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Greater Flexibility in Payments for Ecosystem Services: Evidence from an RCT in the Amazon

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Abstract

In Payment for Ecosystem Services (PES) programs, incentive payments conditional on zero deforestation do not always match the time profile of landowners' opportunity costs. In this study, we examine the impact of adding some flexibility to PES contracts to allow landowners the possibility of receiving part of the financial incentive if some deforestation is detected during the contract period. We ran a pilot PES program in the Brazilian Amazon during the last years of Jair Bolsonaro's mandate, at a time when incentives to deforest were strong. Using the Becker-DeGroot-Marschak (BDM) mechanism, we implemented a PES procurement auction to elicit landowners' reservation prices for forest conservation. We embedded the BDM auction in a randomized controlled trial (RCT), which included one control group and two PES treatment groups of about 150 voluntary landowners each. In line with theoretical predictions, we found that, while the flexible PES contract allowing some deforestation saved slightly more forest, the fixed payment contract requiring zero deforestation exhibited a higher benefit-cost ratio.

Keywords: BDM auctions, Deforestation thresholds, Payments for Ecosystem Services.
JEL codes: D04, D44, D82, Q24, Q28.

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Payments for environmental services (PES) use direct incentives to improve the environmental impacts of farmers' conservation decisions (Ferraro and Simpson, 2002; Engel et al., 2008). Despite the general enthusiasm of policymakers about these mechanisms, their effectiveness is regularly called into question (Jack et al., 2008; Ferraro, 2008; Perevochtchikova et al., 2021; Montero-de-Oliveira et al., 2023). When it comes to forest conservation PES, two major challenges have been identified. Firstly, landowners' opportunity costs for avoiding deforestation are heterogeneous, which induces self-selection into PES programs and likely undermines their environmental impact and cost-effectiveness (Jack and Jayachandran, 2019). Second, landowners' opportunity costs are likely to vary over time, while PES are generally fixed. Thus, if a landowner is credit constrained and experiences an exogenous shock, such as an unexpected health expense or an increase in cattle prices, the incentive not to deforest may well become insufficient (Jayachandran, 2013). In such cases, the landowner violates the contract, the expected environmental benefit is not realized, and implementation costs are never recovered. More complex PES schemes that address these limitations are thus needed to achieve greater effectiveness.

Mechanisms that can deal with the heterogeneity of opportunity costs have been studied for decades (Ferraro, 2008). Although their implementation in the real world may be a challenge, PES procurement auctions can be used to make landowners reveal their opportunity costs through their bid (Latacz-Lohmann and Schilizzi, 2005).[1] In contrast, the question of the time profile of opportunity costs has received less attention, whether in theory or in practice. In this paper, we examine the impact of including some flexibility in PES forest conservation contracts, i.e., the possibility of maintaining partial payment of the financial incentive even when zero deforestation is not achieved, provided the deforestation recorded during the contract period does not exceed a certain threshold.

We ran a pilot PES program in the Brazilian Amazon, in the state of Acre, during the last years of Jair Bolsonaro's mandate, at a time when incentives to deforest were strong.[2] We implemented a PES procurement auction using the Becker-DeGroot-Marschak (BDM) mechanism to elicit landowners' reservation prices for forest conservation (Becker et al., 1964). We embedded this BDM auction in a randomized controlled trial (RCT), which included one control group and two treatment groups of about 150 voluntary landowners each. Each treatment group was offered a different PES contract: contract A, which offered a fixed payment conditional on zero deforestation and contract B, which charged a penalty for each deforestation threshold crossed. The motivation for comparing these two PES contracts comes from the theoretical prediction that a flexible contract may outperform a fixed one in cases when an unexpected shock forces a landowner to cut down trees during the contract period.

Suppose that a landowner under a PES contract faces a shock that pushes him to cut down half a hectare of forest. His behavior thereafter is likely to depend on whether he has signed a fixed

[1] While this type of device has been used for many years in the USA for the provision of various ecosystem services (Latacz-Lohmann and Schilizzi, 2005; Cramton et al., 2021; Balmford et al., 2023), there is no equivalent for the conservation of forests in tropical areas (Jack, 2013).

[2] After years of budget cuts under the government of Jair Bolsonaro, it was expected that Ibama, the environmental police, would be able to resume its control missions against deforestation. This is actually what happened with Luiz Inacio Lula da Silva's return to power in October 2022.

or flexible contract. Under a traditional fixed PES contract, any deforestation by the landowner automatically cancels payment; thus, for the remainder of the contract terms, he has no incentive to make any conservation efforts and will likely return to his business-as-usual deforestation pattern. With a flexible PES, on the other hand, he will still be entitled to payment at the end of the contract period, albeit minus a penalty, dependent on the level of deforestation recorded. The landowner therefore has an incentive to maintain a certain level of conservation effort until the end of the contract. In many situations, one can thus expect a flexible contract to preserve more forest than a fixed one – at least at the individual landowner level.

Even in cases where a flexible contract outperforms a fixed contract at the individual level, however, there is no guarantee that this will be the case at the aggregate level, nor that the total environmental benefit will be obtained at a lower cost. This is because, while fixed PES is associated to a higher risk of default, it also has higher forest conservation potential when the landowner complies with the requirements until the end of the contract. The heterogeneity of individuals' ability to deal with unexpected shocks therefore plays a key role here. Moreover, the two contract types differ in their costs, both implementation costs and the cost of the PES itself. One would indeed expect the price asked for a fixed contract to be higher than that for a flexible contract – at least as long as the cost of the deforestation penalty does not exceed the benefit of having a more flexible contract. And yet, although a fixed contract is more costly that a flexible one, the total amount spent in PES could ultimately be less, the risk of default being higher than with the latter. Finally, the implementation costs are the same under both contract types, which undermines the probability of the fixed contract outperforming the flexible one. Thus, although it is theoretically possible that flexible PES saves more forest than flexible PES at the landowner level, whether or not greater flexibility can ultimately increase the cost-effectiveness of PES programs remains an empirical question.

In our experiment, we found that PES mechanisms indeed provide an incentive not to deforest, since on average they generated a statistically significant environmental benefit in all treated groups. In particular, we estimated that an increase of 1,000 Brazilian reals (BRL) saved approximately 0.1 hectares on each farm per three-month period. Looking then at the effect of the treatments, we found that the flexible PES contract offered in group B saved slightly more forest over the contract period than the fixed contract offered in group A. This is particularly notable in the period between June and August 2022 during which the two treatment groups cleared more than 0.10 hectares of forest. At the same time, we found that the default rate in group A had reached a particularly high level (70 percent) – much higher than in group B (24 percent). Consistently, we also found that contract B (flexible PES) paid out significantly more (about 2,000 BRL versus 1,100 BRL on average) than contract A (fixed PES). Taken all together, these results suggest that introducing more flexibility could save more forest but that the associated costs could render the operation ineffective in the end. Thus, the ability of individuals to anticipate and manage the consequences of unexpected shocks, measured here through their bids and default rates, defines the scenarios in which flexible PES outperform fixed PES.

In addition, our results of the elicited willingness-to-accept (WTA) PES for forest conservation for each type of contract are consistent with theoretical predictions, with the bids being higher, on average, for contract A (fixed PES) than for contract B (flexible PES). By combining landowners' bids with household survey variables, we found that a number of household characteristics, farm characteristics, and socioeconomic variables are likely to drive landowners' reservation prices for forest conservation. We found that two fairly distinct farmer typologies emerge from the experiment: low-income households practicing traditional (slash-and-burn) agriculture based on fallow land and subsistence farming, and wealthier households whose agricultural activities rely on highly deforestation-dependent land uses (e.g., extensive cattle-ranching).

This study makes several contributions to the literature. First, we measure the private opportunity costs of forest conservation in a population that clears forest every year in order to extend pastures for cattle and to cultivate staple crops for self-sustaining purposes. Precise data on individual opportunity costs is a key input for PES design in areas where landowners' livelihoods depend on production systems that are significant drivers of deforestation. This paper adds to a small literature measuring the private costs of forest conservation through directly offering households customized PES (Jack, 2013). Second, and most importantly, we explore the impact of introducing some flexibility to PES contracts and find that, in a context where incentives to deforest were strong, the fixed PES contract allowed more total forest to be saved, but at a higher cost, which makes this option less cost-effective (when considering payments only and not implementation costs) than the standard contract with a fixed payment contingent on zero deforestation.

Providing credible evidence on the net effect of including penalties in PES contracts is of great interest for policymakers seeking to improve PES. Yet to date, very few studies have addressed this question. Several recent studies aimed at improving the PES schemes of the Common Agricultural Policy (CAP) show that greater flexibility (for example, via temporary suspension of requirements) would increase the participation of European farmers in PES programs (Lapierre et al., 2023). We contribute to this stream of research by studying the emblematic case of PES implemented in the Brazilian Amazon, one of the regions of the world most threatened by deforestation. The rest of the paper proceeds as follows. Section 1 presents the theoretical model, and Section 2 describes the experimental setting and design. Section 3 presents the data, which includes secondary data used for randomization, original remote sensing data on forest clearing used as outcomes, and survey and auction data collected in the field. Section 4 presents the results of the experiment. Section 5 discusses a number of implications for the design of future PES programs.

1 Theoretical predictions

To provide a framework for our analysis, we describe a simple model of deforestation decisions under two PES schemes implemented through a BDM auction. The first (contract A) offers a fixed payment for zero deforestation, while the second (contract B) includes a penalty that decreases the payment for any deforestation recorded on the farmland. The model generates predictions about the amount of the bid, the probability of the landowner being enrolled in the scheme, and the

level of deforestation for each PES type. A full description of the model derivation, all proofs, and further theoretical results are given in the Appendix.

1.1 Setup

We consider a group, of size 1, of landowners that get some benefit from deforestation. With $i \in [0,1]$, landowner i's expected net payoff from deforestation is:

$$\pi_i(d_i) = b_i d_i - \frac{c}{2} d_i^2 \tag{1}$$

with $b_i d_i$ the income from deforestation d_i and $\frac{c}{2} d_i^2$ the cost of deforestation. For simplicity, we consider that b_i is the only source of heterogeneity among landowners. In the business-as-usual (BAU) scenario, which constitutes the reference level under no PES scheme, the landowners choose their level of deforestation to maximize their net payoff, described in equation 1. The first-order condition gives the level of deforestation and the net payoff in the BAU: $d_i^{BAU} = \frac{b_i}{c}$ and $\pi_i^{BAU} = \frac{b_i^2}{2c}$.

In the PES scenario, landowners are offered to participate in a BDM auction which randomly designates those who enter the system and for what amount of PES. In the BDM auction, landowner i states her bid w_i for the PES contract. The payment a_i is then randomly drawn from an urn.[3] If the random draw is greater than or equal to her bid, $a_i \geq w_i$, the landowner is enrolled in the PES scheme at the random payment drawn. If the random draw is less than her bid, $a_i < w_i$, she is not enrolled. If we (and the landholder) assume a uniform distribution of the random payments, we then have: $E(a) = \frac{\overline{a}}{2}$, $P(a_i < w_i) = \frac{w_i}{\overline{a}}$, and $P(a_i \geq w_i) = 1 - \frac{w_i}{\overline{a}}$.

Since the BDM mechanism is incentive-compatible, the bidding behavior should reveal the landowners' true opportunity cost, i.e., the money they would lose by suspending activities that drive deforestation, such as slash-and-burn agriculture and raising livestock, over one year. Opportunity costs may also include private costs the landowner incurs as a result of entering the program, such as monitoring the forest and changing her social status, minus the benefits she gets through warm glow and social payoffs. Individual opportunity costs are expected to be highly heterogeneous, whether because individuals have different farming activities and constraints or because they have different time, risk, and social preferences and different market price expectations.

Two types of PES contracts are considered. Under the fixed contract A, the landowner i receives a payment for the full conservation of her forest cover and thus has to set $d^B = 0$. If any deforestation is observed, her remuneration is zero. Participating in the BDM auction, she is enrolled under contract A with probability $1 - \frac{w_i}{\overline{a}}$. If not enrolled, she chooses her BAU deforestation level. With the flexible contract B, full payment is received if no deforestation is observed, but a penalty $\gamma(d_i)$ decreases the payment for any deforestation observed. More precisely, the penalty is increasing and convex in the deforestation level: $\gamma(d_i) = \gamma d_i^2$. Hence, the expected payment made to the landowner is: $(1 - \gamma d_i^2)E(a)$.

[3] The interval $[0, \overline{a}]$ on which the draw is made is not known to the landowner. Yet her bid is made upon her belief on that interval. As a matter of simplicity, we assume that $\overline{a}$ is both the maximum potential draw and the landholder's belief.

1.2 Comparison of PES contracts

		Contract A	Comparison	Contract B
Bid	$w_i^{A,B}$	π_i^{BAU}	$> \iff \gamma < \frac{c^2}{b_i^2 - 2c\overline{a}}$	$\pi_i^{BAU}\frac{(\gamma\overline{a})^2}{(c+\gamma\overline{a})^2-\gamma b_i^2}$
Enrollment	$\int_0^{\bar{i}^{A,B}} f(i)di$	$\int_0^{\bar{i}^{A}} f(i)di$	$<$	$\int_0^{\bar{i}^{B}} f(i)di$
Default	Df_i	Df_i^A	$>$	Df_i^B
Individual def.	$d_i^{A,B}$	0	$<$	$\frac{b_i}{c+\gamma\overline{a}}$
Total avoided def.	$AD^{A,B}$	$\int_0^{\bar{i}^{A}} d_i^{BAU} f(i)di$	$>$ or $<$	$\int_0^{\bar{i}^{B}} b_i\frac{\gamma\overline{a}}{c(c+\gamma\overline{a})} f(i)di$
Average avoided def.	$\frac{AD^{A,B}}{\int_0^{\bar{i}^{A,B}} f(i)di}$	$\frac{AD^{A}}{\int_0^{\bar{i}^{A}} f(i)di}$	$>$ or $<$	$\frac{AD^{B}}{\int_0^{\bar{i}^{B}} f(i)di}$
Individual payoffs	$\pi_i^{A,B}$	$\frac{\overline{a}}{2}$	$<$	$\pi_i^{BAU}\frac{c}{c+\gamma\overline{a}} + \frac{\overline{a}}{2}$

A number of predictions can be made from the comparison of the two contracts:

1. **Bid:** The bid made for the fixed contract A is higher than the bid made for contract B, if the penalty level is low enough: $\gamma < \overline{\gamma}(b_i)$. Indeed, the landowner tends to make a higher offer for contract A, whose conditions are more difficult to meet, as long as the cost of the penalty does not exceed the benefit of a more flexible contract.

2. **Enrollment:** Expected enrollment is greater in B than in A. This result is linked to the previous one. Since the bid for the fixed contract A is higher than that for the flexible contract B, the chances of drawing a price higher than the bid are lower for A than for B (because the urn contains a finite number of tokens). Note, however, that this result only holds in the case where the composition of the urn is the same for both contracts. This is not the case in the experiment presented below, in which we deliberately calibrated the urn contents so that the probability of enrollment in the PES scheme was the same in both groups.

3. **Default:** The risk of default is greater in the fixed contract A than in the flexible contract B, in particular related to medium shocks. Small shocks do not impact the default risk, while large shocks impact landowners under both contracts.

4. **Individual avoided deforestation:** Landowners enrolled in and complying with contract A are expected to save more forest than those enrolled in contract B. This result does not take into account the fact that default risk is higher for contract A, which undermines its generated environmental benefit compared to contract B.

5. **Total avoided deforestation:** The difference between contracts A and B in terms of total avoided deforestation is undetermined, because individual avoided deforestation is greater under contract A (fixed) while enrollment is higher under contract B (flexible). In our experiment, however, enrollment is the same in both contract groups, meaning that total avoided deforestation depends on the default rate only. It is also a matter of the distribution of

avoided deforestation efforts: in contract A, due to lower enrollment and greater default risk, fewer farmers (with lower opportunity costs) make all the avoided deforestation effort. Under contract B, more farmers provide some avoided deforestation effort.

6. **Cost:** The difference between direct PES costs is undetermined; however, transaction costs are lower under contract A (as there are fewer enrolled and complying farmers) than under contract B. Furthermore, fixed implementation costs are spread over a larger number of participants under contract B than under A.

2 Experimental setting and design

Participants were randomly assigned to three groups: two treatment groups and one control group. In treatment group A, individuals were offered a traditional fixed type of PES contract, different from that offered in group B. Group C is the control group. Individuals in both treatment groups were invited to play a BDM-type experimental auction, whose aim was to have them reveal the amount of PES they wished to receive in exchange for the conservation effort requested. The experiment was carried out in three stages: the enrollment of eligible voluntary households, the pre-test phase of the PES contracts, and the data collection itself, which included a survey and the BDM auction. The field team included eight native Portuguese speaker surveyors.

2.1 Study zone and village selection

The experiment was carried out in the western region of the Brazilian Amazon, in the state of Acre. Our study zone is located in the Taraucá-Evira watershed, and the participating households are concentrated in the area along highway BR-364, which is located within the municipalities of Tarauacá and Feijó. This territory is largely occupied by private smallholders who own an average area of less than 100 hectares, mostly covered by forests (about 60 percent on average) and pastures (about 40 percent on average), according to data we extracted from Mapbiomas.[4] The two municipalities are located in a frontier zone of human occupation and deforestation expansion.

In the study region, cattle livestock production is integrated with subsistence slash-and-burn rotational crops that include maize, manioc, bananas, and vegetables. There is a marked dry and wet season and one agricultural cycle per year. To establish new annual crops and expand pasture areas, forest area is cleared and burned during the dry season. Clearing occurs mostly between May and July and burning between August and October. There are two types of complementary clearing practices that are employed in the region: primary forest clearing and secondary forest clearing. Primary forest is cleared using machetes for small vegetation and chainsaws for trees with greater diameters, usually in May, which is the beginning of the dry season, so that the larger vegetation has enough time to dry in order to be set on fire during the fire season. Secondary vegetation is mainly cleared using machetes between June and July. Once the cut vegetation has had time to

[4]We refer here to MapBiomas Project, Collection 5 of the Annual Series of Land Use and Land Cover Maps of Brazil, accessed on September 30, 2020 through the link https://mapbiomas.org/en/download.

dry, controlled fires are set to clear the area for planting. Cleared land generally remains under cultivation for one or two years until the soil nutrients are depleted. After this, the land is either sown with grass and converted into pasture for cattle or is left fallow for one to four years, during which time young secondary forest will establish itself and regenerate soil nutrients for the next agricultural cycle. Some farmers use the same cleared area for up to four cycles of slash-and-burn rotational crops, followed by a period during which the area is uncultivated.

