebo Control group	**0.0064**	0.0006	**0.0078**	0.0005	0.1111	-0.0010
Placebo Difference	**-0.0060*****	-0.0001	**-0.0085*****	-0.0012	-0.0115	0.0006
Standard-Error	**0.0020**	0.0002	**0.0024**	0.0007	0.0078	0.0006
p-value	**0.002**	0.534	**0.000**	0.111	0.140	0.291
	(7)	(8)	(9)	(10)	(11)	(12)
	Priv. for profit VCS only		NGO Both certification		NGO Both certification	
Treated observations	24		100		310	
	Unmatched	Matched	Unmatched	Matched	Unmatched	Matched
Treated group	-0.0005	**-0.0005**	**0.0001**	0.0001	-0.0053	-0.0053
Control group	-0.0005	**0.0035**	**-0.0011**	0.0008	-0.0052	-0.0063
Difference	-0.0001	**-0.0040*****	**-0.0013***	-0.0006	-0.0001	0.0010
Standard-Error	0.0031	**0.0015**	**0.0075**	0.0006	0.0012	0.0013
p-value	0.9852	**0.007**	**0.088**	0.259	0.923	0.437
Placebo Treated group	-0.0001	**-0.0001**	0.0004	**0.0004**	0.0016	0.0016
Placebo Control group	0.0010	**-0.0134**	0.0002	**-0.0009**	0.0013	0.0009
Placebo Difference	-0.0009	**0.0133*****	0.0003	**0.0013*****	-0.0003	0.0007
Standard-Error	0.0023	**0.0027**	0.0008	**0.0003**	0.0011	0.0012
p-value	0.652	**0.000**	0.770	**0.000**	0.798	0.536

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

On the contrary, we do not find any impact for the other projects despite the fact that they seem to focus on areas more likely to be deforested. Our results in Table 4 suggest that the projects implemented by an NGO could increase deforestation but this impact is very small and only significant in one estimation. Those results are consistent with our result 1, that mentions that when local institutions are poor and have a strong and negative influence on the effectiveness of environmental effort, choosing a location with lower development potential may turn out in a better outcome in terms of avoided deforestation.

Table 4: Additionality of the projects using five nearest neighbor matching

	(1)	(2)	(3)	(4)	(5)	(6)
	Priv. for profit Both certification		Priv. for profit Both certification		Priv. for profit VCS only	
Treated observations	72		47		13	
	Unmatched	Matched	Unmatched	Matched	Unmatched	Matched
Treated group	-0.0018	0.0001	-0.0005	-0.0005	0.0001	0.0001
Control group	0.0000	-0.0002	-0.0059	-0.0008	-0.0070	0.0054
Difference	-0.0019	0.0002	0.0054**	0.0003	0.0071	-0.0053**
Standard-Error	0.0019	0.0003	0.0023	0.0006	0.0074	0.0022
p-value	0.321	0.432	0.022	0.661	0.341	0.013
Placebo Treated group	0.0004	0.0005	-0.0006	-0.0006	-0.0004	-0.0004
Placebo Control group	0.0064	0.0005	0.0078	0.0005	0.1111	-0.0009
Placebo Difference	-0.0060***	0.0000	-0..0085***	-0.0012*	-0.0115	0.0005
Standard-Error	0.0020	0.0001	0.0024	0.0007	0.0078	0.0005
p-value	0.002	0.988	0.000	0.089	0.140	0.261
	(7)	(8)	(9)	(10)	(11)	(12)
	Priv. for profit VCS only		NGO Both certification		NGO Both certification	
Treated observations	24		100		310	
	Unmatched	Matched	Unmatched	Matched	Unmatched	Matched
Treated group	-0.0005	-0.0005	0.0001	0.0001	-0.0053	-0.0053
Control group	-0.0005	0.0043	-0.0011	-0.0011	-0.0052	-0.0058
Difference	-0.0001	-0.0047***	-0.0013*	0.0012*	-0.0001	0.0005
Standard-Error	0.0031	0.0014	0.0075	0.0007	0.0012	0.0012
p-value	0.9852	0.000	0.088	0.073	0.923	0.649
Placebo Treated group	-0.0001	-0.0001	0.0004	0.0004	0.0016	0.0016
Placebo Control group	0.0010	0.0148	0.0002	0.0002	0.0013	0.0010
Placebo Difference	-0.0009	0.0147***	0.0003	0.0002	-0.0003	0.0006
Standard-Error	0.0023	0.0029	0.0008	0.0003	0.0011	0.0011
p-value	0.652	0.000	0.770	0.305	0.798	0.594

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

In order to test that the matching procedure succeeded in balancing confounding factors between the treated and the control group, we use balancing tests for each estimation. Results are available in the Appendix for each matching procedure (Table 14 to 25). Despite some remaining imbalances, the bias has been largely reduced for most estimations which confirms the validity of our results at the notable exception of the the second project implemented by a private-for profit organisation with only VCS certification (Columns 7 and 8 in Tables 3 and 4). Especially, one should worry about the biases regarding deforestation rates ex-ante highlighted in Tables 17 and 23 which confirm the bias identified in the placebo estimates. Therefore, the results regarding this project must be interpreted with lots of caution.

Moreover, as a robustness tests, we increase the size of the buffer around each project that is excluded from the control group. The results, which are available upon request, confirm our findings but, in most cases, we are not able to validate the conditional parallel trend assumption with a larger buffer. It is probably due to the fact that, with a lower number of control observations, the procedure fails to find appropriate matches.

Eventually, since all treated observations are part of the same project, our estimates of standard errors could be biased by a correlation in the unobserved component of the outcome variable (Abadie et al., 2017). In order to check for the robustness of our results to this potential bias, we use a pre-matching procedure and cluster standard-errors at project level in our estimations of additionality. First, for each type of proponent, we run a matching procedure for both projects the are implemented by this type of proponent in order to select a control group for each project. As previously, we use covariate matching based on the Mahalanobis distance with Abadie and Imbens (2011)'s correction with three and five nearest neighbor matching. Second, we merge the samples of treated and matched observations for both projects implemented by the same type of proponent and estimate the impact of the REDD projects using Ordinary Least Square. Our outcome variable is the variation in average yearly deforestation rates as defined in Equation 16 ans standard errors are clustered at project level in these estimates. Results are displayed in Table 26 and 27 in the Appendix. The robustness test confirms the additonality of the projects implemented by private-for-profit organisations with only VCS certification. Moreover, Table 26 confirms that the impact of the other two types of projects is very close to zero but this result is not statistically significant in Table 27.

4.3 Analysis of the empirical results

These results imply that even if a location bias exists when choosing a remote location for a REDD+ project, as shown in section 3, the existence of this bias does not necessarily preclude additionality. According to our findings, the only project for which we find an additional impact only obtained an environmental certification. This suggests a trade-off between social and environmental objectives. Moreover, the projects managed by an NGO failed to avoid deforestation even though NGOs target more threatened forests. On the contrary, the only project that achieved additionality on the short-run is led by private-for-profit organisations even though the forests within the boundary of the projects seemed less threatened.

In the context of Brazil, it is likely that conservation and environmental issues often compete as it is hypothesised in the theoretical model developed in Section 3. In this context, our model shows that the objectives of the project proponents influence her choice of a location, defined by a marginal benefit b_i, his environmental effort e and the certification scheme m.

Moreover, we also show that the choices of the proponents are influenced by the efficiency of the environmental effort $\delta_i(b_i)$ that depends on the quality of the local institutions. As explained in Section 3.3, if the marginal benefit b_i strongly and negatively influences the environmental effort efficiency $\delta_i(b_i)$ as it is the case with weak institutions, choosing an area with a low b_i is likely to increase environmental efficiency. In this case, project proponents will favour areas with lower b_i if they have larger environmental objectives and lower development objectives. Moreover, according to Result 1, this choice can lead to higher level of avoided deforestation because the efficiency of the environmental effort e_i will be larger. This result is reinforced by the fact that the environmental effort of the proponents with strong environmental objectives is larger than the effort of other proponents according to Result 3.

In relation with our empirical results, this explains why it might be optimal for the private-for-profit organisations to focus on areas where development pressure is low and where there is little deforestation. As a matter of fact, it is more profitable for them to focus on areas where the efficiency of the effort will be higher. On the contrary, the other types of proponents try to target areas with higher development pressure but the efficiency of the effort is lower in those areas which explains why they are not additional.

5 Conclusion

In this article, we both empirically and theoretically study how the type of project proponent, the REDD+ projects implementation and local characteristics influence projects 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 project is effective, large avoided deforestation can be achieved. But the effectiveness of effort may be challenged by local institutions, leading to lower effective additionality.

According to our results, the project proponent preferences strongly affects community selection and thus the project additionality. Moreover, the choices of the project proponents are influenced by the quality of local institutions. Our consideration of local institutions refers to the local characteristics that favours (or prevent) the effectiveness of effort to reduce deforestation. As a matter of fact, in the context of weak institutions, it can be difficult to enforce conservation activities in areas with high development potential, which decreases the efficiency of the funds allocated to forest conservation. Given this trade-off, our results suggest that it can be optimal for project proponents to focus on areas with low development potential in order to achieve additionality. This is especially the case if the proponents have strong environmental objectives.