We selected the villages for the study using Global Forest Change (GFC) deforestation data (Hansen et al., 2013) to identify settlements having recent deforestation activity. We also chose a region with relatively easy access, that is roads and navigable rivers, and a high enrollment rate of farmholds in the Brazilian rural environmental registry (designated by the acronym CAR in Portuguese) to facilitate the monitoring of the compliance with the contract specifications. We selected six villages for the study and then conducted door-to-door visits to the eligible farms to present the program and enroll farmers interested in participating. In practice, to be eligible to participate in the study, a farmer had to (i) own a rural property with less than 500 hectares, (ii) be registered in the CAR, (iii) exercise a productive activity such as livestock or agriculture on the property, and (iv) have been actively clearing forest on their land in recent years, meaning that deforestation activities had been recorded at least twice between 2017 and 2020.

2.2 Data collection and experimental design

2.2.1 Enrollment of volunteer families

Beginning in May 2021, in each of the six selected villages we conducted an initial individual meeting with each eligible household that we were able to reach. We provided a description of the PES program objectives and the course of each step for participants. In particular, we clarified that we were registering families interested in participating in the project but that only some of them would be selected at random to participate in the auction, the outcome of which would also be random. Each willing participant was asked to sign a Free Prior and Informed Consent (FPIC) form stating that they understood that their participation in the pilot program did not guarantee that they would be offered a PES contract, as the program included two randomization phases, one as part of the RCT and one as part of the auction. Additionally, it was specified that even if they did not ultimately sign a PES contract, deforestation data on their farm would still be collected as part of the study. We informed the willing households that we would contact them in the following weeks to inform them whether they had been assigned to a treatment arm of the trial and to schedule a second visit to play the auction game. Interviewees were encouraged to discuss with their families what amount of money they would be willing to accept as part of a PES contract.

The final part of the interview was devoted to the verification or, if necessary, the registration of the boundaries of the farm in the rural registry (CAR) by manual entry of the polygon. The field team was trained to use a GIS software program containing the property boundaries overlaid with high-resolution image mosaics. Since the CAR contained many geometry errors (most often overlaps or displacements), in many cases we had to correct the property boundaries of willing

farmholders, along with their help. Figure 1 displays the mapping of the farmholds along the BR-364 highway that were ultimately enrolled in the study.

2.2.2 Design of PES contracts

In August 2021, a draft version of the protocol was tested in the field with twenty volunteer households. The contracts offered included different conservation thresholds and terms that were often misunderstood by participants. As a result, at the end of this pre-test, several adjustments were made, and the BDM auction was reframed accordingly. The final version of the protocol was then registered with the American Economic Association (Demarchi Dias and Subervie, 2021). We launched the protocol in September 2021, and the signing of the contracts took place until December 2021.

Participants were offered two types of PES contracts that included different forest conservation thresholds: contract A with a zero deforestation target and contract B with deforestation threshold penalties. Under both contracts, conditional payment for the full conservation of forest cover was made at the end of the twelve-month contract period. Under contract A, if any deforestation had been detected through satellite imagery during that time, the landowner received no payment. Under contract B, however, if satellite images had indicated that deforestation had exceeded certain thresholds, the final payment was adjusted according to a system of penalties. A 20-percent penalty was applied if a deforestation area of less than 0.5 hectares had been detected. A 50-percent penalty was applied if a deforestation area of between 0.5 and 1 hectare had been detected. Finally, no payment was issued if a deforestation patch greater than 1 hectare had been detected. The two contracts (written in Portuguese) can be found in the Appendix.

2.2.3 Randomization

Due to the large distance between settlements and to avoid the time constraints due to the rainy season, we registered eligible voluntary households in each village and performed the randomization and data collection in sequence before moving on to the next village. The PES contract, if applicable, was signed the same day, as soon as the BDM draw was revealed. In practice, we thus ran stratified randomization of participants, using settlements as strata. Randomization was carried out in order to obtain three groups balanced on a set of immediately available covariates: (i) the average size of the landholding, the average forest cover in 2021 computed from Planet satellites data,[5] (ii) the average deforestation in 2015, 2016, 2017, 2018 and 2019 computed from GFC deforestation data, (iii) the distance to the main road, and (iv) the distance to the nearest village or local market. Descriptive statistics and results of the balancing tests are shown in Table 1.

[5]The forest cover was manually vectorized by the field team using Planet satellites data after they verified the actual borders of the farms with the participants during the enrollment phase. Planet satellites data can be found at https://www.planet.com.

2.2.4 Household survey and BDM auction

Landowners who were randomly chosen to participate in the BDM were contacted by phone, and a follow-up visit was scheduled. The survey and experimental auction were conducted face-to-face with each participant individually. Before beginning the bidding exercise, each participant was administered a survey covering a number of socioeconomic characteristics such as income, assets, and land-use. The survey questionnaire (in Portuguese) can be found in the Appendix. Next, the surveyor made a detailed presentation of the two types of contracts and explained the bidding procedure. Finally, he presented individual participants with a range of conditional payments in exchange for not cutting down forest for a period of twelve months.

Participants were informed that they were going to make two bids, one for each of the two contracts. They were also informed that only one of these bids would be taken into account in the real world for the possible granting of a PSE, which would be determined by a random drawing, and that it was therefore in their interest to play each auction with the same precision. During this phase, we also collected qualitative data regarding the reasoning behind the landowner's bid, which typically included an example of how much money they would lose by not expanding their pasture or how much it would cost to buy corn or cassava from their neighbors rather than cultivating it themselves.

The surveyors collected the bids on each of the two contracts, each time following the same procedure. The order in which contracts were offered to participants in the BDM was random. After the participant confirmed her final bid for each of the two contracts, the surveyor revealed what kind of contract was randomly assigned to her, and the participant drew a token from the urn corresponding to the contract. This randomization was done beforehand in order to have balanced groups. Neither the enumerators or the participants knew which contract had been drawn before playing the BDM.

The tokens in urn A ranged from 4,500 to 6,100 BRL, in increments of 100 BRL, while in urn B tokens ranged from 3,900 to 5,500, also in increments of 100 BRL. The price range shown on the tokens placed in the urn was not known to the players. If the price written on the token was lower than the price requested by the participant, she was not offered a contract but received an in-kind compensation for her time spent with the surveyors. If the price written on the token was greater than or equal to the price requested by the participant, she was offered a PES contract for the amount written on the token. None of the participants in the auction refused the contract offered to them. The original auction script (in Portuguese) can be found in the Appendix.

2.2.5 Follow-up, monitoring and payments

The first PES contracts were signed in September 2021 and the last in December 2021. Since forest clearing occurs mostly between May and July, we implemented a follow-up procedure with the aim of maintaining participants' interest in the study, checking their bank details, and reminding them of their commitments as described in their contract. Reminders were sent via telephone in the form of calls, text messages, and short videos until December 2022.

Deforestation monitoring was done using satellite data.[6] At the end of each twelve-month contract period, we checked the plots enrolled in the program, including those from the control group. Landowners who complied with the contract terms received the expected amount by bank transfer in the weeks following the end of the contract period. The plots of those who had not honored their commitment were examined one by one, in order to avoid any penalties that could have been wrongly assigned due to a measurement error on our part.

3 Data

3.1 Balance of pre-treatment variables

Of the 305 eligible landowners who were randomly assigned to the BDM treatment arms, only three ultimately declined to participate in the experimental auction. We thus ended up with a sample of 456 landowners, including 302 treated and 154 control landowners. This attrition did not modify the balance of the groups, as shown by the equality tests of the means of pre-treatment variables, shown in Table 1. On average, the individuals in the sample own more than 50 hectares of land, including 30 hectares of forest. They live 40 kilometers from the nearest village and regularly exploit their forest, since they usually cut down between one and two hectares each year.

3.2 Forest loss

To obtain the most precise measurement possible of the cuts made by the participants, we used data from Sentinel-1 satellites, covering a total of 60 Synthetic-Aperture Radar (SAR) images captured between October 2020 and October 2021, to which we applied a recently developed approach based on the cumulative sum technique (Manogaran and Lopez, 2018; Ygorra et al., 2021). One of the key advantages of radar-based methods is the regular availability of data – typically every 6 to 12 days with Sentinel-1, regardless of cloud cover, haze, smoke, or aerosols.[7] We also used PlanetScope optical cloud-free mosaics to delineate deforestation polygons, and we validated the radar-based output data manually. In line with the requirements specified in the PES contracts, we used the definition of primary forest defined by the Brazilian National Institute for Space Research (de Almeida et al., 2021). Furthermore, our main emphasis was on deforestation, defined as the complete removal of visible canopy cover at pixel scale. A detailed description of the method is provided in Pfefer et al. (2023).

During a preliminary experiment in the study area, we found that eliminating the wet season resulted in a 19 percent increase in precision and a 3.8 percent decrease in detected deforestation events. Consequently, a decision was made to omit the rainy season, a period during which farmers traditionally refrain from engaging in clear-cutting activities. Therefore, we focused on three specific temporal intervals: April to June, June to August, and August to October. We produced forest

[6] We used cloud-free PlanetScope optical mosaics, sourced from Norway's International Climate and Forest Initiative (NICFI) program, to delineate deforestation areas and visually assess participants' compliance with the program.

[7] In contrast, acquiring cloud-free optical images in tropical zones is challenging and often limited. For instance, in our study area, only seven Sentinel-2 images in 2020 were completely free of clouds.

clearing data starting before the contract period and ending a few months after the end of all contracts. Ultimately, the dataset comprised eleven observations per individual, including six observations in the pre-contract phase, three observations during the contractual period, and two observations in the post-contract phase. Table 2 gives the average evolution of the clearings made in the three trial groups throughout the eleven periods. In the impact analysis, we looked at both the clear-cutting done during each period and the cumulative clear-cuts spanning the entirety of the eleven periods.

Data displayed in Table 2 call for three comments. Firstly, the pattern of deforestation differs between treated and control groups during at least two periods during which the PES contracts were in force (periods 8 and 9), with larger cuts made in the control group than in the treated ones. Secondly, the difference between the treated groups, if it exists, appears less clearly. Over one period however, it appears that group A cut down more forest than did group B. Finally, we observe that the periods during which the groups behave differently coincide with the end of the mandate of President Jair Bolsonaro, whose policy was clearly in favor of deforestation. During this period, we observe record levels of forest cutting, which exceed 0.5 hectares per period, i.e., almost two hectares per year.

3.3 BDM respondent characteristics

The survey data collected from the 302 participants in the BDM auction made it possible to highlight a certain typology of the individuals in the sample. Key characteristics of participants are given in Table 3, which breaks the full sample into three groups: (i) landholders who reported that growing crops was their main source of income (from here on we will refer to them as crop farmers); (ii) landholders who reported that cattle livestock was their main source of income (we will refer to them subsequently as cattle ranchers, and (iii) landholders, whose main source of income was other livelihood activities (hereafter diversified farmers). Note that the three groups have similar livelihood activities, such as livestock farming and agriculture. What differentiates them is which activity represents the largest share of their income.

The first column of Table 3 (Full sample) shows that the average respondent is most often a man around 50 who has spent less than four years at school and is the head of a family of six persons, including four or five who work on the farm. He has been living in the village for 20 years and his annual gross income is around 45,000 BRL. He has about sixty hectares, the majority of which are covered with mature forest. Over the past three years, he has cut down one and a half hectares of forest per year.

Comparing column 2 (crop farmers), column 3 (cattle ranchers), and column 4 (diversified farmers) highlights some significant differences between the three groups. Almost a quarter of the sample is made up of women, but they are more present in the crop farmer subgroup (28 percent). Diversified farmers are the most highly educated, followed by cattle ranchers. Crop farmers have larger families (7 members, on average) and the majority of family members are working on-farm (5 members, on average). Diversified farmers have the highest annual total gross income (61,590 BRL on average), followed by cattle ranchers (51,455 BRL) and crop farmers (39,387 BRL). Cattle

ranchers have larger farmholds (68 hectares) and less mature forest area (35 hectares) than do crop farmers (55 hectares of total area and 38 hectares of forest area). This is because cattle ranching is more extensive and requires the clearing of very large areas. Crop farmers also have larger fallow vegetation areas (4.8 hectares) than cattle ranchers do (3.6 hectares), suggesting that crop farmers employ traditional slash and burn systems where a portion of the land is typically kept fallow. Cattle ranchers have the highest rate of deforestation (1.55 hectares per year). Note that the deforestation rate of crop farmers includes clearing of fallow areas that are left to grow back in the next agricultural season.

3.4 Auction bids

Table 4 presents the summary statistics of the two auctions. According to the FPIC principle, participants could withdraw at any time without explanation. As each participant posted one bid per contract, we ended up with a balanced panel dataset of 604 observations. The distribution of bids in both contracts was skewed to the right, with the mean bid greater than the respective median bid in both cases. The mean (median resp.) bid for contract A was 9,284 BRL (4,500 BRL resp.), which is roughly equivalent to eight (four resp.) times the minimum wage in Brazil in 2021. The mean (median resp.) bid for contract B was significantly lower, at 6,692 BRL (3,500 BRL resp.). Note that the highest bids amounted to several thousand Brazilian reals (100K BRL for contract A and 60K BRL for contract B). Although one cannot formally exclude that this is the true opportunity cost of the respondents, an alternative explanation could be that these individuals knowingly made an excessively high bid, in order to be certain not to win the auction (a so-called protest bid). Finally, Table 4 highlights a difference between the bids of the crop farmers and those of the cattle ranchers. The mean (median resp.) bid of crop farmers for contract A indeed amounted to 7,492 BRL (4,000 BRL resp.), while that of cattle ranchers reached 11,054 BRL (4,550 BRL).

Figure **??** displays the BDM demand curves for each of the two PES contracts. The bids are log transformed for ease of viewing. Regardless of the percentile group considered, we observe that the bid for contract B (flexible) is always lower than the bid for contract A. For example, 75 percent of the sample requested less than 5,000 BRL for contract B and less than 9,500 BRL for contract A. Table 5 provides the results of two tests that compare the distributions of the bids, using both the Wilcoxon-Mann-Whitney rank-sum and Kolmogorov-Smirnov tests. In both cases, we find that the distribution under the contract A treatment is significantly different from the contract B treatment at the 1% level. This is in line with theoretical predictions, since the more demanding contract (A) is associated to a higher cost of compliance.

Finally, Table 6 presents the auction results. As mentioned before, each participant made a bid for each contract, but only one contract was binding, and participants discovered the type of contract in question at the end of the auction. We calibrated the tokens in the urns in such a way as to (i) respect our budgetary constraint, i.e., around a total of 150K euros in payments; and

(ii) have the same proportion of contracts signed in the two treatment groups.[8] Thus, although participants who placed high bids had less chance of winning the auction, it was not easier to win in auction B than in auction A, because by calibrating the urns we ensured that the probability of winning was the same in both cases. More than 70 percent of players effectively won a PES contract, whether contract A or B. The median value of the payment allocated for contract A was 5,300 BRL (5,000 BRL for contract B). The highest contract awarded was 6,100 for contract A (5,500 BRL for contract B). Interestingly, crop farmers had the highest awarding rate (78.5 percent contracts won), followed by cattle ranchers (65.1 percent) and diversified farmers (58.3 percent). We explore this heterogeneity further in what follows.

4 Results

Below we present the results of the analyses carried out using forest cut data computed from satellite images for the 456 farmers distributed among the three treatment arms of the trial, 302 of whom participated in the experimental auction and responded to the survey. Figure 3 summarizes the distribution of individuals according to the different categories of the experimental protocol. Results include the determinants of the WTA a PES, the effects of the PES treatments, and the determinants of deforestation under the PES contract.

4.1 Bid determinants and farmer heterogeneity

We used an ordinary least squares (OLS) pooled regression to examine whether observable characteristics can predict farmers' bids.[9] We regressed the bid price on the participant characteristics likely to drive private opportunity costs, according to the standard non-separable farm household model. An individual's bid was therefore modeled as a function of observed characteristics, as measured from the survey data:

$$\text{bid}_{ic} = X_i\beta + D_c + \epsilon_{ic} \tag{2}$$

where individual i's specific bid_i is a function of labor, land-use, and household characteristics. The c denotes the auction round, i.e., game A or B, with the dummy variable D taking the value 1 for bidding on the flexible contract (B) and 0 for bidding on the fixed contract (A). We reran the same model separately for the subset of crop farmers and for the subset of cattle ranchers.

Table 7 reports the results for both the whole sample and the sub-samples. Generally speaking, labor force and land use are good predictors of the bid amount. The results further show that bidding behavior predictors of cattle ranchers are quite different from those of crop farmers. Looking at the contract type variable, results are in line with theory, since bidding for a flexible contract (B) rather than a fixed contract (A) reduced the bid by 2,353 BRL on average (column 1). This

[8] We were able to do so by calculating the minimum detectable effect of the PES making plausible assumptions about the distribution of opportunity costs.

[9] An alternative model is the random effect regression. It gives results extremely similar to those of the OLS pooled-regression.

result is statistically significant and has the same sign across all three samples, but the magnitude is higher for cattle ranchers (column 3). Farmer-specific variables that seem to correlate with the value of the bid also include the bidder's age (for cattle ranchers) and gender (for crop farmers). On average, male crop farmers bid higher than women crop farmers by 1,822 BRL (column 2). Family size and labor seem to play a significant role for crop farmers while less significantly for cattle ranchers. This makes sense since cattle ranching is much less labor intensive. Results from the crop farmer sample indicate that, on average, one additional family member working on the farm increased the value of the bid by 1,641 BRL (column 2), while one additional family member working off farm would decrease the bid by 743 BRL. Nothing similar could be found for cattle ranchers.

Looking at the whole sample, all land-use variables included in the model appear to play a significant role in the bidding decision (column 1), but only average deforestation is significant across all three models. All else being equal, one additional hectare of average deforestation increases the value of the bid by 2,349 BRL. This result is statistically significant and has the same sign across all models, but the magnitude is higher for crop farmers (Column 3). Looking at the two groups separately, one can observe that the weight of the total area, in forest and in pasture, seems driven by the group of cattle ranchers, while the cultivated area, as one might expect, plays a significant role primarily in the group of crop farmers. Overall, the signs on the coefficients are consistent with theoretical expectations, which suggests that participants understood the BDM exercise well.