Our empirical results confirm these findings: among all projects, we were only able to confirm additionality for the project relying exclusively on VCS (carbon) certification; and we found a statistically significant impact of this project on deforestation despite the fact that they target forests that are less threatened. On the contrary, we cannot exclude the possibility that the projects that combined both CCB and VCS certification were not additional, even though they are located in areas with higher development potential.

Our work therefore underlines the fact that location biases, often identified in the literature, are not independent of the REDD+ project manager's type. Furthermore, the existence of a location bias, frequently represented by implementing conservation projects in remote areas, does not necessarily imply a lack of additionality. In contrast, choosing a location with high development potential may lead to low (if any) levels of additionality.

Given the conclusions of our theoretical model, we acknowledge that our approach suffers from our lack of data regarding the social impact of REDD projects. As a matter of fact, the theoretical model considers both social and environmental benefits. The empirical analysis confirms the results regarding deforestation but, unfortunately, we are unable to confirm the results of the model regarding social benefits. Moreover, we were only able to georeference six REDD projects so our results rely on a small sample of projects. In order to increase the external validity of our results, it would be interesting to expand it to other projects.

Our analysis provides innovative theoretical and empirical evidence regarding the mechanisms that lead to additionality. We show how the incentives behind REDD+ can lead to target areas with lower development potential and that the quality of governance can impact the behavior of the proponents. Following recent calls by Baylis et al. (2016), among others, we do not wonder if REDD+ projects are effective instruments for forest conservation but, instead, how and under which conditions they deliver the expected results. We believe that this focus on the mechanisms is a crucial issue that needs to be tackled by academics in order to improve our understanding of conservation policies.

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Appendices

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

Table 5: Functions

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

Table 6: Parameters

Variable	Figure 2	Figure 3		Figure 4		Figure 5	
b	$\in [1,10]$	b^*					
e	0.5	e^*					
a	(0.5, 1.5)	$\in [0.1,3]$		0.5	1.5	0.5	1.5
α	n.a	0.8	0.2	$[0,1]$		$[0,0.7]$	
β	n.a	0.2	0.8	$[1,0]$		$[0.7,0]$	
p_c	n.a	1				2	1
p_u	n.a	1				1	2
b^*	n.a	[10, 1.58]	[10, 10]	10	$[10,1.58]$	10	10
e^*	n.a	[0.45, 1]	[0.09, 1]	$[0,1]$	$[0,1]$	$[0,1]$	$[0,1]$
v^*	n.a	[1.24, -1.05]	$[2.87,2.20]$	$[3,91,0.87]$	$[3,91,-0.63]$	$[3.91,1.5]$	$[4.1,0.5]$
$\bar{e}$	[0.5, 1]	[0.63, 1]	[0.63, 1]	1	1	1	1

B Data sources

Table 7: Data sources

Variable	Source
Distance to waters (100km)	ESRI - Digital Chart of the World
Distance to roads in 1993 (100km)	ESRI - Digital Chart of the World
Distance to the closest urban area (100km)	IBGE
Slope (Percentage rise)	SRTM
Total deforestation in neighbouring cells before the implementation (100ha)	PRODES
Total deforestation before the implementation (100ha)	PRODES
REDD+ projects	Simonet et al. (2018a)
Federal, regional and indigenous protected areas	UNEP-WCMC (2018)

C Descriptive statistics

Table 8: Descriptive statistics: Distance to roads (100km)

	Minimum	1st decile	Median	9th decile	Maximum
Private for profit with VCS and CCB certification	0.0000	0.0498	0.5944	1.0531	1.0971
Private for profit with only VCS certification	0.2277	0.3639	0.9430	1.0893	1.1454
NGOs with VCS and CCB certification	0.2454	0.4950	0.8449	1.3004	1.4715

Table 9: Descriptive statistics: Distance to closest urban area (100km)

	Minimum	1st decile	Median	9th decile	Maximum
Private for profit with VCS and CCB certification	0.0169	0.1277	0.4204	0.6546	0.7180
Private for profit with only VCS certification	0.4477	0.5386	0.9953	1.1930	1.2067
NGOs with VCS and CCB certification	0.0000	0.1450	0.3842	0.7254	1.0237

Table 10: Descriptive statistics: Distance to waters (100km)

	Minimum	1st decile	Median	9th decile	Maximum
Private for profit with VCS and CCB certification	0.0000	0.0000	0.0626	0.3088	0.5160
Private for profit with only VCS certification	0.0000	0.0887	0.5099	0.7103	0.7597
NGOs with VCS and CCB certification	0.0000	0.0139	0.3134	1.4240	1.6984

Table 11: Descriptive statistics: Av. yearly def. rates ex-ante

	Minimum	1st decile	Median	9th decile	Maximum
Private for profit with VCS and CCB certification	0.0000	0.0000	0.0000	0.0030	0.0120
Private for profit with only VCS certification	0.0000	0.0000	0.0000	0.0021	0.0054
NGOs with VCS and CCB certification	0.0000	0.0000	0.0000	0.0430	0.1087

D Balancing tests

Table 12: Descriptive statistics: Av. yearly def. rates in neighbouring cells ex-ante

	Minimum	1st decile	Median	9th decile	Maximum
Private for profit with VCS and CCB certification	0.0000	0.0000	0.0000	0.0040	0.0116
Private for profit with only VCS certification	0.0000	0.0000	0.0000	0.0041	0.0099
NGOs with VCS and CCB certification	0.0000	0.0000	0.0027	0.0354	0.0753

Table 13: Descriptive statistics: Slope (Percent rise)

	Minimum	1st decile	Median	9th decile	Maximum
Private for profit with VCS and CCB certification	0.087	0.172	0.364	2.458	4.981
Private for profit with only VCS certification	0.430	0.637	1.008	2.357	3.030
NGOs with VCS and CCB certification	0.373	0.574	0.929	1.990	3.413

Table 14: Balancing test using three nearest neighbour matching: First private-for-profit project with both certification

Variable		Treated	Control	% Biais	%Reduction Bias	t-stat	p-value
Distance to waters (100km)	Unmatched	0.1129	0.4087	-103.3		-7.09	0.000***
	Matched	0.1129	0.1139	-0.4	99.7	-0.04	0.966
Distance to road (100km)	Unmatched	0.8581	10.0629	-26.9		-1.72	0.085*
	Matched	0.8581	0.8002	7.6	71.7	1.83	0.069*
Distance to the closest urban area (100km)	Unmatched	0.5453	0.7144	-43.6		-2.80	0.005***
	Matched	0.5453	0.5222	6.0	86.3	0.94	0.349
Slope (Percent rise)	Unmatched	0.3661	0.9677	-71.5		-4.75	0.000***
	Matched	0.3413	0.3740	-3.9	94.6	-0.77	0.440
Area of the cell	Unmatched	1633.4000	1961.5000	-52.2		-4.56	0.000***
	Matched	1633.4000	1719.0000	-13.6	73.9	-0.85	0.398
Av. yearly def. rates in	Unmatched	0.0006	0.0053	-45.8		-2.98	0.003***
neigbouring cells ex-ante	Matched	0.0005	0.0005	0.4	99.0	0.27	0.788
Av. yearly def. rates ex-ante	Unmatched	0.0006	0.0059	-34.8		-2.20	0.028**
	Matched	0.0006	0.0002	2.2	93.7	1.44	0.152

Table 15: Balancing test using three nearest neighbour matching: Second private-for-profit project with both certification

Variable		Treated	Control	% Biais	%Reduction Bias	t-stat	p-value
Distance to waters (100km)	Unmatched	0.1073	0.4086	-112.4		-5.57	0.000***
	Matched	0.1073	0.1187	-4.2	96.2	-0.68	0.501
Distance to road (100km)	Unmatched	0.2414	10.0631	-107.5		-5.33	0.000***
	Matched	0.2414	0.2793	-5.0	95.4	-0.88	0.381
Distance to the closest urban area (100km)	Unmatched	0.2591	0.7145	-117.3		-5.83	0.000***
	Matched	0.2591	0.2630	-1.0	99.2	-0.17	0.867
Slope (Percent rise)	Unmatched	1.6610	0.9669	61.7		4.12	0.000***
	Matched	1.6610	1.5289	11.7	81.0	0.58	0.566
Area of the cell	Unmatched	1619.6000	1961.4000	-52.0		-3.66	0.000***
	Matched	1619.6000	1623.4000	-0.6	98.9	-0.03	0.977
Av. yearly def. rates in	Unmatched	0.0021	0.0042	-26.3		-1.32	0.186
neigbouring cells ex-ante	Matched	0.0021	0.0019	2.6	90.2	0.32	0.752
Av. yearly def. rates ex-ante	Unmatched	0.0014	0.0046	-30.0		-1.47	0.140
	Matched	0.0014	0.001	3.6	88.0	0.73	0.467