4.2 Impact of PES treatments

4.2.1 Forest loss

To identify the impact of the treatment on the treated landowners, we exploited the panel dataset by running an FE panel regression that gives the impact on deforestation of being assigned to a PES group, whether or not one is the beneficiary of a PES contract:

$$d_{it} = \alpha + \sum_t \text{PES}_i \text{period}_t \beta_{it} + \mu_i + \nu_t + \eta_{it} \tag{3}$$

where d designates the forest loss observed in period t, resulting from cuts carried out during period t or from cumulative cuts since the beginning. PES is a binary variable that takes the value 1 when the individual has been assigned to a PES group and 0 otherwise. Individual and time fixed effects are denoted by μ_i and ν_t respectively, while η_{it} is an error term. Standard errors are adjusted for clusters in strata. Since we also wanted to know which group outperformed the other, we ran another regression that includes two treatment variables, namely PES^A and PES^B:

$$d_{it} = \alpha + \sum_t \text{PES}_i^A \text{period}_t \beta_{it}^A + \sum_t \text{PES}_i^B \text{period}_t \beta_{it}^B + \mu_i + \nu_t + \eta_{it} \tag{4}$$

Columns 3 and 4 in Table 8 show that the average impact observed using Model 3 is actually most often driven by the performance of group B, although it is possible to detect an effect of group A, at least over period 8. We ran t-tests of the equality of the β^A and β^B coefficients for

periods 8, 9, and 10 but failed to reject the null of no difference in all cases for the regression on cumulative cuts, which indicates that, although point estimates suggest that flexible PES B outperformed fixed PES A, we lack the precision to show it when looking at cumulative forest cuts. When it comes to the regression on by-period cuts, however, we reject the null of no difference for period 8 at the 5 percent significance level ($F(1,5) = 7.27$ with p-value= 0.0430), for period 9 at the 15 percent significance level ($F(1,5) = 3.31$ with p-value= 0.1285), and for period 10 at the 10 percent significance level ($F(1,5) = 6.42$ with p-value= 0.0523).

4.2.2 Default rate and cost

To test the assumption that the default rate was higher in group A, we simply ran an OLS regression that gives the impact of being assigned to a PES group, whether or not you have signed a PES contract, on having broken the contract:

$$\text{default}_i = \alpha + \text{PES}_i\beta_i + \eta_i \tag{5}$$

where the outcome default is a binary variable that takes the value 1 when the landowner broke the contract and cleared some forest when under contract A, or cleared more than one hectare when under contract B. By design, individuals in the control group are defined as never defaulting:

$$\text{default}_i = \alpha + \text{PES}_i^A\beta_i^A + \text{PES}_i^B\beta_i^B + \eta_i \tag{6}$$

We ran both regressions for two additional outcomes, namely the total forest loss and the total amount spent via payments made at the end of the contract period. The estimation results are presented in Table 9. Column 1 provides the impact of the treatment on total forest loss, which is measured by the cumulative cuts recorded in the last period. Unsurprisingly, we obtain an impact similar to that previously obtained using panel data, i.e., around 0.7 hectares of forest saved per landowner on average. The estimates presented in column 2 again suggest that the effect is probably driven by group B, although it is not possible to reject the null hypothesis of no difference at the usual significance level. When it comes to the default rate and the total cost of PES, however, the results are much more precise. Columns 3 and 4 show that the default was much higher in group A than in group B. This difference is statistically significant at the 1 percent significance level. Concretely, 76 landowners among the 108 signatories in group A ultimately broke their contract, while in group B, only 26 among the initial 109 did so (Figure 3).

Consistently, the total amount that was spent in group B greatly exceeds that which was spent in group A, since no payment was made to those who did not respect the terms of the contract. Results shown in columns 5 and 6 indicate that the PES cost was twice as high on average for a group B participant than for a group A participant. In addition, results displayed in columns 7 and 8 show a difference in the total cost between the two groups of about 910 BRL, which includes not only the PES paid but also the costs linked to canvassing each of the 406 participants in the RCT (280 BRL per participant), and the additional costs linked to each of the 302 participants at the BDM auction (830 BRL per participant). Taken together, these results suggest that the

difference in forest conservation between the two groups comes from a difference in participant default rates.

We also verified that the PES had not encouraged treated farmers to cut down their forest outside the boundaries of the rural registry, as part of an informal arrangement with their neighbors for example. To do this, we compared the crown of land surrounding each treated farm to that surrounding each control farm, by varying the width of the crown. The results are presented in Table 10. They do not allow us to exclude a zero difference between the two groups, which suggests the absence of this type of spillover effect from the program.

4.3 Determinants of forest loss

We looked at the impact of incentives, namely the contract price drawn from the urn, and the impact of selection, i.e., the WTA, as elicited from the BDM auctions.

4.3.1 Impact of incentives

We again ran an FE panel regression using the same specification as for model (3), except that we looked at the impact of the contract price rather than of the treatment:

$$d_{it} = \alpha + \sum_t \text{price}_i \text{period}_t \beta_{it} + \mu_i + \nu_t + \eta_{it} \tag{7}$$

where the variable price is the price set in the PES contract signed by the participant expressed in thousands of reals. The sample includes individuals assigned to groups A and B only and thus excludes controls ($N = 302$). Since we implemented a BDM design, there is a random variation in the actual PES paid to landowners with identical reservation prices (Guiteras and Jack, 2018). This random variation allows us to isolate the causal effect of the PES on deforestation. The estimation results are presented in Table 11. Columns 1 and 2 provide results that are quite similar to those obtained when looking at the impact of the treatment. The incentive represented by the PES amount, whatever contract type, has a significant impact on deforestation. In particular, we found that an increase of 1,000 reals led to a reduction in cumulative cuts, which reached 0.30 hectares and around 0.10 hectares per period over periods 8 and 9, respectively. These results are also represented graphically in Figures 8 and 9.

Columns 3 and 4 provide the results obtained for group A, while columns 5 and 6 provide the results obtained for group B. The results are quite similar both to each other and to those obtained for the entire treated group. In fact, there is no a priori reason why the impact of PES (which is randomly distributed in each group due to the BDM design used) would be different. Figures 10 and 11 show the similarity of the estimated effects in each group.

4.3.2 Impact of selection

We also looked at the causal effect of the PES on deforestation by WTA level, i.e., we checked whether the impact of PES was different for landowners who exhibited greater WTA. To do so, we

ran an FE effect model regression where the level of WTA interacts with the payment and looked at this effect for each period. Since the WTA levels were different in the two groups (we calibrated the urns differently), we estimated model (8) for the two treated groups separately:

$$d_{it} = \alpha + \sum_t \text{price}_i \text{WTA}_i \text{period}_t \beta_{it} + \sum_t \text{price}_i \text{period}_t \gamma_{it} + \sum_t \text{WTA}_i \text{period}_t \lambda_{it} + \mu_i + \nu_t + \eta_{it} \tag{8}$$

The estimation results are presented in Table 12. If payment efficiency had been higher for those with a higher WTA, the β coefficients would have been statistically negative. However, since the sample only includes landowners enrolled at or above their reservation price, we lack the statistical power to make any conclusions regarding the impact of selection on the effectiveness of the PES.

5 Discussion

5.1 Stable Unit Treatment Value Assumption (SUTVA)

One concern with our design is that SUTVA does not hold due to the close proximity of treated and control farms, i.e., the PES program directly or indirectly affected the deforestation decisions of the control group, which would compromise the validity of the identification strategy. In order to test this hypothesis, we employed a matching approach that uses pre-treatment outcomes to construct a valid remote control group for the initial control group, from farmlands that were not enrolled in the RCT at any stage of the project (Imbens and Wooldridge, 2009). In practice, we focused on farmlands located in the direct neighborhood of farms enrolled in the RCT. To perform the matching procedure, we used the variables previously used to construct the balanced treatment arms of the RCT, which notably included GFC data on the deforestation that occurred over the period before the program. Results of the matching approach between these new plots and the control group are displayed in Table 13. They show that the matching procedure performed well. Results of the comparison between the two groups are shown in Figure 12. They suggest that the landowners used as controls in the RCT behaved in the same way as their matched counterparts throughout the duration of the program and even afterward. This result supports our identification strategy.

5.2 A typology of private landowners

Another interesting result of this experiment is the emergence of a typology of farmers who agreed to participate in the auction. The so-called crop farmers' are low-income households practicing traditional agriculture based on fallow land and subsistence farming and who have a relatively low opportunity cost of conserving the forest located in their farmhold. On the other hand, cattle ranchers a wealthier households, more specialized in cattle farming and highly dependent on deforestation, because they do not use the fallow and rotation system for their pasture areas. Their agricultural activity indeed depends on less sustainable systems. Although spread over quite a

small area, the private costs of forest conservation of the two groups differ significantly. Therefore, on average they have different WTAs, regardless of the contract offered, with the less deforestation-dependent crop farmers systematically exhibiting lower WTA than cattle ranchers. In addition, again consistent with the typology, the two groups value the contract types quite differently; the flexibility gap between the two contracts translates into a 50 percent higher average bid by cattle ranchers than by crop farmers.

It is also worth mentioning that the revealed-preference WTA data we computed are much higher than those found in previous studies. Palmer et al. (2017) found that, on average, a payment of 9.5 USD per hectare of forest is needed to avoid deforestation during a five-year period in the State of Acre. Thus, if we take the average forest area of surveyed landholders (37 ha), we get an average payment of 70 USD per year. However, according to our estimates, the median landholder would require between 700 USD and 900 USD to preserve her forest cover during a one-year period, that is more than ten times the amount estimated by Palmer et al. (2017). This may be due, in part, to the choice of targeting the program to a deforestation-front area.

5.3 Cost-effectiveness

The social cost of carbon (SCC) is a key metric informing climate policy that measures the monetized value of the societal damages caused by an incremental metric ton of CO2 emissions. It can also be used to quantify the benefits of reducing CO_2 emissions.[10] Table 14 provides a comprehensive cost-benefit analysis based on the SCC from the Trump (Interagency Working Group on the Social Cost of Carbon (IWGSCC), 2021) and Biden (U.S. Environmental Protection Agency (EPA), 2023) administrations in the US. The impacts are evaluated in terms of avoided deforestation (in hectares), with corresponding avoided emissions measured in carbon dioxide equivalent (CO_2 eq).[11] The benefits are quantified in USD and are compared across the different PES contracts. The table distinguishes between scenarios involving only PES costs and those integrating the implementation costs.[12] The annual benefit of delaying emissions is computed using a discount rate of 3%, represented by the formula $\frac{r}{r+1}SCC$. We convert the PES and implementation costs from BRL to USD using a conversion rate of 0.19.

In terms of avoided CO_2 emissions, the flexible PES (contract B) outperforms the fixed PES (contract A) with 67,366 CO_2 eq compared to 41,550 CO_2 eq. However, when assessing cost-

[10] Current policy recommendations for the SCC range from 54 USD to 204 USD (Interagency Working Group on the Social Cost of Carbon (IWGSCC), 2021; U.S. Environmental Protection Agency (EPA), 2023)

[11] To estimate the avoided CO_2 emissions, we take into account the average above-ground biomass (AGB) stored in forests in our study zone (315 metric tons), provided by Harris et al. (2021), and assume that 48% of biomass is in the form of carbon (Carvalho Jr et al., 1995). We ignored carbon stocks in the below-ground biomass (BGB) that is composed of roots, litter, dead wood, and soil. The reason we take only the AGB into account is that this is the portion of the total biomass most rapidly emitted after forests are cleared and set on fire. The carbon contained in BGB takes longer to be emitted, and part of this carbon is fixed again by pasture and crops. We compute that, on average, one hectare covered in forests stores 151 tons of carbon above-ground. Since one CO_2 molecule weighs 3.67 times as much as a carbon atom, this means that 554 metric tons of CO_2 are stored in one hectare of land covered by the PES contracts.

[12] Implementation costs include both fixed and variable expenses. Fixed costs encompass salaries for staff involved in the project and do not change with the level of activity. Variable costs fluctuate based on the number of participants, such as fuel expenses for vehicles used to visit participants' locations, which would vary depending on the number of visits made.

effectiveness using PES costs, contract A has a higher benefit-cost ratio (ranging from 3.8 to 8.9 depending on the value of the SCC) than contract B (3.4 to 7.9). Interestingly, when implementation costs are also considered, contract B becomes more cost-effective, and the cost-benefit gap between the two contracts narrows. This implies that, despite additional costs associated with flexibility, the overall cost-effectiveness gap diminishes, prompting a nuanced evaluation of trade-offs between these PES contract structures.

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7 Tables

Table 1: Balance in pre-treatment covariates between groups

	Control group (n=154)		PES A (n=150)		PES B (n=152)		p-value for t-tests	
Variable	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.	A vs B	A vs C
Total area 2021 (ha)	56.39	29.72	54.81	40.57	57.68	42.45	0.55	0.70
Forest area 2021 (ha)	31.88	22.75	30.76	28.80	33.17	31.19	0.49	0.71
Forest loss 2015 (ha)	0.74	1.24	0.70	1.05	0.72	1.06	0.84	0.77
Forest loss 2016 (ha)	1.67	2.11	1.58	1.76	1.64	1.97	0.78	0.69
Forest loss 2017 (ha)	1.54	1.93	1.61	1.74	1.57	1.75	0.84	0.75
Forest loss 2018 (ha)	1.71	2.20	1.59	1.93	1.67	2.29	0.73	0.59
Forest loss 2019 (ha)	1.85	2.54	1.77	2.57	1.78	2.09	0.96	0.79
Dist. to main road (km)	5.89	5.44	5.97	5.40	5.66	5.20	0.62	0.90
Dist. to village (km)	42.32	41.69	42.64	42.32	43.44	42.61	0.87	0.95
Strata 1 (yes=1)	0.31	0.46	0.31	0.46	0.32	0.47	0.86	0.92
Strata 2 (yes=1)	0.09	0.29	0.09	0.28	0.09	0.28	0.97	0.90
Strata 3 (yes=1)	0.22	0.42	0.23	0.42	0.22	0.41	0.84	0.90
Strata 4 (yes=1)	0.08	0.28	0.09	0.28	0.08	0.27	0.81	0.94
Strata 5 (yes=1)	0.05	0.21	0.04	0.20	0.05	0.21	0.80	0.81
Strata 6 (yes=1)	0.25	0.43	0.25	0.44	0.26	0.44	0.95	0.90

Notes: Mean values were computed using Global Forest Change (GFC) deforestation data and the Brazilian rural environmental registry (CAR). The p-values are associated with the test of the null hypothesis of equality of means. "A" refers to the PES A treatment group, "B" refers to the PES B treatment group, and C refers to the control group.

Table 2: Change in forest loss by group (in ha)

	Control group (n=154)		PES A (n=150)		PES B (n=152)		p-value for t-tests	
Period	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	A vs B	A vs C
1 - April-June 2020	0.023	0.158	0.016	0.083	0.049	0.245	0.120	0.625
2 - June-Aug 2020	0.156	0.531	0.169	0.352	0.190	0.371	0.623	0.790
3 - Aug-Oct 2020	0.100	0.619	0.046	0.175	0.020	0.089	0.095	0.309
4 - April-June 2021	0.010	0.067	0.043	0.230	0.010	0.083	0.093	0.088
5 - June-Aug 2021	0.255	0.509	0.206	0.468	0.208	0.571	0.980	0.390
6 - Aug-Oct 2021	0.042	0.181	0.018	0.114	0.026	0.148	0.601	0.177
7 - April-June 2022	0.055	0.167	0.026	0.094	0.070	0.297	0.082	0.581
8 - June-Aug 2022	0.671	1.553	0.471	1.194	0.360	0.742	0.062	0.027
9 - Aug-Oct 2022	0.495	1.126	0.322	0.862	0.237	0.523	0.210	0.011
10 - April-June 2023	0.112	0.308	0.071	0.316	0.043	0.155	0.134	0.256
11 - June-Aug 2023	0.350	1.298	0.254	0.516	0.198	0.444	0.318	0.397

Note: These figures were computed from radar imagery provided by Sentinel-1. The p-values are associated with the test of the null hypothesis of equality of means. "A" refers to PES A treatment group; "B" refers to PES B treatment group; and C refers to the control group.

Table 3: Descriptive statistics of respondent characteristics

	Full sample			Crop farmers			Cattle ranchers			Diversified farmers		
Variable	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.
Age	302	48.56	12.96	158	47.42	11.98	132	49.78	13.82	12	50.00	15.39
Gender	302	0.23	0.42	158	0.28	0.45	132	0.17	0.38	12	0.25	0.45
Education	302	3.69	4.18	158	3.03	3.64	132	4.17	4.38	12	7.08	6.27
Family size	302	5.99	3.93	158	7.07	4.25	132	4.73	3.16	12	5.50	3.18
Family members working on farm	302	4.62	2.91	158	5.33	3.25	132	3.81	2.31	12	4.25	1.76
Family members working off farm	302	1.43	1.52	158	1.62	1.60	132	1.19	1.30	12	1.58	2.27
Village years	302	20.79	12.55	158	21.76	11.86	132	19.89	13.24	12	17.89	13.53
Total income (BRL)	302	45543.93	39425.43	158	39387.03	39595.28	132	51454.74	37786.98	12	61590.75	43673.36
Crop income (BRL)	302	9799.54	26243.58	158	15920.10	34313.61	132	3299.88	8705.27	12	708.33	1814.82
Cattle income (BRL)	302	13234.40	23943.24	158	3257.24	6777.87	132	24656.41	30929.75	12	18958.33	24645.17
Other livestock income (BRL)	302	3235.63	7418.47	158	2055.98	5988.79	132	3998.07	7200.02	12	10380.83	17146.17
Forest income (BRL)	302	395.70	1831.32	158	439.84	2257.39	132	374.29	1257.95	12	50.00	173.21
Business income (BRL)	302	889.40	4478.56	158	1146.42	5565.22	132	634.58	2956.92	12	308.33	757.34
Retirement (BRL)	302	8334.67	11818.64	158	7354.56	11182.48	132	9397.36	12326.28	12	9550.00	14106.38
Government transfer (BRL)	302	3674.05	3925.93	158	4520.82	3925.65	132	2689.97	3583.29	12	3349.83	5182.08
Agricultural subsidy (BRL)	302	83.53	537.06	158	71.03	469.63	132	90.92	607.89	12	166.75	577.32
Other source of income (BRL)	302	5897.01	10371.57	158	4621.04	7785.65	132	6313.27	10235.54	12	18118.33	25342.77
Total area (hectares)	299	61.44	40.05	157	54.96	31.28	130	67.60	47.81	12	79.53	36.89
Mature forest area (hectares)	291	37.47	32.38	153	38.03	28.48	126	35.31	36.57	12	53.13	30.27
Fallow vegetation area (hectares)	294	4.23	5.83	154	4.84	6.14	128	3.60	5.52	12	3.04	4.27
Crop area (hectares)	297	2.30	2.45	155	2.43	2.40	130	2.12	2.56	12	2.63	1.73
Pasture area (hectares)	295	15.91	16.59	155	8.37	8.58	128	25.01	19.47	12	16.25	13.56
Other LULC area (hectares)	295	0.79	1.29	155	0.65	1.21	128	0.93	1.38	12	1.30	1.24
2018-2021 average deforestation	282	1.43	0.91	148	1.35	0.77	123	1.55	1.07	11	1.05	0.72
Cattle herd size	302	25.18	32.03	158	9.23	12.57	132	44.2197	37.7493	12	25.67	29.03

Table 4: Summary statistics of bids

	Contract A	Contract B
Full sample		
Number of participants	302	302
Average bid (BRL)	9,284	6,692
Median bid (BRL)	4,500	3,500
Std. dev.	13,176	9,850
Minimum bid (BRL)	100	100
Maximum bid (BRL)	100,000	60,000
Cattle ranchers		
Number of participants	132	132
Average bid (BRL)	11,054	7,639
Median bid (BRL)	4,550	3,600
Std. Dev.	15,472	10,849
Crop farmers		
Number of participants	158	158
Average bid (BRL)	7,492	5,548
Median bid (BRL)	4,000	3,500
Std. dev.	15,472	10,849
Diversified farmers		
Number of participants	12	12
Mean bid (BRL)	13,417	11,342
Median bid (BRL)	5,050	4,500
Std. dev.	17,989	16,559

Table 5: Test of equality of bid distributions (contract A versus contract B)

Kolmogorov-Smirnov		
D-statistic	P-value	Num. Obs.
-0.162	0.000	302

Wilcoxon rank-sum		
Z-statistic	P-value	Num. Obs.
3.903	0.000	302

Table 6: Auction results

	PES A	PES B
Number of bids	150	152
incl. cattle ranchers	65	67
incl. crop farmers	78	80
incl. diversified farmers	7	5
Number of contracts awarded	108	109
incl. cattle ranchers	41	45
incl. crop farmers	62	62
incl. diversified farmers	5	2
Mean value (in reals)	5,345	4,831
Median value (in reals)	5,300	5,000
Std. dev.	422	477
Minimun value	4,500	3,900
Maximum value	6,100	5,500

Table 7: Determinants of auction bids

	(1)	(2)	(3)
	Full sample	Crop farmers	Cattle ranchers
Type B contract (0/1)	-2352.84***	-1906.76***	-2930.08**
	(722.92)	(736.50)	(1190.44)
Age of the participant	-45.56	-31.60	-102.08*
	(32.83)	(33.47)	(57.36)
Female participant (0/1)	-1923.71***	-1822.03***	-1544.40
	(731.88)	(675.47)	(1377.40)
Education	148.42	-61.10	8.29
	(129.71)	(109.27)	(196.48)
Family size	-744.72***	-1061.20***	-591.55
	(228.66)	(300.71)	(479.03)
Family members working on farm	893.61***	1640.96***	725.54
	(283.29)	(377.36)	(657.19)
Family members working off farm	-246.73	-743.03**	-161.44
	(277.22)	(328.13)	(516.31)
Total income (BRL)	0.05	-0.02	-0.03
	(0.04)	(0.03)	(0.05)
Crop income (BRL)	0.02	0.12**	0.06
	(0.06)	(0.05)	(0.07)
Cattle income (BRL)	-0.10*	-0.04	-0.02
	(0.05)	(0.08)	(0.05)
Other livestock income (BRL)	0.13	-0.20***	0.17
	(0.11)	(0.07)	(0.17)
Business income (BRL)	0.26	0.84***	-0.25*
	(0.21)	(0.28)	(0.13)
Total area (hectares)	-99.58**	19.55	-133.54**
	(45.81)	(55.38)	(62.26)
Forest area (hectares)	115.42**	-15.21	127.63*
	(52.25)	(58.55)	(70.74)
Crop area (hectares)	421.06**	517.58**	257.88
	(202.37)	(238.39)	(354.11)
Pasture area (hectares)	232.24***	25.04	309.68***
	(54.61)	(61.80)	(69.07)
2018-2021 average deforestation (hectares)	2348.60***	3466.53***	2223.20**
	(619.18)	(1000.98)	(861.68)
Constant	3373.67	1788.54	9028.97**
	(2061.53)	(2009.16)	(3904.96)
Number of observations	564	296	246
Prob > F	0.000	0.000	0.000
R2	0.261	0.326	0.330

Notes: ***, ** and * indicate that the estimated coefficients are statistically significant at the 1%, 5%, and 10% levels, respectively. Robust standard errors are given in parentheses.

Table 8: Impact of treatment on forest loss

Model (3)	(1) Cumulative forest cuts		(2) By-period forest cuts		Model (4)	(3) Cumulative forest cuts		(4) By-period forest cuts	
PES*period 2	0.024		0.015		PES^A*period 2	0.014		0.021	
	(0.038)		(0.042)			(0.034)		(0.047)	
PES*period 3	-0.043		-0.076		PES^A*period 3	-0.040		-0.046	
	(0.095)		(0.065)			(0.089)		(0.072)	
PES*period 4	-0.027		0.007		PES^A*period 4	-0.007		0.040	
	(0.100)		(0.013)			(0.097)		(0.034)	
PES*period 5	-0.074		-0.057		PES^A*period 5	-0.055		-0.041	
	(0.090)		(0.017)			(0.062)		(0.028)	
PES*period 6	-0.094		-0.029		PES^A*period 6	-0.078		-0.016	
	(0.095)		(0.020)			(0.060)		(0.022)	
PES*period 7	-0.101		-0.016		PES^A*period 7	-0.108	*	-0.022	
	(0.092)		(0.008)			(0.051)		0.011)	
PES*period 8	-0.356	**	-0.265	***	PES^A*period 8	-0.308	**	-0.193	*
	(0.118)		(0.064)			(0.082)		(0.078)	
PES*period 9	-0.572	**	-0.225	*	PES^A*period 9	-0.481	**	-0.166	
	(0.181)		(0.102)			(0.143)		(0.094)	
PES*period 10	-0.627	**	-0.064	**	PES^A*period 10	-0.522	**	-0.034	
	(0.183)		(0.022)			(0.155)		(0.030)	
PES*period 11	-0.751	**	-0.134		PES^A*period 11	-0.618	**	-0.089	
	(0.191)		(0.097)			(0.218)		(0.111)	
					PES^B * period 2	0.034		0.008	
						(0.043)		(0.039)	
					PES^B * period 3	-0.046		-0.106	
						(0.105)		(0.060)	
					PES^B * period 4	-0.046		-0.026	
						(0.105)		(0.010)	
					PES^B * period 5	-0.093		-0.073	
						(0.118)		(0.037)	
					PES^B * period 6	-0.109		-0.041	
						(0.129)		(0.021)	
					PES^B * period 7	-0.093		-0.011	
						(0.135)		(0.011)	
					PES^B * period 8	-0.404	*	-0.337	***
						(0.166)		(0.059)	
					PES^B * period 9	-0.662	**	-0.284	*
						(0.236)		(0.118)	
					PES^B * period 10	-0.731	**	-0.094	***
						(0.237)		(0.018)	
					PES^B * period 11	-0.883	**	-0.178	*
						(0.214)		(0.084)	
Indiv. FE	Yes		Yes			Yes		Yes	
Time FE	Yes		Yes			Yes		Yes	
Nb. farmers	456		456			456		456	
Nb. obs.	5016		5016			5016		5016	

Notes: This table provides estimates from FE regression models (3) and (4). ***, ** and * indicate that the estimated coefficients are statistically significant at the 1%, 5%, and 10% levels, respectively. Standard errors adjusted for clusters in strata are given in parentheses.

Table 9: Impact of treatment on total forest loss, default rate, and costs

	Total forest loss (ha)		Default (yes=1)		PES cost (BRL)		Total cost (BRL)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PES	-0.66***		0.34***		1587.9***		2417.9***	
	(0.19)		(0.03)		(97.1)		(97.1)	
PES^A		-0.53***		0.51***		1130.9***		1960.9***
		(0.23)		(0.04)		(129.3)		(129.3)
PES^B		-0.78***		0.17***		2038.9***		2868.9***
		(0.18)		(0.04)		(81.1)		(81.1)
cons	1.93***	1.93***	0.04	0.04	-28.2	-32.6	251.8**	247.4**
	(0.12)	(0.12)	(0.02)	(0.02)	(64.3)	(65.6)	(64.3)	(65.6)
Strata FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Nb. obs.	456	456	456	456	456	456	456	456
Prob > F		0.20		0.00		0.00		0.00

Notes: This table provides estimates from OLS regression models (5) and (6). ***, ** and * indicate that the estimated coefficients are statistically significant at the 1%, 5%, and 10% levels, respectively. Standard errors adjusted for clusters in strata are given in parentheses. Prob > F is the probability of rejecting the null of no difference between the impacts of PES^A and PES^B.

Table 10: Impact of treatment on total forest loss around treated farms

	Coef	Std. Err.	t-stat	P>t	[95%	CI]
Buffer 100m	-0.14	0.17	-0.82	0.41	-0.48	0.19
Buffer 250m	-0.39	0.42	-0.92	0.36	-1.22	0.44
Buffer 500m	-0.82	0.83	-1.00	0.32	-2.45	0.80
OLS regression including strata dummies as controls						
N=459 ; Std. Err. are clustered at strata level						

Table 11: Impact of price on forest loss

	(1) Cumulative forest cuts		(2) By-period forest cuts			(3) Cumulative forest cuts		(4) By-period forest cuts			(5) Cumulative forest cuts		(6) By-period forest cuts	
Price*period 2	-0.014		-0.015		$Price^A$*period 2	-0.014		-0.014		$Price^B$*period 2	-0.014		-0.018	
	(0.010)		(0.011)			(0.020)		(0.020)			(0.015)		(0.017)	
Price*period 3	-0.020		-0.007		$Price^A$*period 3	-0.021		-0.007		$Price^B$*period 3	-0.019		-0.009	
	(0.010)		(0.006)			(0.023)		(0.004)			(0.014)		(0.012)	
Price*period 4	-0.015		0.004		$Price^A$*period 4	-0.015		0.007		$Price^B$*period 4	-0.017		-0.002	
	(0.012)		(0.004)			(0.025)		(0.003)			(0.014)		(0.009)	
Price*period 5	-0.034		-0.020		$Price^A$*period 5	-0.045		-0.030		$Price^B$*period 5	-0.022		-0.010	
	(0.023)		(0.026)			(0.038)		(0.026)			(0.023)		(0.026)	
Price*period 6	-0.035		-0.002		$Price^A$*period 6	-0.043		0.003		$Price^B$*period 6	-0.027		-0.010	
	(0.025)		(0.007)			(0.039)		(0.006)			(0.027)		(0.011)	
Price*period 7	-0.038		-0.005		$Price^A$*period 7	-0.039		0.004		$Price^B$*period 7	-0.037		-0.014	
	(0.027)		(0.008)			(0.038)		(0.003)			(0.030)		(0.015)	
Price*period 8	-0.166	**	-0.129	**	$Price^A$*period 8	-0.198	*	-0.158	**	$Price^B$*period 8	-0.135	**	-0.102	***
	(0.059)		(0.038)			(0.084)		(0.053)			(0.036)		(0.024)	
Price*period 9	-0.252	***	-0.087	**	$Price^A$*period 9	-0.279	**	-0.080	**	$Price^B$*period 9	-0.231	***	-0.101	**
	(0.036)		(0.024)			(0.069)		(0.029)			(0.029)		(0.030)	
Price*period 10	-0.266	***	-0.015		$Price^A$*period 10	-0.298	***	-0.019	*	$Price^B$*period 10	-0.240	***	-0.013	
	(0.039)		(0.008)			(0.072)		(0.008)			(0.034)		(0.018)	
Price*period 11	-0.282	***	-0.017		$Price^A$*period 11	-0.321	**	-0.022		$Price^B$*period 11	-0.251	***	-0.015	
	(0.050)		(0.018)			(0.090)		(0.022)			(0.030)		(0.016)	
Indiv. FE	Yes		Yes			Yes		Yes			Yes		Yes	
Time FE	Yes		Yes			Yes		Yes			Yes		Yes	
Nb. farmers	302		302			150		150			152		152	
Nb. obs.	3322		3322			1650		1650			1672		1672	

Notes: This table provides estimates from FE regression model (7). ***, ** and * indicate that the estimated coefficients are statistically significant at the 1%, 5%, and 10% levels, respectively. Standard errors adjusted for clusters in strata are given in parentheses.

Table 12: Impact of selection on price effectiveness

	(1) Cumulative forest cuts		(2) Cumulative forest cuts
WTA*Price^A*period 2	0.0032	WTA*Price^B*period 2	0.0042
	(0.0024)		(0.0046)
WTA*Price^A*period 3	0.0006	WTA*Price^B*period 3	0.0055
	(0.0036)		(0.0054)
WTA*Price^A*period 4	-0.0048	WTA*Price^B*period 4	0.0070
	(0.0041)		(0.0047)
WTA*Price^A*period 5	-0.0033	WTA*Price^B*period 5	0.0162
	(0.0041)		(0.0058)
WTA*Price^A*period 6	-0.0034	WTA*Price^B*period 6	0.0178
	(0.0050)		(0.0056)
WTA*Price^A*period 7	-0.0075	WTA*Price^B*period 7	0.0121
	(0.0053)		(0.0085)
WTA*Price^A*period 8	-0.0264	WTA*Price^B*period 8	0.0128
	(0.0145)		(0.0149)
WTA*Price^A*period 9	-0.0326	WTA*Price^B*period 9	0.0181
	(0.0264)		(0.0203)
WTA*Price^A*period 10	-0.0331	WTA*Price^B*period 10	0.0184
	(0.0258)		(0.0221)
WTA*Price^A*period 11	-0.0344	WTA*Price^B*period 11	0.0282
	(0.0243)		(0.0227)
Indiv. FE	Yes		Yes
Time FE	Yes		Yes
Nb. farmers	150		152
Nb. obs.	1650		1672

Notes: This table provides estimates from FE regression model (8). ***, ** and * indicate that the estimated coefficients are statistically significant at the 1%, 5%, and 10% levels, respectively. Standard errors adjusted for clusters in strata are given in parentheses.

Table 13: Balancing tests before and after the matching procedure

	Standardized differences		Variance ratio	
	Raw	Matched	Raw	Matched
Total area 2021 (ha)	-0.612	0.126	0.355	1.179
Dist. to village (km)	0.220	0.007	2.098	1.006
Dist. to main road (km)	-0.520	-0.026	0.237	0.982
Forest area 2021 (ha)	-0.511	0.070	0.327	1.067
Forest loss 2015 (ha)	-0.259	0.101	0.430	1.117
Forest loss 2016 (ha)	-0.238	0.103	0.525	1.270
Forest loss 2017 (ha)	-0.321	0.095	0.438	1.196
Forest loss 2018 (ha)	-0.389	0.115	0.350	1.301
Forest loss 2019 (ha)	-0.319	0.079	0.386	1.060

Notes: This table compares mean values of pre-treatment covariates as measured in the control group (C) and a group of matched counterpart farms that were not offered to participate in the program.

Table 14: Cost-benefit analysis using different SCC estimates

			Benefits		PES cost only			PES + implementation cost		
	Impact (ha)	Av. emissions (CO_2 eq)	EPA 2021 (USD)	EPA 2023 (USD)	Cost (USD)	EPA 2021 (B/C)	EPA 2023 (B/C)	Cost (USD)	EPA 2021 (B/C)	EPA 2023 (B/C)
PES^A	75	41,550	123,871	285,934	32,231	3.8	8.9	55,886	2.2	5.1
PES^B	122	67,366	200,837	463,594	58,883	3.4	7.9	82,854	2.4	5.6

Note: This table displays the benefits of delayed CO_2 emissions compared to the costs, for each contract.