Table 16: Balancing test using three nearest neighbour matching: First private-for-profit project with only VCS certification

Variable		Treated	Control	% Biais	%Reduction Bias	t-stat	p-value
Distance to waters (100km)	Unmatched	0.1903	0.4085	-77.5		-2.12	0.034**
	Matched	0.1903	0.2572	-23.7	69.4	-1.13	0.269
Distance to road (100km)	Unmatched	0.3919	1.0628	-89.6		-2.29	0.022**
	Matched	0.3919	0.3669	3.3	96.3	0.41	0.688
Distance to the closest urban area (100km)	Unmatched	0.6332	0.7143	-20.7		-0.55	0.585
	Matched	0.6332	0.6394	-1.6	92.3	-0.10	0.919
Slope (Percent rise)	Unmatched	1.0783	0.9672	13.3		0.35	0.729
	Matched	1.0783	1.1734	-11.4	14.4	-0.68	0.501
Area of the cell	Unmatched	1509.9000	1961.3000	-73.8		-2.54	0.011**
	Matched	1509.9000	1534.8000	-4.1	94.5	-0.11	0.912
Av. yearly def. rates in neigbouring cells ex-ante	Unmatched	0.0002	0.0053	-49.2		-1.26	0.209
	Matched	0.0002	0.0012	-9.1	81.4	-1.50	0.146
Av. yearly def. rates ex-ante	Unmatched	0.0000	0.0059	-38.8		-0.99	0.323
	Matched	0.0000	0.0004	-3.1	92.0	-1.03	0.314

Table 17: Balancing test using three nearest neighbour matching: Second private-for-profit project with only VCS certification

Variable		Treated	Control	% Biais	%Reduction Bias	t-stat	p-value
Distance to waters (100km)	Unmatched	0.6279	0.4084	80.7		2.90	0.004***
	Matched	0.6279	0.7290	-37.2	53.9	-1.97	0.055*
Distance to road (100km)	Unmatched	1.0036	1.0627	-7.9		-0.27	0.784
	Matched	1.0036	1.3121	-41.2	-421.7	-4.80	0.000***
Distance to the closest urban area (100km)	Unmatched	1.0723	0.7142	93.3		3.27	0.001***
	Matched	1.0723	0.9097	42.4	54.6	2.03	0.048**
Slope (Percent rise)	Unmatched	1.2217	0.9672	25.8		1.08	0.280
	Matched	1.2217	1.2249	-0.3	98.7	-0.01	0.989
Area of the cell	Unmatched	1517.1	1961.3	-70.1		-3.40	0.001***
	Matched	1517.1	1718.6	-31.8	54.6	-1.19	0.239
Av. yearly def. rates in neigbouring cells ex-ante	Unmatched	0.0012	0.0047	-37.8		-1.33	0.184
	Matched	0.0012	0.0049	-39.6	-4.6	-3.09	0.003***
Av. yearly def. rates ex-ante	Unmatched	0.0004	0.0052	-36.8		-1.28	0.201
	Matched	0.0004	0.0069	-50.1	-36.1	-3.26	0.002***

Table 18: Balancing test using three nearest neighbour matching: First NGO project with both certification

Variable		Treated	Control	% Biais	%Reduction Bias	t-stat	p-value
Distance to waters (100km)	Unmatched	1.3900	0.4075	347.9		26.56	0.000***
	Matched	1.3900	1.4088	-6.6	98.1	-0.85	0.395
Distance to road (100km)	Unmatched	0.5535	1.0632	-67.5		-4.82	0.000***
	Matched	0.5535	0.4692	11.2	83.4	3.16	0.002***
Distance to the closest urban area (100km)	Unmatched	0.3721	0.7146	-87.5		-6.39	0.000***
	Matched	0.3721	0.4184	-11.8	86.5	-2.25	0.025**
Slope (Percent rise)	Unmatched	1.3060	0.9669	36.9		2.94	0.003***
	Matched	1.3060	1.3331	-2.9	92.0	-0.31	0.756
Area of the cell	Unmatched	2240.6	1960.9	51.8		4.37	0.000***
	Matched	2240.6	2248.6	-1.5	97.1	-0.13	0.897
Av. yearly def. rates in	Unmatched	0.0005	0.0047	-47.0		-3.33	0.001***
neigbouring cells ex-ante	Matched	0.0005	0.0009	-4.3	90.9	-2.73	0.007***
Av. yearly def. rates ex-ante	Unmatched	0.0006	0.0052	-34.9		-2.49	0.013**
	Matched	0.0006	0.0006	0.5	98.7	0.20	0.838