8 Figures

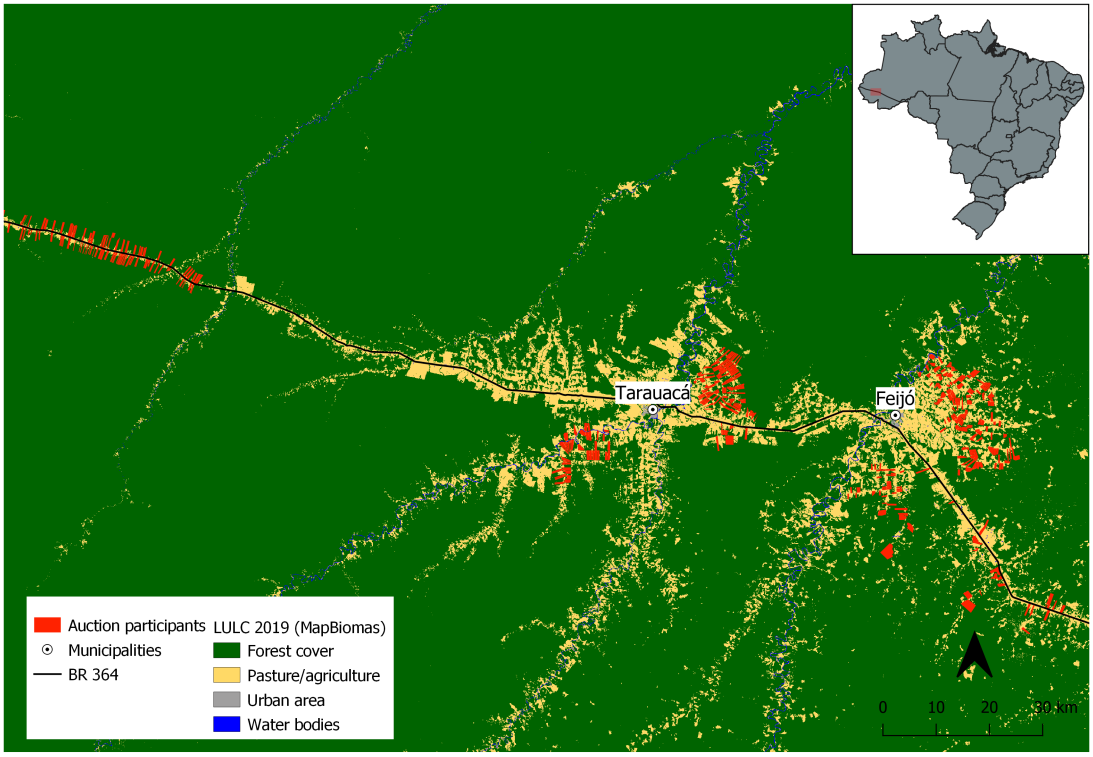


Figure 1: Study zone

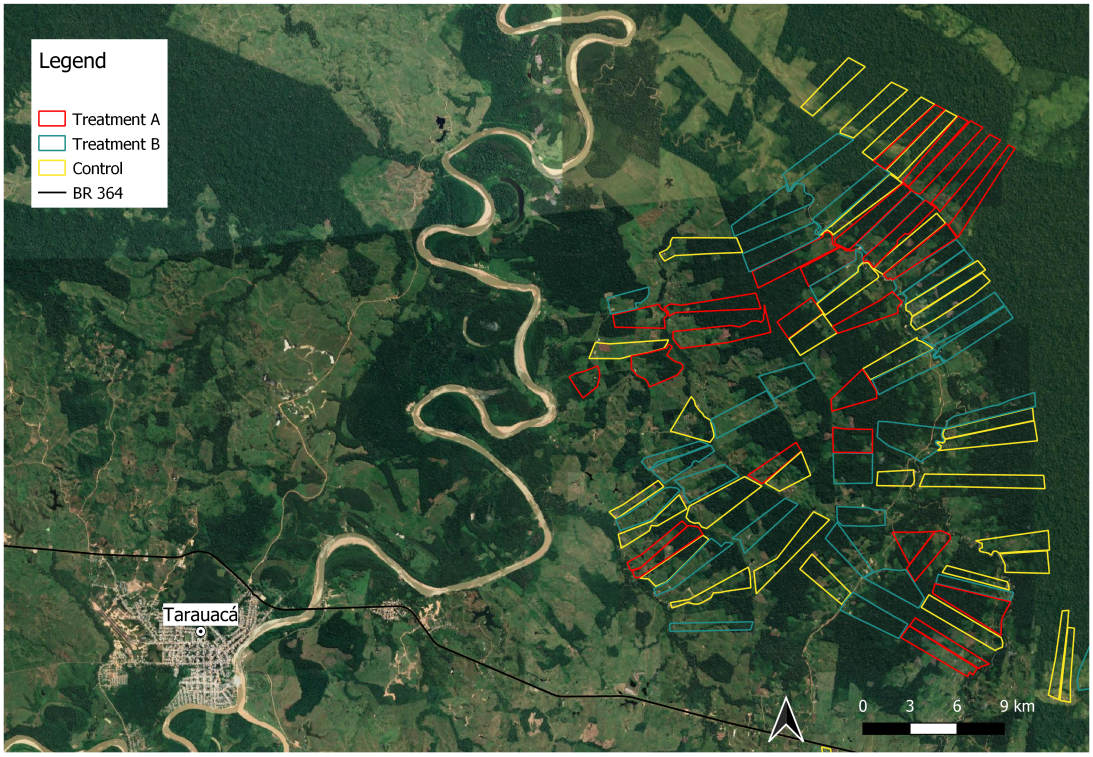


Figure 2: Map of treatment groups (partial picture)

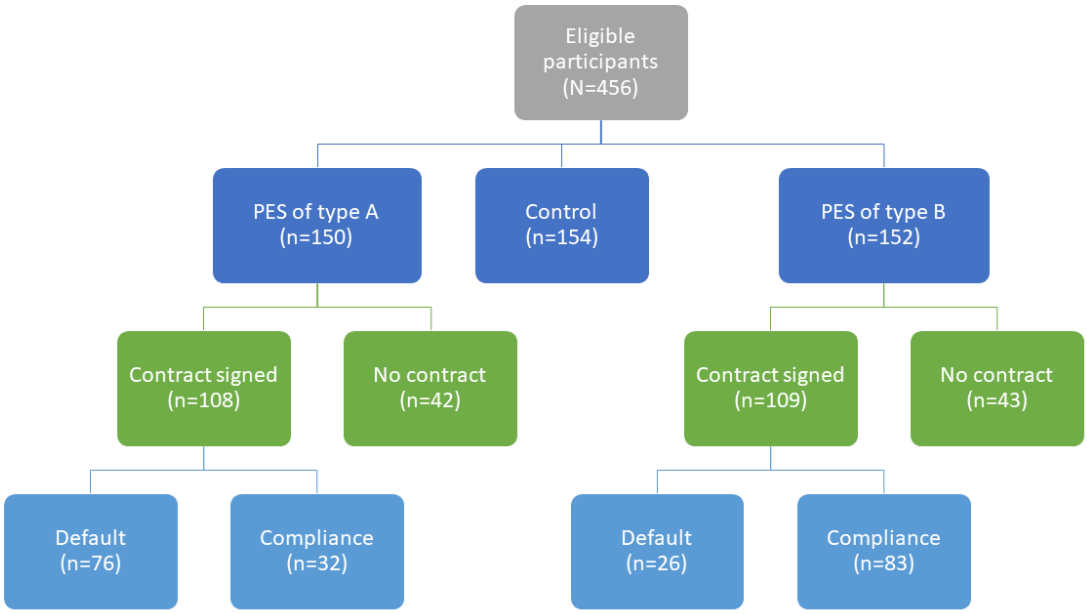


Figure 3: Experimental protocol with sample sizes

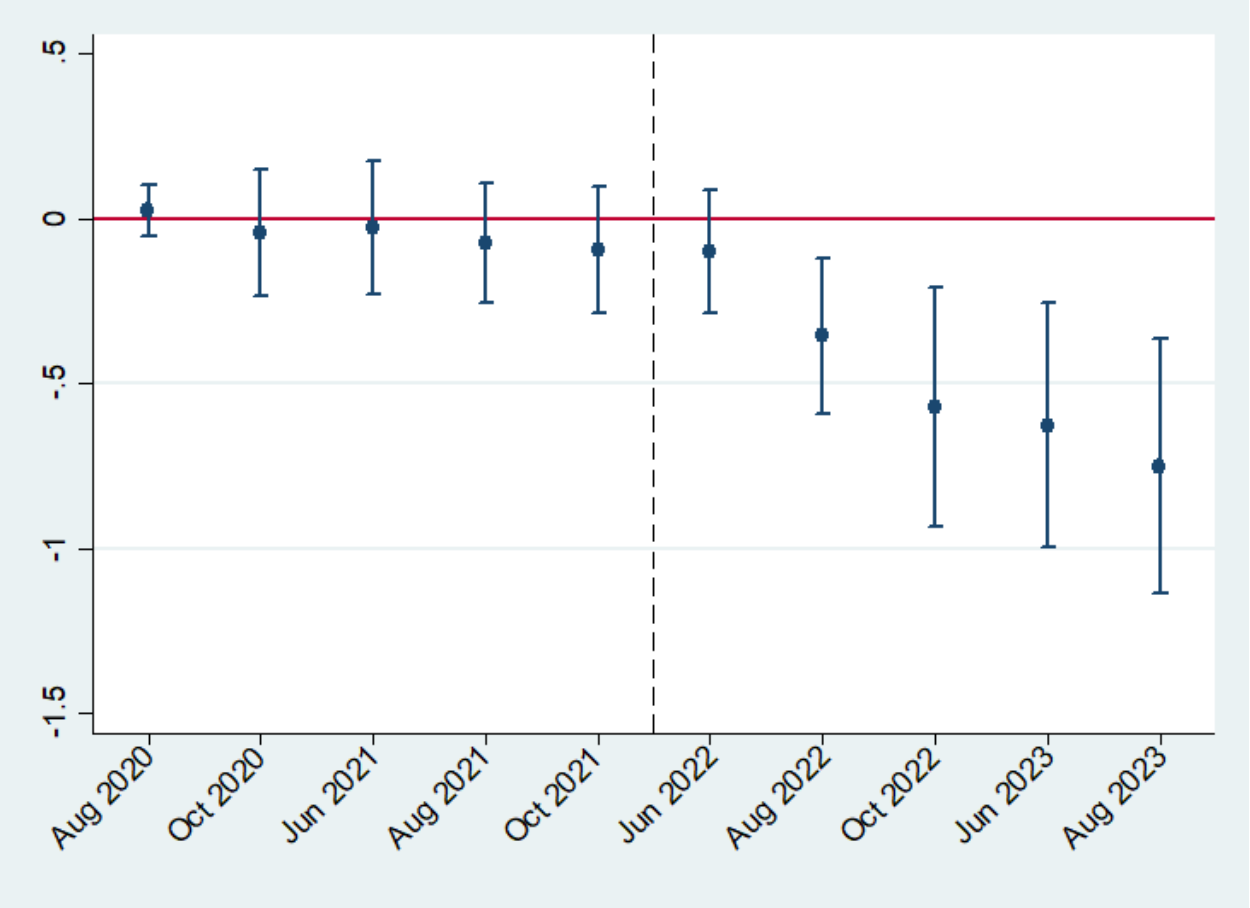


Figure 4: Impact of treatment on cumulative forest loss

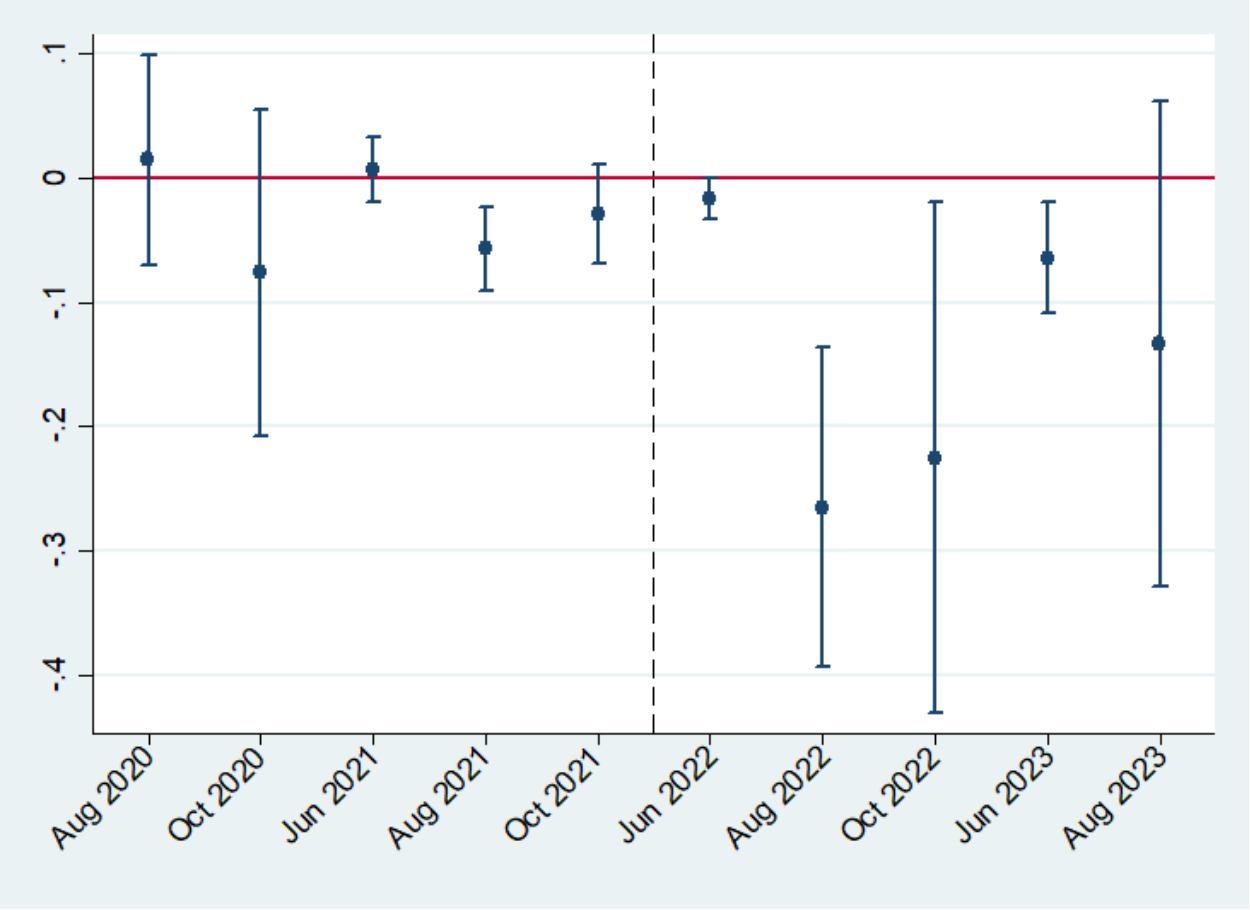


Figure 5: Impact of treatment on forest loss by period

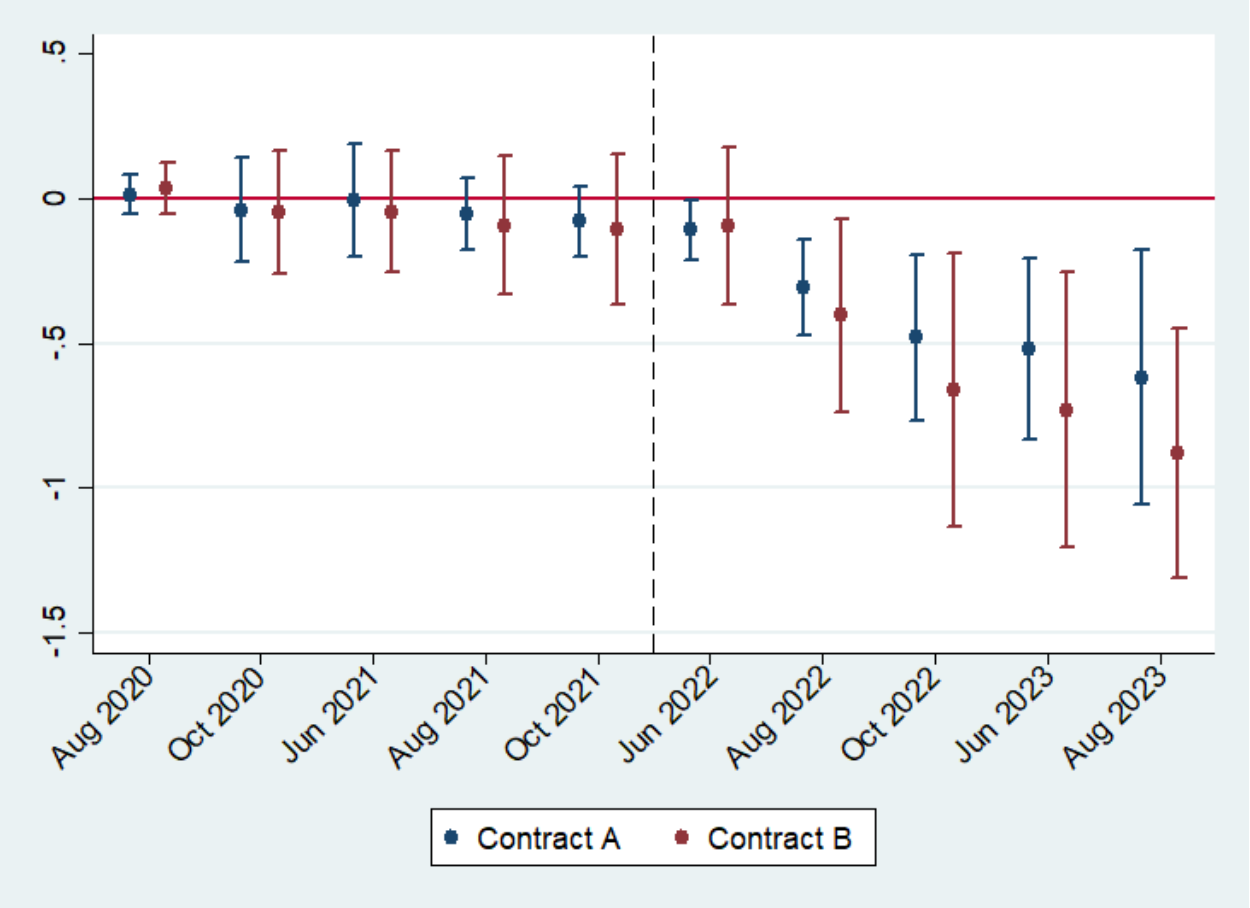


Figure 6: Impact of treatment on cumulative forest loss (A versus B)

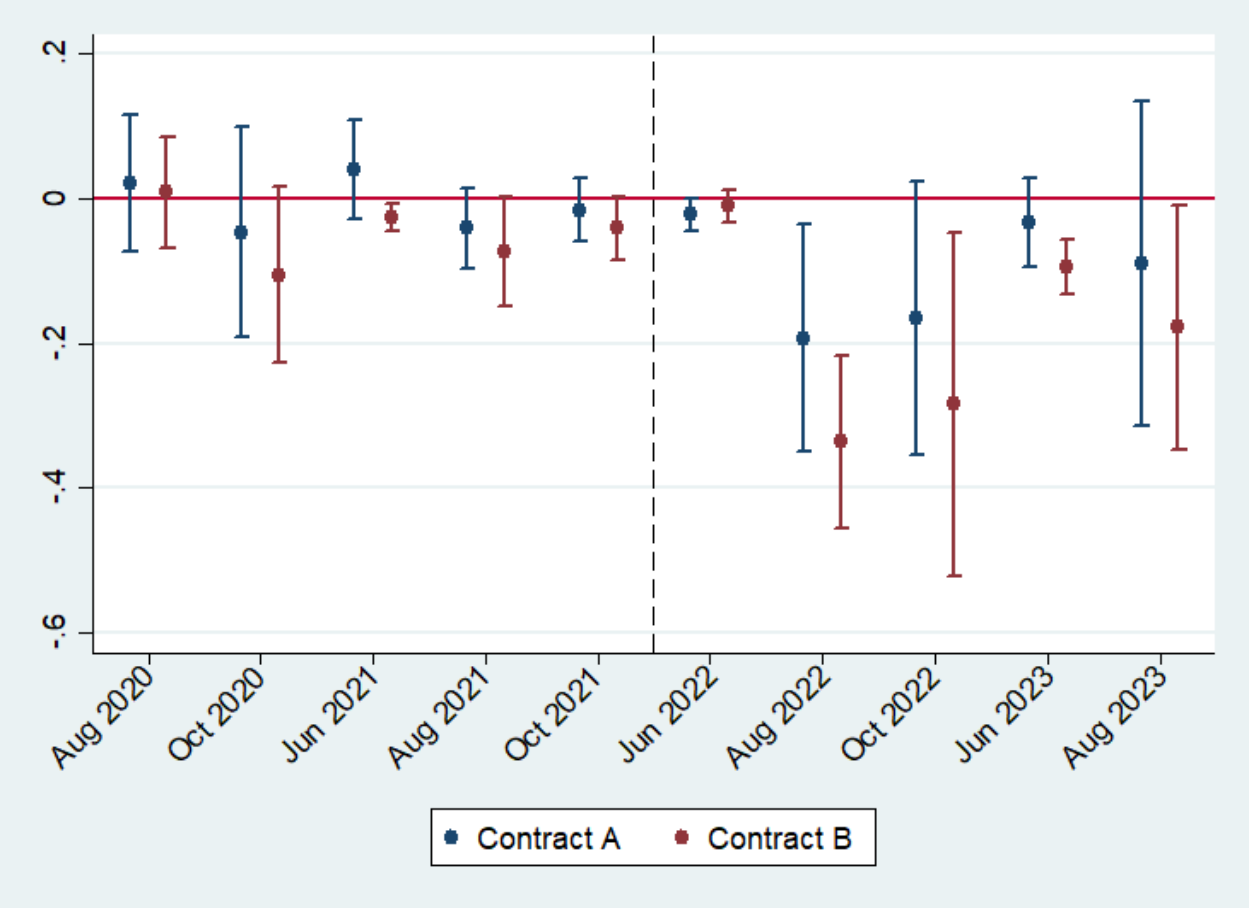


Figure 7: Impact of treatment on forest loss (A versus B) by period

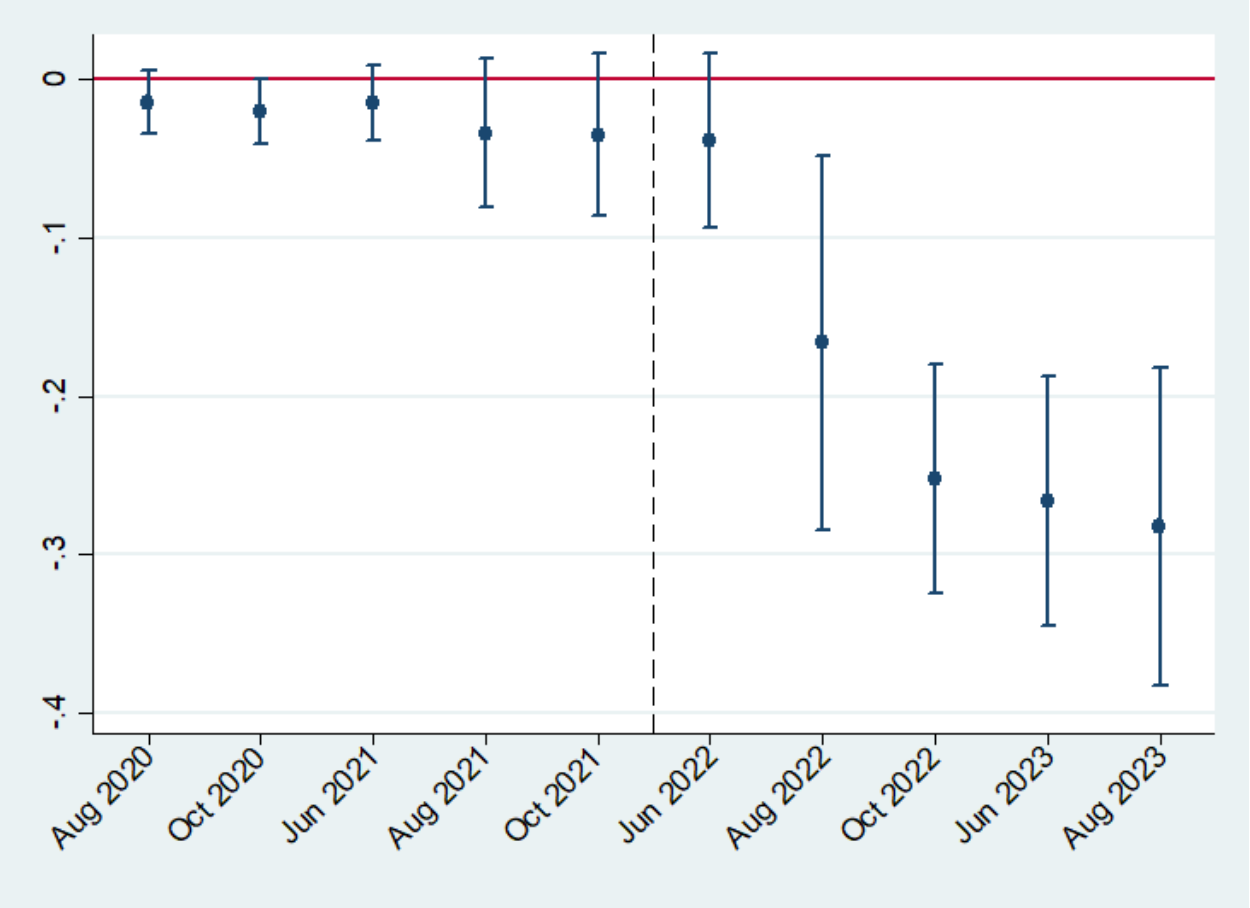


Figure 8: Impact of price on cumulative forest loss

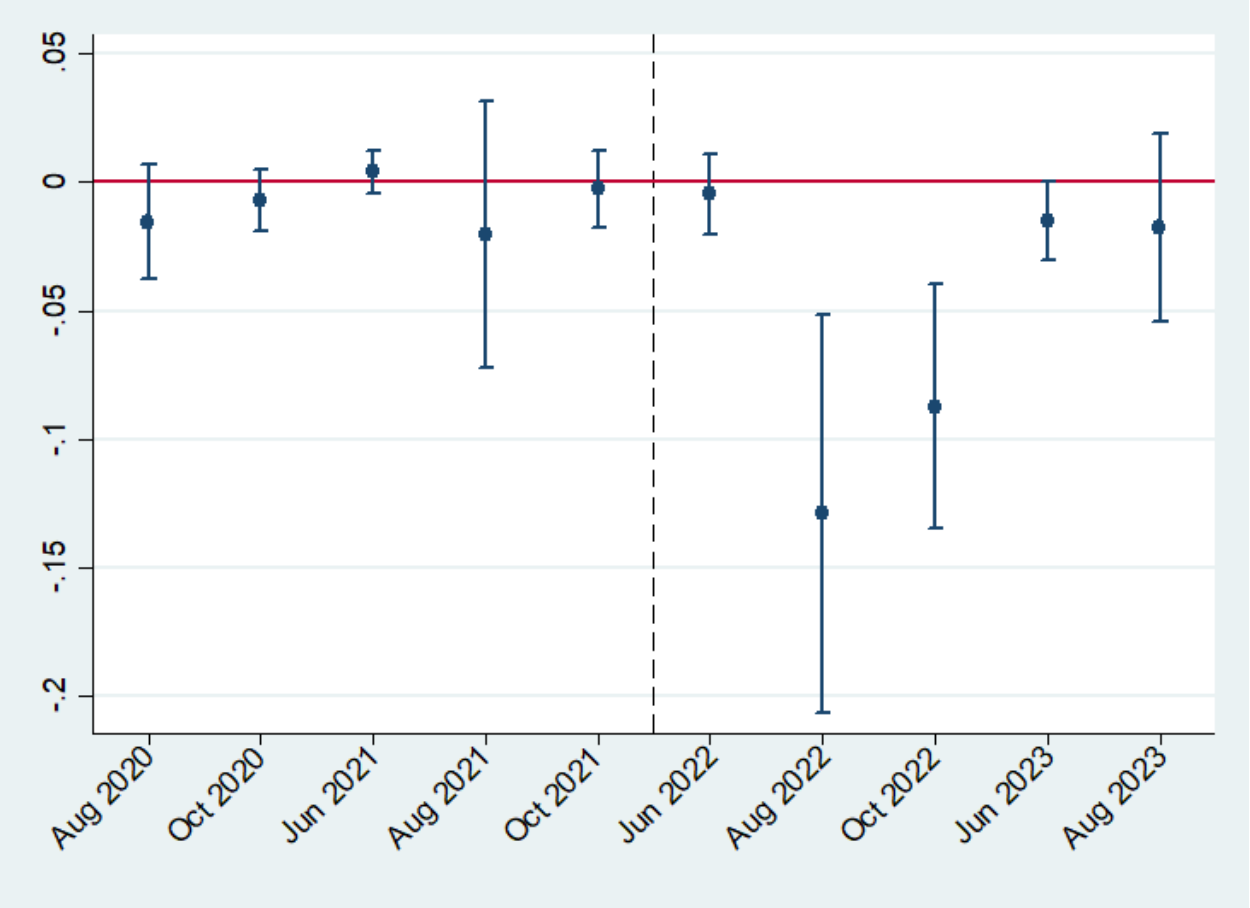


Figure 9: Impact of price on forest loss by period

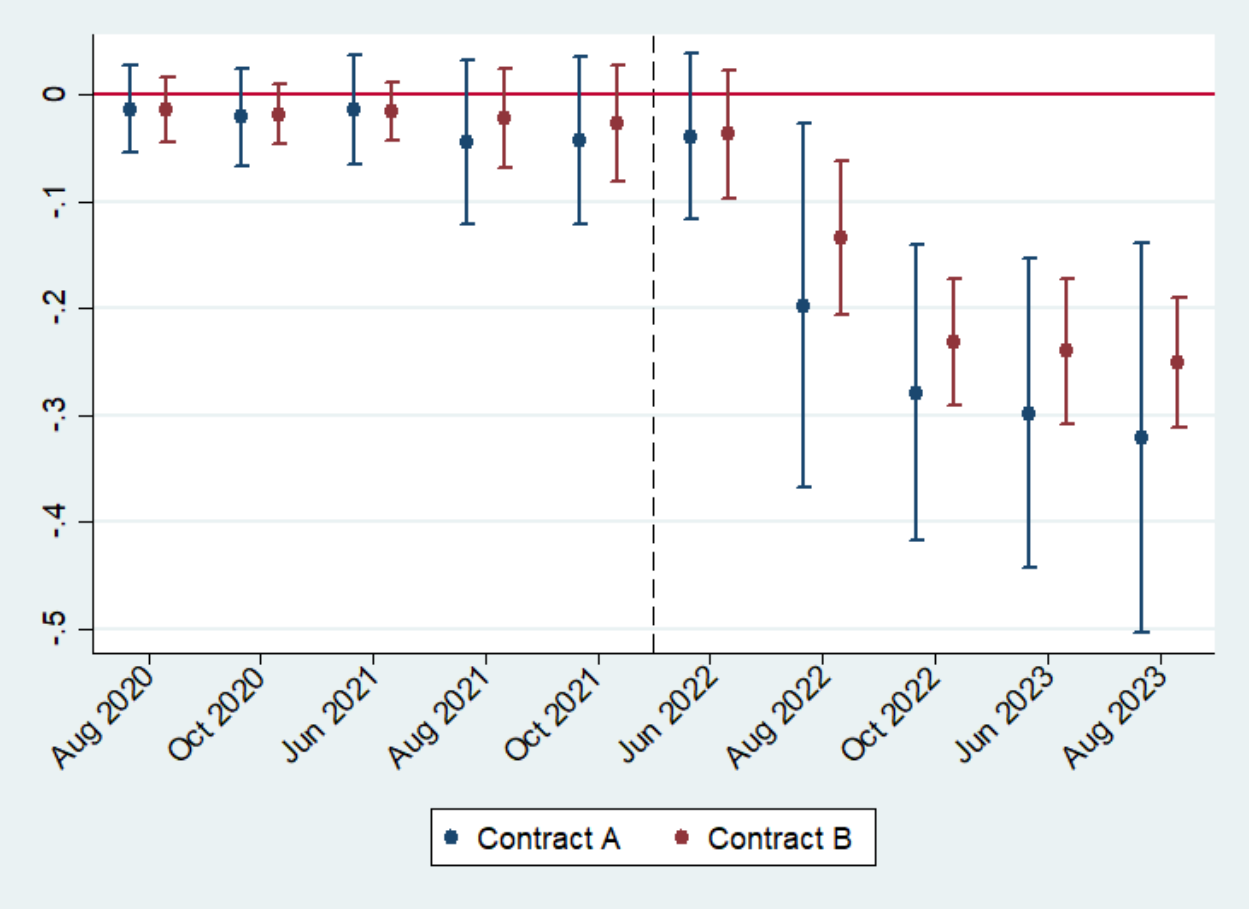


Figure 10: Impact of price on cumulative forest loss (A versus B)