Table 19: Balancing test using three nearest neighbour matching: Second NGO project with both certification

Variable		Treated	Control	% Biais	%Reduction Bias	t-stat	p-value
Distance to waters (100km)	Unmatched	0.2429	0.409	-56.5		-7.87	0.000***
	Matched	0.2429	0.3066	-21.7	61.6	-3.99	0.000***
Distance to road (100km)	Unmatched	0.9800	1.063	-10.8		-1.38	0.167
	Matched	0.9800	0.9845	-0.6	94.5	-0.18	0.861
Distance to the closest urban area (100km)	Unmatched	0.4226	0.7152	-70.3		-9.60	0.000***
	Matched	0.4226	0.3943	6.8	90.3	1.51	0.132
Slope (Percent rise)	Unmatched	1.0475	0.967	8.9		1.23	0.220
	Matched	1.0475	1.0313	1.8	79.8	0.40	0.693
Area of the cell	Unmatched	1879.5	1961.5	-13.1		-2.25	0.024**
	Matched	1879.5	1875.6	0.6	95.3	0.08	0.936
Av. yearly def. rates in neigbouring cells ex-ante	Unmatched	0.0122	0.0047	55.6		10.43	0.000***
	Matched	0.0122	0.0117	3.7	93.3	0.45	0.654
Av. yearly def. rates ex-ante	Unmatched	0.0134	0.0052	41.9		7.88	0.000***
	Matched	0.0134	0.0126	4.1	90.2	0.49	0.627

Table 20: Balancing test using five nearest neighbour matching: First private-for-profit project with both certification

Variable		Treated	Control	% Biais	%Reduction Bias	t-stat	p-value
Distance to waters (100km)	Unmatched	0.1129	0.4087	-103.3		-7.09	0.000***
	Matched	0.1129	0.1159	-1.0	99.0	-0.12	0.902
Distance to road (100km)	Unmatched	0.8581	1.0629	-26.9		-1.72	0.085*
	Matched	0.8581	0.8005	7.6	71.9	1.80	0.073*
Distance to the closest urban area (100km)	Unmatched	0.5453	0.7144	-43.6		-2.80	0.005***
	Matched	0.5453	0.5257	5.1	88.4	0.78	0.437
Slope (Percent rise)	Unmatched	0.3661	0.9677	-71.5		-4.75	0.000***
	Matched	0.3413	0.3670	-3.1	95.7	-0.62	0.536
Area of the cell	Unmatched	1633.4000	1961.5000	-52.2		-4.56	0.000***
	Matched	1633.4000	1742.4000	-17.3	66.8	-1.08	0.280
Av. yearly def. rates in	Unmatched	0.0006	0.0053	-45.8		-2.98	0.003***
neigbouring cells ex-ante	Matched	0.0005	0.0005	0.9	98.1	0.51	0.608
Av. yearly def. rates ex-ante	Unmatched	0.0006	0.0059	-34.8		-2.20	0.028**
	Matched	0.0006	0.0002	2.1	93.9	1.40	0.163

Table 21: Balancing test using five nearest neighbour matching: Second private-for-profit project with both certification

Variable		Treated	Control	% Biais	%Reduction Bias	t-stat	p-value
Distance to waters (100km)	Unmatched	0.1073	0.4086	-112.4		-5.57	0.000***
	Matched	0.1073	0.1204	-4.9	95.6	-0.76	0.447
Distance to road (100km)	Unmatched	0.2414	1.0631	-107.5		-5.33	0.000***
	Matched	0.2414	0.2881	-6.1	94.3	-1.07	0.287
Distance to the closest urban area (100km)	Unmatched	0.2591	0.7145	-117.3		-5.83	0.000***
	Matched	0.2591	0.2703	-2.9	97.5	-0.48	0.631
Slope (Percent rise)	Unmatched	1.6610	0.9669	61.7		4.12	0.000***
	Matched	1.6610	1.5165	12.8	79.2	0.62	0.540
Area of the cell	Unmatched	1619.6000	1961.4000	-52.0		-3.66	0.000***
	Matched	1619.6000	1625.6000	-0.9	98.2	-0.05	0.964
Av. yearly def. rates in neigbouring cells ex-ante	Unmatched	0.0021	0.0042	-26.3		-1.32	0.186
	Matched	0.0021	0.0017	4.7	82.0	0.61	0.545
Av. yearly def. rates ex-ante	Unmatched	0.0014	0.0046	-30.0		-1.47	0.140
	Matched	0.0014	0.0010	3.7	87.8	0.75	0.453

Table 22: Balancing test using five nearest neighbour matching: First private-for-profit project with only VCS certification

Variable		Treated	Control	% Biais	%Reduction Bias	t-stat	p-value
Distance to waters (100km)	Unmatched	0.1903	0.4085	-77.5		-2.12	0.034**
	Matched	0.1903	0.2351	-15.9	79.5	-0.76	0.456
Distance to road (100km)	Unmatched	0.3919	1.0628	-89.6		-2.29	0.022**
	Matched	0.3919	0.3431	6.5	92.7	0.75	0.461
Distance to the closest urban area (100km)	Unmatched	0.6332	0.7143	-20.7		-0.55	0.585
	Matched	0.6332	0.6286	1.2	94.4	0.08	0.940
Slope (Percent rise)	Unmatched	1.0783	0.9672	13.3		0.35	0.729
	Matched	1.0783	1.0841	-0.7	94.8	-0.04	0.968
Area of the cell	Unmatched	1509.9000	1961.3000	-73.8		-2.54	0.011**
	Matched	1509.9000	1563.1000	-8.7	88.2	-0.24	0.813
Av. yearly def. rates in neigbouring cells ex-ante	Unmatched	0.0002	0.0053	-49.2		-1.26	0.209
	Matched	0.0002	0.0017	-14.5	70.6	-1.70	0.103
Av. yearly def. rates ex-ante	Unmatched	0.0000	0.0059	-38.8		-0.99	0.323
	Matched	0.0000	0.0011	-7.2	81.3	-1.03	0.312

Table 23: Balancing test using five nearest neighbour matching: Second private-for-profit project with only VCS certification

Variable		Treated	Control	% Biais	%Reduction Bias	t-stat	p-value
Distance to waters (100km)	Unmatched	0.6279	0.4084	80.7		2.90	0.004***
	Matched	0.6279	0.7400	-41.2	48.9	-2.22	0.031**
Distance to road (100km)	Unmatched	1.0036	1.0627	-7.9		-0.27	0.784
	Matched	1.0036	1.3554	-47.0	-494.9	-5.14	0.000***
Distance to the closest urban area (100km)	Unmatched	1.0723	0.7142	93.3		3.27	0.001***
	Matched	1.0723	0.8344	62.0	33.6	2.94	0.005***
Slope (Percent rise)	Unmatched	1.2217	0.9672	25.8		1.08	0.280
	Matched	1.2217	1.2469	-2.5	90.1	-0.12	0.908
Area of the cell	Unmatched	1517.1	1961.3	-70.1		-3.40	0.001***
	Matched	1517.1	1689.8	-27.3	61.1	-1.02	0.312
Av. yearly def. rates in	Unmatched	0.0012	0.0047	-37.8		-1.33	0.184
neigbouring cells ex-ante	Matched	0.0012	0.0046	-36.9	2.4	-2.96	0.005***
Av. yearly def. rates ex-ante	Unmatched	0.0004	0.0052	-36.8		-1.28	0.201
	Matched	0.0004	0.0063	-45.7	-24.0	-3.08	0.003***

Table 24: Balancing test using five nearest neighbour matching: First NGO project with both certification

Variable		Treated	Control	% Biais	%Reduction Bias	t-stat	p-value
Distance to waters (100km)	Unmatched	1.3900	0.4075	347.9		26.56	0.000***
	Matched	1.3900	1.4016	-4.1	98.8	-0.51	0.611
Distance to road (100km)	Unmatched	0.5535	1.0632	-67.5		-4.82	0.000***
	Matched	0.5535	0.4786	9.9	85.3	2.74	0.007***
Distance to the closest urban area (100km)	Unmatched	0.3721	0.7146	-87.5		-6.39	0.000***
	Matched	0.3721	0.425	-13.5	84.5	-2.52	0.012**
Slope (Percent rise)	Unmatched	1.3060	0.9669	36.9		2.94	0.003***
	Matched	1.3060	1.3368	-3.4	90.9	-0.35	0.726
Area of the cell	Unmatched	2240.6	1960.9	51.8		4.37	0.000***
	Matched	2240.6	2252.2	-2.2	95.8	-0.19	0.849
Av. yearly def. rates in neigbouring cells ex-ante	Unmatched	0.0005	0.0047	-47.0		-3.33	0.001***
	Matched	0.0005	0.0009	-4.5	90.3	-2.93	0.004***
Av. yearly def. rates ex-ante	Unmatched	0.0006	0.0052	-34.9		-2.49	0.013**
	Matched	0.0006	0.0006	0.1	99.6	0.06	0.951

Table 25: Balancing test using five nearest neighbour matching: Second NGO project with both certification