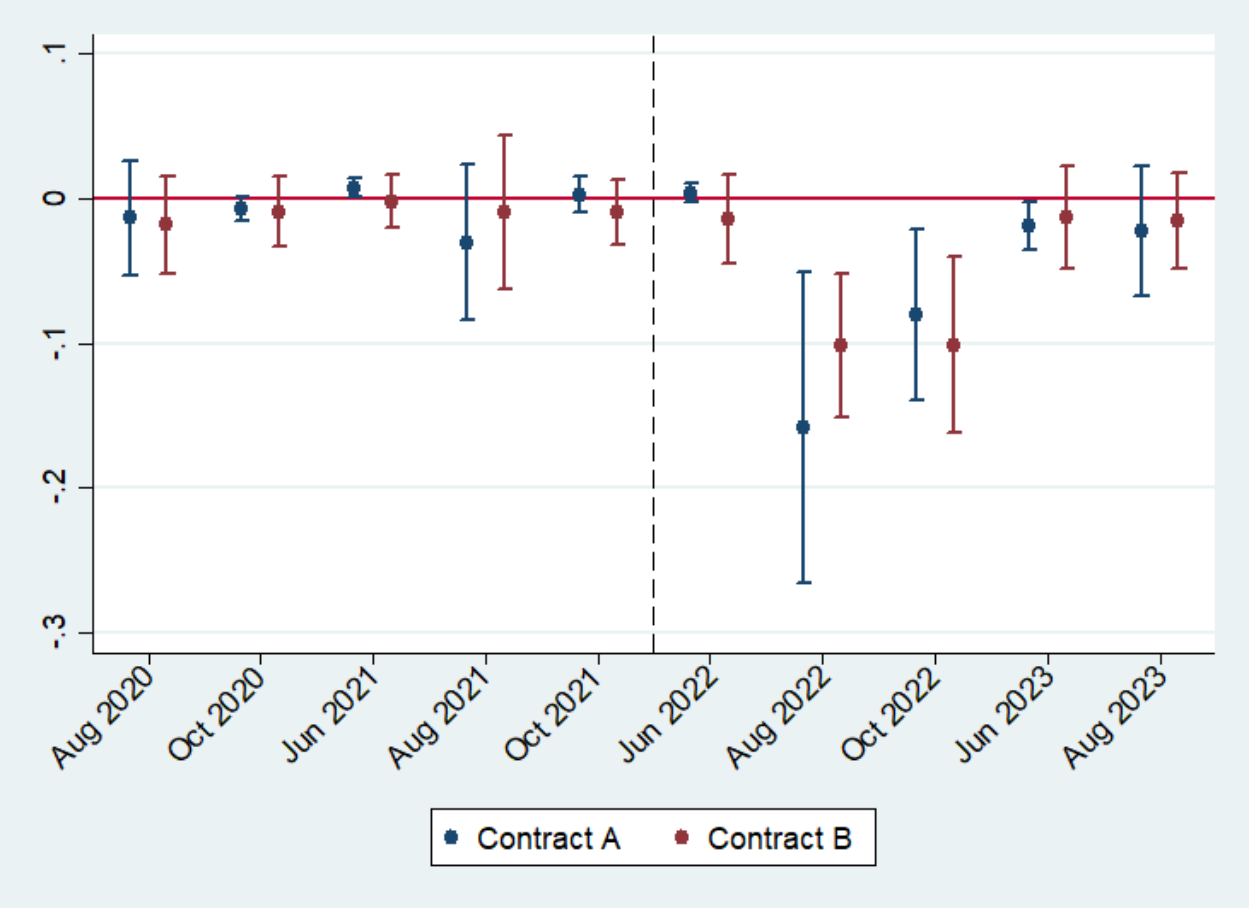


Figure 11: Impact of price on forest loss (A versus B) by period

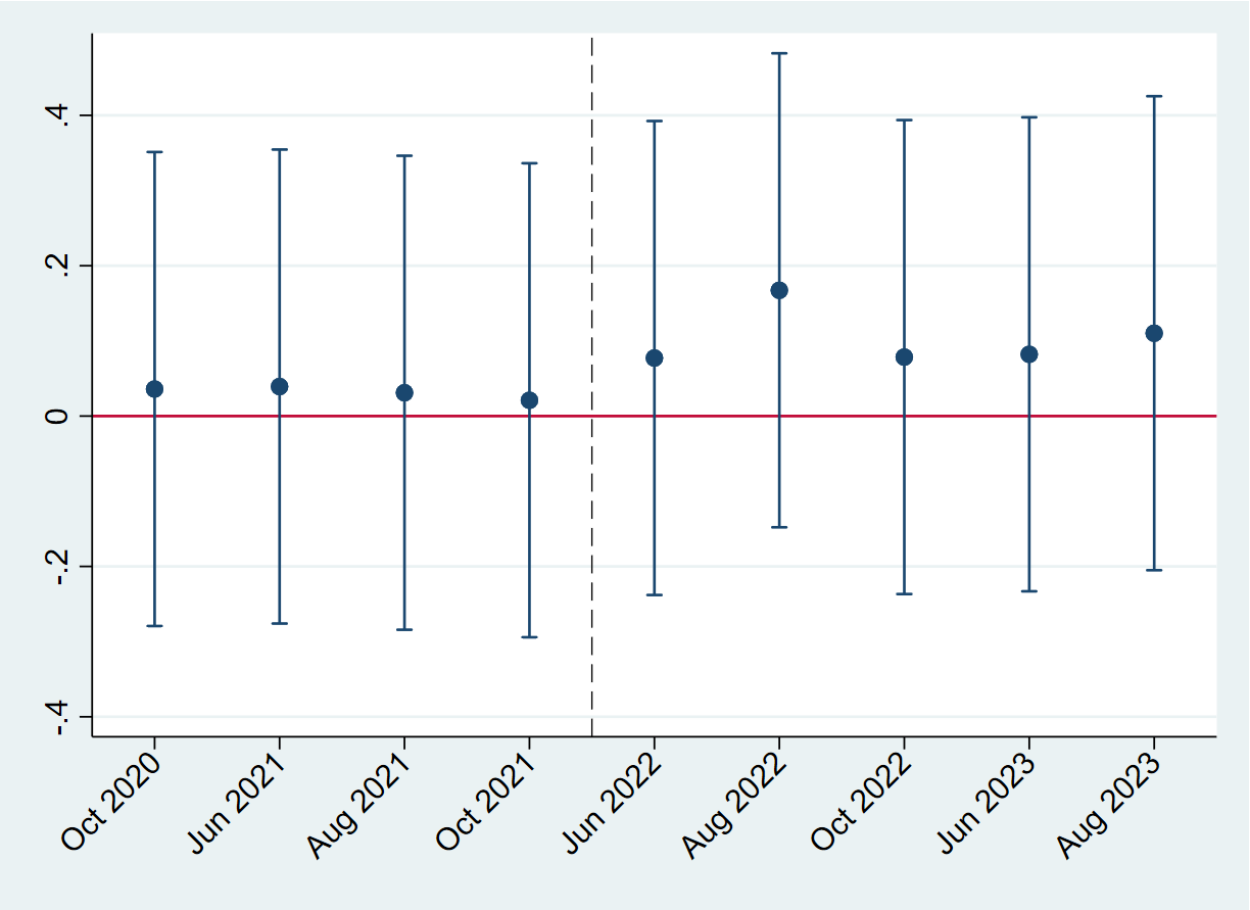


Figure 12: Comparison between control group and matched counterparts

Appendix A: Survey material

INRAE-USP-CIRAD F4F Program		**Interview date:** ____/____/2021 **Start:** ____:____ **End:** ____:____
1	**Experimental Auction**	**Household code:** |__||__||__| *HH number* |__| *Municipality* |__||__| - |__|__| *Surveyors Initials*
Municipality: **Village:** **Respondent:** **Approx. forest area (ha):**		
HH Coordinates		**UTM X :** **UTM Y :**

(Note: The statements in italics are instructions for the surveyors and should not be read to the participants).

Now I will ask you whether you will be willing to participate on the two forest conservation contracts mentioned earlier for several different contract values. But remember that only one kind of contract will be offered to you.

The auction will occur as follows.

The first step will be to ask you the minimum amount of money that you are willing to accept to conserve the forest on your farmhold for one year, according to the requirements of each of the two contracts presented earlier. In the second part, we will reveal what kind of contract was randomly assigned to you. And finally, you will draw a token from an urn. The urn will contain several tokens, once you have drawn one token, two things can happen.

1. If the token value is greater than or equal to the value you requested, **we will offer you a forest conservation contract.** In this contract, we will commit to pay you the same amount you drew from the urn, even if it is higher than the amount you previously requested, but only if the requirements of the contract are met during a period of twelve months from today's date. During these twelve months we will monitor your forest with satellite images. **If you follow the requirements of the contract regarding the conservation of your forest, you will be paid the value written on the token.** SOS Amazônia will make the payment up to 2 (two) months after the end of the 12 (twelve) month period established in the contract. If you do not have a bank account, you will have 6 (six) months to open one and inform SOS Amazônia. **If you do not open a bank account within 6 (six) months after signing the contract, the contract will be cancelled.** If you do not follow the requirements of the contract you signed, you will not receive the payment. You can choose whether or not to sign the contract with SOS Amazônia. If you choose not to sign, we will not make any payment to you and we will thank you for your participation in the study.

2. The second thing that can happen is that the amount drawn is smaller than you requested. In that case **you will not be given a forest conservation contract and you will not have a chance to change your mind**. We will thank you for participating in our study, and we will give you a food parcel as compensation for your time spent on the study. **Only participants who sign a PES contract and follow the conditions of the contract**, i.e. conserve their forests for a period of twelve (12) months as required by the contract, **will receive payment at the end of fourteen (14) months.**

Please note: It is in your best interest to actually state the lowest amount you are willing to accept for each forest conservation contract. Otherwise, there is a risk that you will not be able to sign the contract, even though you would be interested in signing the contract for the drawn amount. In other words, you should not ask for less than the minimum you would be willing to receive to conserve your forests according to the requirements of the contact. But if you ask for a higher value, you risk losing the opportunity to sign a contract that would be advantageous to you.

The bids will be posted separately for each of the two contacts, because each one of them has different rules. After the bids are posted, we will let you know which contract was randomly picked to be offered to you.

Before we continue, do you have any questions?

Do you wish to proceed?

a) Yes
b) No

Remember that we will calculate the forest area on your property by satellite images based on the boundaries of your property provided by you when signing up for the program, and we will monitor the forest conservation activity on your property to make sure that you follow the contract. Is this clear?

c) Yes
d) No

Instructions for the surveyor:

1- *Ask the participant what is the minimum amount of money he/she would be willing to accept to fulfill the PES contract. If he/she doesn't know what to answer, use the selected question randomly picked before the interview.*
2- *Imagine the respondent selected (or you randomly picked) the **option 17** as the opening question.*
    a. *If the respondent says yes to this value, go halfway to the lower bound (option 1), i.e., to **option 9** (17/2=8.5). Round up it is not a whole number.*
    b. *If the respondent says no to this value, go halfway to the upper bound (option 31), i.e., to **option 24** [(31-17)/2]+17= 24.*
    c. *Keep choosing between the midpoint of the two previous options, or between the last option and the extreme, until you identify the shift options.*
3- *The procedure should be the quickest way to identify the shift options, that is, two options for which the respondent alternates between 'yes' and 'no'. Remember that you need to write down these two options, and that the two options should be neighbors.*

Type A Contract

1. What is the minimum price that you are willing to accept to conserve the forest on your property for one year? Note that in the **type A contract**, if you do not conserve all the forest on your property for 12 months, you will not receive any financial compensation.

2. For each of the following values, confirm whether you would be willing to sign a contract for forest conservation:

	Question:	Answer (Yes/No)	
1	If you pick 3000 BRL, would you accept this payment for your PES contract?		
2	If you pick 3100 BRL, would you accept this payment for your PES contract?		
3	If you pick 3200 BRL, would you accept this payment for your PES contract?		
4	If you pick 3300 BRL, would you accept this payment for your PES contract?		
5	If you pick 3400 BRL, would you accept this payment for your PES contract?		
6	If you pick 3500 BRL, would you accept this payment for your PES contract?		
7	If you pick 3600 BRL, would you accept this payment for your PES contract?		
8	If you pick 3700 BRL, would you accept this payment for your PES contract?		
9	If you pick 3800 BRL, would you accept this payment for your PES contract?		
10	If you pick 3900 BRL, would you accept this payment for your PES contract?		
11	If you pick 4000 BRL, would you accept this payment for your PES contract?		
12	If you pick 4100 BRL, would you accept this payment for your PES contract?		
13	If you pick 4200 BRL, would you accept this payment for your PES contract?		
14	If you pick4,300 BRL, would you accept this payment for your PES contract?		
15	If you pick 4400 BRL, would you accept this payment for your PES contract?		
16	If you pick 4500 BRL, would you accept this payment for your PES contract?		
17	If you pick 4600 BRL, would you accept this payment for your PES contract?		

18	If you pick 4700 BRL, would you accept this payment for your PES contract?		
19	If you pick 4800 BRL, would you accept this payment for your PES contract?		
20	If you pick 4900 BRL, would you accept this payment for your PES contract?		
21	If you pick 5000 BRL, would you accept this payment for your PES contract?		
22	If you pick 5100 BRL, would you accept this payment for your PES contract?		
23	If you pick 5200 BRL, would you accept this payment for your PES contract?		
24	If you pick 5300 BRL, would you accept this payment for your PES contract?		
25	If you pick 5400 BRL, would you accept this payment for your PES contract?		
26	If you pick 5500 BRL, would you accept this payment for your PES contract?		
27	If you pick 5600 BRL, would you accept this payment for your PES contract?		
28	If you pick 5700 BRL, would you accept this payment for your PES contract?		
29	If you pick 5800 BRL, would you accept this payment for your PES contract?		
30	If you pick 5900 BRL, would you accept this payment for your PES contract?		
31	If you pick 6000 BRL, would you accept this payment for your PES contract?		

Type B Contract

1. What is the minimum price that you are willing to accept to conserve the forest on your property for one year? Note that if any portion of your forest area is found to have been deforested, penalties will apply as follows: i) a **20% penalty** will be applied to the total payment if a deforestation patch **between 0.1 to 0.5 hectare** is detected through satellite imagery; ii) a **50% penalty** will be applied to the total payment if a deforestation patch **between 0.6 to 1 hectare** is detected through satellite imagery; and iii) **you will not receive any financial compensation** if a deforestation patch **greater than 1 hectare** is detected through satellite imagery.

3. For each of the following values, confirm whether you would be willing to sign a contract for forest conservation:

	Question:	Answer (Yes/No)	
1	If you pick 3000 BRL, would you accept this payment for your PES contract?		
2	If you pick 3100 BRL, would you accept this payment for your PES contract?		
3	If you pick 3200 BRL, would you accept this payment for your PES contract?		
4	If you pick 3300 BRL, would you accept this payment for your PES contract?		
5	If you pick 3400 BRL, would you accept this payment for your PES contract?		
6	If you pick 3500 BRL, would you accept this payment for your PES contract?		
7	If you pick 3600 BRL, would you accept this payment for your PES contract?		
8	If you pick 3700 BRL, would you accept this payment for your PES contract?		
9	If you pick 3800 BRL, would you accept this payment for your PES contract?		
10	If you pick 3900 BRL, would you accept this payment for your PES contract?		
11	If you pick 4000 BRL, would you accept this payment for your PES contract?		
12	If you pick 4100 BRL, would you accept this payment for your PES contract?		
13	If you pick 4200 BRL, would you accept this payment for your PES contract?		
14	If you pick4,300 BRL, would you accept this payment for your PES contract?		
15	If you pick 4400 BRL, would you accept this payment for your PES contract?		
16	If you pick 4500 BRL, would you accept this payment for your PS contract?		

17	If you pick 4600 BRL, would you accept this payment for your PES contract?		
18	If you pick 4700 BRL, would you accept this payment for your PES contract?		
19	If you pick 4800 BRL, would you accept this payment for your PES contract?		
20	If you pick 4900 BRL, would you accept this payment for your PES contract?		
21	If you pick 5000 BRL, would you accept this payment for your PES contract?		
22	If you pick 5100 BRL, would you accept this payment for your PES contract?		
23	If you pick 5200 BRL, would you accept this payment for your PES contract?		
24	If you pick 5300 BRL, would you accept this payment for your PES contract?		
25	If you pick 5400 BRL, would you accept this payment for your PES contract?		
26	If you pick 5500 BRL, would you accept this payment for your PES contract?		
27	If you pick 5600 BRL, would you accept this payment for your PES contract?		
28	If you pick 5700 BRL, would you accept this payment for your PES contract?		
29	If you pick 5800 BRL, would you accept this payment for your PES contract?		
30	If you pick 5900 BRL, would you accept this payment for your PES contract?		
31	If you pick 6000 BRL, would you accept this payment for your PES contract?		

Auction Answers

	Question:	*Code:*	*Answer:*
1	*What kind of contract was drawn?*	A=1 B=2	
2	*What was the amount drawn from the urn?*	BRL	
3	*Did the participant say he/she would accept a contract with that value?*	Yes=1 No=0	
4	*If yes, read: You said you would accept a payment of <<contract value>>, so we will offer you a contract for PES for that amount.*		

INRAE-USP-CIRAD A Renda da Floresta		**Dia da semana**: _____ **Data de entrevista:** ____/____/2021 **Início:** ____:____ hs **Término:** ____:____ hs
1	**Questionário de Unidades Familiares**	**Registro da Unidade Amostral (UA):** |__||__| |__| |__||__| |__|__| *UA* *Município* *Iniciais Entrevistadores*
Município :_____ **Comunidade:**_____		**Entrevistado:** _____ _____
Coordenadas da UA		UTM X : UTM Y :

(Nota: As declarações em itálico são instruções para os entrevistadores e não devem ser lidas para os participantes).

1. INFORMAÇÕES BÁSICAS SOBRE O/A CHEFE/A DA UNIDADE FAMILIAR
1.1. Sexo do entrevistado: a) Masculino b) Feminino
1.2. Quantos anos o(a) senhor(a) tem?
1.3. Onde o(a) senhor(a) nasceu?
1.3.1 Comunidade:
1.3.2 Cidade:
1.3.3 Estado:
1.4. Até qual série da escola o(a) senhor(a) completou? *(Calcular total de anos de estudo depois, antes de entrar os dados)*
1.5. Há quanto tempo o(a) senhor(a) vive nessa comunidade? *(anos/meses)*

1.6. Qual a ocupação principal do(a) senhor(a)?

a) Produtor rural
b) Diarista (motosserra, roçadeira, terçado, etc.)
c) Dona de casa
d) Outro (especifique):

1.7. Há quanto tempo o(a) senhor(a) trabalha com isso? *(anos/meses)*

1.8. O(a) senhor(a) participa de alguma organização ou associação ou sindicato?

a) Não
b) Sim
c) Qual? *(pode ser mais de um)*

Por organização, associação ou sindicato, queremos saber se ele(a) é associado(a), por exemplo, ao(à): i) associação da comunidade/assentamento; ii) sindicato dos trabalhadores rurais ou outro sindicato; iii) organizações diversas (ex. ONG, conselho de meio ambiente/saúde).

1.9. O(a) senhor(a) já participou de algum programa ambiental proposto por uma ONG ou pelo governo?

a) Não
b) Sim
c) Qual?

Por programa ambiental, queremos dizer programas voltados estritamente à conservação das florestas (ex. PSA prévio, programa de regeneração florestal), ou mesmo aqueles com objetivos múltiplos ligados à melhoria da produção (através, p. ex., de assistência técnica e doação de insumos agropecuários), mas com algum componente de conservação (p. ex., com o objetivo de melhorar a produção gerando menos desmatamento).

1.9.1. A sua experiência com este programa ambiental foi:

a) Muito positiva
b) Positiva
c) Neutra
d) Negativa
e) Muito negativa

1.9.2. Por que?

2. INFORMAÇÕES BÁSICAS SOBRE A UNIDADE FAMILIAR

Identifique e preencha as informações sobre os membros da unidade familiar. Considerar, aqui, a definição de "agregado familiar" ou "unidade doméstica". Ou seja, incluir pessoas que, mesmo que não morem na mesma casa, morem na mesma propriedade e compartilhem recursos, como trabalho, alimentos e dinheiro. Isso inclui até, eventualmente, pessoas que não sejam membros da mesma família.

2.1.	2.1.1. Primeiro nome *(preencher a primeira linha com as informações do entrevistado obtidas nas perguntas anteriores)*	2.1.2. Gênero (F/M)	2.1.3. Idade	2.1.4. Trabalha na propriedade (*Não/Sim*)	2.1.5. Trabalha fora da propriedade (*Não/Sim*)	2.1.6. Ocupação fora da propriedade a) trabalho formal (ex. professor, agente de saúde, vendedor) b) diárias (trabalho rural) c) ambos acima d) outro *(especificar*)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						

13						
14						
15						

2.2. Existem funcionários ou trabalhadores por diária na propriedade?

a) Não
b) Sim

2.2.1. Se sim, quantos?

2.3. Qual é a renda mensal média da família aproximadamente? (*Soma de todos os ingressos*)

a) Até 500 reais
b) Entre 500 e 1000 reais
c) Entre 1000 e 1500 reais
d) Entre 1500 e 2000 reais
e) Entre 2000 e 2500 reais
f) Entre 2500 e 3000 reais
g) Acima de 3000 reais

Incluir a renda proveniente de todos os membros do agregado familiar/unidade doméstica identificados na pergunta 2.1. Incluir: salários/diárias, transferências governamentais, renda monetária proveniente da produção agropecuária, da venda de madeira e produtos florestais não madeireiros, negócios próprios e qualquer outra fonte de renda.

2.4. Qual o uso da terra gera mais renda para a família?

a) Gado
b) Agricultura
c) Outro (especifique):

3. RENDA MISTA NOS ÚLTIMOS 12 MESES

3.1. Agricultura: _____ reais.

3.2. Criação de gado: _____ reais.

3.3. Criação de outros animais *(especifique)*: _____ reais.
3.4. Produtos da floresta (ex: açaí, andiroba, patuá, etc.) : _____ reais.
3.5. Negócio familiar *(especifique):* _____ reais.
3.6. Aposentadoria: _____ reais.
3.7. Apoio do governo (ex: bolsa família, auxílio emergencial, etc.): _____ reais.
3.8. Programa do governo para a agricultura familiar (ex: PAA, PNAE.): _____ reais.
3.9. Outro *(especifique):* _____ reais.

4. FINANCIAMENTO AGRÍCOLA
4.1. O(a) senhor(a) já fez um financiamento agrícola?
4.2. Qual foi o propósito do financiamento? a) Comprar terra b) Comprar gado c) Comprar maquinário d) Outros, especifique:

5. INFORMAÇÕES BÁSICAS SOBRE A PROPRIEDADE RURAL

5.1. O(a) senhor(a) é proprietário da área?

a) Não
b) Sim

5.1.2. Se não, quem é?

Por proprietário da terra, entenda quem é responsável por ela e toma decisões sobre seu uso. Não necessariamente precisa ter o título da propriedade.