Variable		Treated	Control	% Biais	%Reduction Bias	t-stat	p-value
Distance to waters (100km)	Unmatched	0.2429	0.409	-56.5		-7.87	0.000***
	Matched	0.2429	0.309	-22.5	60.2	-4.15	0.000***
Distance to road (100km)	Unmatched	0.9800	1.063	-10.8		-1.38	0.167
	Matched	0.9800	0.9908	-1.4	86.9	-0.41	0.682
Distance to the closest urban area (100km)	Unmatched	0.4226	0.7152	-70.3		-9.60	0.000***
	Matched	0.4226	0.3941	6.8	90.3	1.52	0.129
Slope (Percent rise)	Unmatched	1.0475	0.967	8.9		1.23	0.220
	Matched	1.0475	1.041	0.7	92.0	0.16	0.876
Area of the cell	Unmatched	1879.5	1961.5	-13.1		-2.25	0.024**
	Matched	1879.5	1877.4	0.3	97.5	0.04	0.965
Av. yearly def. rates in neigbouring cells ex-ante	Unmatched	0.0122	0.0047	55.6		10.43	0.000***
	Matched	0.0122	0.0115	5.4	90.3	0.65	0.513
Av. yearly def. rates ex-ante	Unmatched	0.0134	0.0052	41.9		7.88	0.000***
	Matched	0.0134	0.012	6.8	83.7	0.82	0.413

E Additionality estimates with clustered standard errors

Table 26: Additionality of the projects: OLS after pre-matching using three nearest neighbour matching

VARIABLES	(1) Variation in average yearly deforestation rates	(2) Variation average yearly deforestation rates	(3) Variation in average yearly deforestation rates
Priv. for profit with both certif.	0.0005**		
	(0.0001)		
Priv. for profit with only VCS certif.		-0.0056**	
		(0.0013)	
NGOs with both certif.			0.0013*
			(0.0005)
Distance to waters (100km)	-0.0005	-0.0011	0.0010
	(0.0005)	(0.0078)	(0.0018)
Distance to road (100km)	0.0012**	-0.0070	-0.0007
	(0.0004)	(0.0035)	(0.0064)
Distance to the closest urban area (100km)	-0.0016	0.0044	0.0079
	(0.0008)	(0.0040)	(0.0038)
Slope (Percent rise)	-0.0000	0.0006	-0.0003
	(0.0000)	(0.0007)	(0.0014)
Av. yearly def. rates in neigbouring cells ex-ante	0.1566* (0.0645)	0.3114* (0.1323)	0.4386* (0.1656)
Av. yearly def. rates ex-ante	-0.7882***	-0.3403**	-0.7427***
	(0.0730)	(0.0873)	(0.0435)
Area of the cell	-0.0000	-0.0000	0.0000
	(0.0000)	(0.0000)	(0.0000)
Constant	0.0005	0.0124	-0.0050
	(0.0007)	(0.0056)	(0.0026)
Observations	274	93	767
R-squared	0.4438	0.0937	0.5795

Clustered standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 27: Additionality of the projects: OLS after pre-matching using five nearest neighbour matching

VARIABLES	(1) Variation in average yearly deforestation rates	(2) Variation average yearly deforestation rates	(3) Variation in average yearly deforestation rates
Priv. for profit with both certif.	0.0001		
	(0.0002)		
Priv. for profit with only VCS certif.		-0.0032**	
		(0.0009)	
NGOs with both certif.			0.0010
			(0.0007)
Distance to waters (100km)	-0.0030*	-0.0045	0.0014
	(0.0009)	(0.0068)	(0.0015)
Distance to road (100km)	0.0002	-0.0027	0.0004
	(0.0004)	(0.0037)	(0.0051)
Distance to the closest urban area (100km)	0.0006	0.0023	0.0080**
	(0.0010)	(0.0018)	(0.0021)
Slope (Percent rise)	-0.0002**	0.0006**	-0.0007
	(0.0000)	(0.0001)	(0.0012)
Av. yearly def. rates in	0.3367*	0.4863*	0.4071*
neigbouring cells ex-ante	(0.1417)	(0.1534)	(0.1484)
Av. yearly def. rates ex-ante	-0.7102***	-0.2482**	-0.7277***
	(0.0708)	(0.0778)	(0.0312)
Area of the cell	-0.0000**	-0.0000	0.0000
	(0.0000)	(0.0000)	(0.0000)
Constant	0.0009	0.0083*	-0.0053
	(0.0005)	(0.0033)	(0.0025)
Observations	341	125	888
R-squared	0.2066	0.0696	0.5628

Clustered standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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