5.2. Essa propriedade foi:

a) Comprada
b) Doada pelo governo (ex: INCRA)
c) Posse
d) Herdada
e) Outros, especifique:

5.3. O(a) senhor(a), ou o proprietário da terra (*caso ele tenha respondido "não" na 5.1.*), possui documento da propriedade?

a) Não
b) Sim

5.4. Tamanho da propriedade? (hectares)

a) Mata bruta *(floresta primária):*

b) Capoeira *(floresta secundária):*

c) Roçado (ex: mandioca, milho, feijão, banana) *(agricultura de subsistência e eventuais vendas)*

d) Pasto:

e) Outro uso do solo (ex: açude, plantio de açaí, graviola, etc.):

5.5. Quantidade de cabeças de gado: (unidades)

5.5.1. Quantidade de bezerros que nasceram no último ano:

5.5.2. Quantidade de cabeças de gado compradas no último ano:

5.5.3. Quantidade de cabeças de gado vendidas no último ano:

6. PRODUÇÃO E CUSTOS DE PRODUÇÃO AGRÍCOLA NOS ÚLTIMOS 12 MESES

6.1. Qual o custo médio para brocar um hectare de floresta?
Este custo inclui o custo de diárias para brocar, para derrubar, combustível, óleo, etc.

6.2. Qual o custo médio para formar um hectare de pasto?

Este custo inclui o custo de adquirir sementes, diárias, combustível, etc.

6.3. Qual o custo médio para formar um hectare de roçado?
Este custo inclui sementes, diárias, etc.

7. MUDANÇAS NA COBERTURA FLORESTAL

7.1. Com qual frequência o(a) senhor(a) derruba a mata bruta seja para fazer roçado, pasto ou outra finalidade?

a) Todo ano
b) A cada dois anos
c) A cada três anos
d) A cada quatro anos
e) Outro:

7.2. Quantas vezes você faz o roçado em uma área de derrubada?

a) Uma vez
b) Duas vezes

c) Três vezes
d) Quatro vezes
e) Outro:

7.3. Qual o intervalo de tempo antes de fazer o roçado na mesma área de novo?

a) Um ano
b) Dois anos
c) Três anos
d) Quatro anos
e) Outro:

7.4. O que acontece com a área após a colheita do roçado?

a) Vira capoeira
b) Vira pasto
c) Outro:

7.5. Qual foi a área total de derrubada nos últimos 4 anos e qual o foi o principal propósito da derrubada? (número de hectares derrubados por mês)

7.5.1 2018		7.5.2 2019		7.5.3 2020		7.5.4 2021	
Abril	_____ha	Abril	_____ha	Abril	_____ha	Abril	_____ha
Maio	_____ha	Maio	_____ha	Maio	_____ha	Maio	_____ha
Junho	_____ha	Junho	_____ha	Junho	_____ha	Junho	_____ha
Julho	_____ha	Julho	_____ha	Julho	_____ha	Julho	_____ha
Agosto	_____ha	Agosto	_____ha	Agosto	_____ha	Agosto	_____ha
Setembro	_____ha	Setembro	_____ha	Setembro	_____ha	Setembro	_____ha
Outubro	_____ha	Outubro	_____ha	Outubro	_____ha	Outubro	_____ha

7.5.1.1 Qual foi o principal propósito da derrubada? a) Roçado b) Pastagem c) Outros, especifique (ex: plantar açaí, café, açude):	7.5.2.1 Qual foi o principal propósito da derrubada? a) Roçado b) Pastagem c) Outros, especifique (ex: plantar açaí, café, açude):	7.5.3.1 Qual foi o principal propósito da derrubada? a) Roçado b) Pastagem c) Outros, especifique (ex: plantar açaí, café, açude):	7.5.4.1 Qual foi o principal propósito da derrubada? d) Roçado e) Pastagem f) Outros, especifique (ex: plantar açaí, café, açude):

8. CRENÇAS SOCIAIS, NORMATIVAS E DE CONTROLE

8.1. Na opinião do(a) senhor(a) quais são as vantagens, ou pontos positivos, em brocar a floresta da sua colônia?

a) Fazer roçado para alimentar a minha família
b) Fazer roçado para alimentar a criação de animais
c) Aumentar a minha área de pasto
d) Valorizar o preço da minha terra
e) Abertura de açude
f) Outro (especifique):

8.2. Na opinião do(a) senhor(a) quais são as desvantagens, ou pontos negativos, em brocar a floresta da sua colônia?

a) Risco de multa
b) Poluição do ar pelas queimadas
c) Calor
d) Seca
e) Diminuição dos animais de caça
f) Diminuição da água nos igarapés
g) Outro (especifique)

8.3. Na percepção do(a) senhor(a), quem aprova, ou acha boa a sua decisão de derrubar a floresta? Por exemplo membros da sua família, vizinhos, governo, etc.

a) Mais velhos da família
b) Mais jovens da família
c) Produtores vizinhos
d) Amigos
e) Comprador de gado

f) Governo federal
g) Agronegócio
h) Outro (especifique)

8.4. Na percepção do(a) senhor(a), quem desaprova, ou acha ruim a sua decisão de derrubar a floresta? Por exemplo membros da sua família, vizinhos, governo, etc.

a) Mais velhos da família
b) Mais jovens da família
c) Produtores vizinhos
d) Órgão de assistência técnica (SEPA, EMATER, Secretaria de Agricultura, etc.)
e) Órgão ambiental (IMAC, Secretaria do Meio Ambiente, etc.)
f) Governo regional
g) Outro:

8.5. Na sua opinião, quais são as coisas que impedem ou dificultam o(a) senhor(a) usar as áreas já derrubadas por mais vezes?

a) Falta de dinheiro para investir
b) Falta de mão de obra
c) Falta de crédito do governo
d) Preço do gado
e) Falta de estradas de acesso
f) Falta de maquinários
g) Outro:

8.6. Na sua opinião, quais são as coisas que facilitam ou iriam facilitar o(a) senhor(a) usar as áreas já derrubadas por mais vezes?

a) Maquinário para arar a terra
b) Maquinário para construir açudes
c) Disponibilidade de crédito do governo
d) Disponibilidade de insumos (ex: arame, mudas, adubo)
e) Assistência técnica qualificada
f) Outro:

8.7. Quais são as preocupações do(a) senhor(a) em relação à sua colônia? Por exemplo, tem algo que preocupa o(a) senhor(a) com relação à sua produção, como: secas, enchentes, doenças do gado, pragas do roçado, etc.? Ou tem alguma outra preocupação que o senhor tenha com relação à segurança em permanecer na propriedade ou em relação à sua segurança pessoal e de seus familiares?

a) Enchentes
b) Pragas da lavoura
c) Doença do gado
d) Seca
e) Grilagem e especulação de terras
f) Criminalidade (assalto ou roubo)
g) Perda de produtividade do solo
h) Outro:

9. HISTÓRICO DE CONFLITOS POR TERRA

9.1. A terra do(a) senhor(a) já passou por algum tipo de disputa ou conflito? Por exemplo, a terra já foi invadida ou houve divergência com o vizinho sobre os limites das propriedades?

a) Não
b) Sim

9.2. Qual foi o principal motivo?

a) Disputa com o vizinho sobre a terra (ex: limites das parcelas que se sobrepõem)
b) Invasão de pessoas de fora da comunidade (ex: madeireiros)
c) Outro, especifique:

10. HISTÓRICO DE FISCALIZACAO

10.1. Em seu conhecimento, de que forma os órgãos de fiscalização monitoram o desmatamento aqui na região?

a) Imagens de satélite
b) Visitas de campo
c) Denúncias
d) Outros, especifique:

10.2. O(a) senhor(a) já foi fiscalizado por algum órgão ambiental do governo aqui na região?

a) Não
b) Sim

10.2.1. Se sim, quando foi a última vez? *(mês/ano)*

10.3. Qual órgão?

a) IBAMA
b) IMAC
c) Outros, especifique:

10.4. Qual foi o principal motivo?

a) Derrubada (corte raso)
b) Queimada
c) Caça de animais silvestres
d) Outros, especifique:

Via 1/2 - Participante

A RENDA DA FLORESTA

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

1. TERMO DE ESCLARECIMENTO

Gostaríamos de convidar você a participar da segunda fase do estudo chamado “A Renda da Floresta”. Como parte do estudo, será implementado um programa piloto de pagamentos por serviços ambientais. Este programa irá recompensar proprietários de terra pelos esforços de conservar suas florestas e será implementado pela SOS Amazônia em parceiria com o Instituto Nacional Francês de Pesquisa em Agricultura, Alimentação e Meio Ambiente (INRAE), e a Universidade de São Paulo (USP) na região da rodovia BR 364, nos municípios de Tarauacá e Feijó.

Neste documento, nós explicaremos como vai funcionar a segunda fase do projeto. Sempre que necessário, nós vamos explicar e tirar todas as suas dúvidas. Você pode escolher agora se quer continuar participando ou não. Mas poderá também desistir de participar a qualquer momento sem explicar o motivo. Nós fizemos duas cópias deste documento. Caso você concorde em participar, pediremos que assine as duas cópias. Uma das cópias ficará com você e a outra cópia será guardada pelo pesquisador responsável.

Por que eu fui convidado(a) a participar da segunda fase?

Você fez um cadastro para participar do programa piloto A Renda da Floresta e foi sorteado(a) para participar da segunda fase do estudo. Hoje nós estamos convidando você para participar de uma dinâmica/sorteio experimental e responder um questionário socioeconômico.

O que acontece se eu participar da segunda fase?

A primeira etapa da atividade é explicar os dois tipos de contratos de Pagamento por Serviços Ambientais que poderão ser oferecidos a você:

Contrato Fixo: Por meio deste contrato, o proprietário da terra concorda em receber, ao final do contrato, um pagamento **pela preservação integral da área de floresta** existente em sua propriedade. A SOS Amazônia apenas pagará a compensação financeira caso toda a sua área de floresta seja preservada até o final do contrato. Ou seja, se for constatado que o proprietário da terra desmatou parte da área de floresta, mesmo que mínima, o pagamento não será realizado.

Contrato Flexível: Por meio deste acordo, o proprietário da terra concorda em receber, ao final do contrato, um pagamento também **pela preservação integral da área de floresta** existente em sua

propriedade. Porém, caso seja constatado desmatamento de alguma porção de sua área de floresta, penalidades serão aplicadas da seguinte forma:

- O valor a ser pago por hectare terá uma redução de 20% caso a área de floresta tenha de 0,1 a 0,5 hectare de desmatamento.
- O valor a ser pago por hectare terá uma redução de 50% caso a área de floresta tenha de 0,6 a 1 hectare de desmatamento.
- Nenhuma compensação será paga caso a área de floresta tenha ultrapassado 1 hectare de desmatamento.

Na segunda parte da atividade, pediremos que você nos diga o valor que gostaria de receber por hectare de floresta para cada um dos dois tipos de contratos de PSA mostrados anteriormente. Este valor representa o valor mais baixo que você está disposto a aceitar para cada tipo de contrato. Entre os dois contratos apresentados, **sortearemos um contrato a ser oferecido a você**. Lembrando que você pode declarar um valor diferente para cada tipo de contrato.

Na terceira parte da atividade, você vai sortear um valor de uma urna de forma aleatoria. Uma vez sorteado o valor, duas coisas podem acontecer:

1. **Se o valor sorteado for maior ou igual ao valor que você solicitou, iremos oferecer um contrato de pagamentos por serviços ambientais**. Neste contrato, nos comprometeremos a pagar o mesmo valor que o(a) senhor(a) tirou na urna, mesmo que ele seja maior que o valor que senhor(a) solicitou anteriormente, mas somente se as exigências do contrato forem cumpridas durante um período de doze meses, ou seja, de dozes meses a partir da data de hoje. Durante esses 12 (doze) meses, verificaremos sua floresta com imagens de satélite e faremos uma comparação com a situação atual. Se o(a) senhor(a) tiver seguido as exigências do contrato referentes à conservação de sua floresta, será pago o valor sorteado na urna. No caso, a SOS Amazônia irá realizar o pagamento até 2 (dois) meses após o término do período de 12 (doze) meses estabelecido no contrato. Se o(a) senhor(a) não tiver uma conta bancária em seu nome, terá 6 (seis) meses para abrir uma e informar a SOS Amazônia. Se o(a) senhor(a) não abrir uma conta bancária dentro de 6 (seis) meses após a assinatura do contrato, o contrato será cancelado. Se o(a) senhor(a) não seguir os requisitos do contrato que assinou, não receberá o pagamento. O(a) senhor(a) pode optar por assinar ou não o contrato com a SOS Amazônia. Se o(a) senhor(a) optar por não assinar, não faremos qualquer pagamento e lhe agradeceremos por sua participação no estudo.

2. A segunda coisa que pode acontecer é **o valor sorteado ser inferior ao que o(a) senhor(a) solicitou. Nesse caso, não o(a) convidaremos a assinar um contrato de Pagamento por Serviço Ambiental**. Assim sendo, lhe agradeceremos por participar de nosso estudo e lhe daremos uma cesta de alimentos em compensação pelo tempo dedicado ao estudo.

Todos os participantes, sorteados ou não para receber um contrato de pagamentos por serviços ambientais, farão parte do estudo. É importante entender que a participação no estudo não garante que as famílias receberão um pagamento ao final, pois o projeto possui duas fases de sorteio e os pagamentos são condicionais ao cumprimento das exigências dos contratos de Pagamentos por Serviços Ambientais.

Ou seja, apenas os participantes do estudo que assinarem um contrato de pagamentos por serviços ambientais com a gente e seguirem os compromissos do contrato referentes à conservação de suas florestas no período de doze meses, irão receber um pagamento ao final do estudo.

Quais são os benefícios esperados caso eu participe?

Nós apresentaremos os resultados do nosso estudo para todos os participantes, tenham eles assinado ou não um contrato de Pagamentos por Serviços Ambientais com a gente. Acreditamos que este estudo será bom para a região, pois ajudará a entender se Pagamentos por Serviços Ambientais seriam uma boa estratégia para ajudar a conservar a floresta dessa região, se são bem aceitos pelos moradores daqui e se tem alguma questão neles que pode ser melhorada.

Além disso, caso você assine um contrato de Pagamentos por Serviços Ambientais com a gente e, ao final de doze meses, nós tenhamos confirmado, por meio de imagens de satélite, que sua floresta foi conservada conforme as exigências do contrato, você receberá um pagamento em dinheiro em troca do seu esforço feito para conservar a floresta, como explicamos antes.

Quais são os riscos e desconfortos para a minha participação?

Os riscos para a sua participação no estudo são mínimos, pois todas as etapas do estudo foram preparadas para evitar qualquer constrangimento ou inconveniente para os participantes. Você poderá decidir se quer participar ou não do estudo. Poderá fazer perguntas para a gente a qualquer momento. Poderá também se retirar do estudo a qualquer momento sem precisar explicar o motivo. Caso seja oferecido um contrato de pagamentos por serviços ambientais, você poderá decidir se quer ou não assinar o contrato. Mesmo assinando o contrato, poderá decidir ou não cumprir com o que solicitaremos no contrato, ou seja, conservar a floresta localizada em sua propriedade (mas, lembrando que, nesse caso, não receberá nenhum pagamento em dinheiro no final, ou receberá algum pagamento, mas com os descontos estabelecidos no contrato do tipo Flexível). Seu nome e outros dados pessoais não serão divulgados fora da equipe do estudo, em nenhuma etapa do estudo, ou mesmo no futuro. Os dados

serão analisados somente pela equipe do estudo. A equipe do estudo transformará os nomes em números, de modo que só sejam identificáveis pela própria equipe.

Sua participação é essencial para este estudo e queremos lembrar que não existe resposta certa para nenhuma pergunta que iremos fazer. Vamos sempre respeitar sua opinião, costumes, crenças, visão de mundo e sua vivência.

Se, durante o desenvolvimento do estudo, você ou sua propriedade forem filmados e fotografados, você:

☐ concorda que elas poderão ser apresentadas em publicações científicas, aulas, palestras e materiais de divulgação do projeto.

☐ não concorda que elas sejam incluídas em qualquer tipo de publicação ou material de divulgação.

E se eu precisar falar com alguém sobre esse estudo?

Para dúvidas, você pode ligar ou enviar um e-mail à nossa equipe. Telefones para contato: (68) 3223-1036 e (68) 9 9281 4417. E-mail: arendadafloresta@sosamazonia.org.br.

2. TERMO DE CONSENTIMENTO LIVRE, APÓS ESCLARECIMENTO

Eu,_____, declaro que concordo em participar voluntariamente deste estudo e que fui esclarecido sobre a natureza da pesquisa, seus objetivos, métodos, benefícios previstos e potenciais riscos. Afirmo que aceitei participar por minha própria vontade, sem sofrer qualquer tipo de coação ou constrangimento, sem receber qualquer incentivo prévio financeiro, e sem ter qualquer ônus, com a finalidade de colaborar com o sucesso do estudo. Fui ainda informada(o) de que posso me retirar desse estudo/pesquisa a qualquer momento, sem precisar esclarecer meus motivos, sem qualquer prejuízo ou sofrer quaisquer sanções ou constrangimentos, e de que posso entrar em contato com as/os pesquisadores responsáveis pelo estudo a qualquer momento pelos telefones e e-mails que constam neste documento.

Confirmo que recebi uma cópia assinada deste Termo de Consentimento Livre e Esclarecido.

Local: _____Data _____/_____/_____.

Assinatura do participante: _____

Assinatura do pesquisador: _____

CONTRATO PSA/SOS AMAZÔNIA/ARDF Nº ____ /2021

A RENDA DA FLORESTA

CONTRATO DE PAGAMENTO POR SERVIÇOS AMBIENTAIS (PSA)

CONTRATO TIPO FIXO

Por meio deste acordo particular:

A **ASSOCIAÇÃO SOS AMAZONIA**, pessoa jurídica de Direito Privado inscrito no CNPJ/MF sob o nº 14.364.434/0001-85, situada na Rua Pará, nº 61, Bairro Habitasa na cidade de Rio Branco-Acre, neste ato representado por seu Secretário Técnico **Alisson Sobrinho Maranho,** brasileiro, inscrito no CPF/MF nº 938.646.042-49, residente e domiciliado na rua José Maria Rios, nº 412, apto 01, bairro Santa Quitéria, Rio Branco Acre e, por sua Secretária Administrativa **Gabriela Silva de Souza**, brasileira, inscrita no CPF/MF nº 895.043.482-20, residente e domiciliado na Rua Casa Nova I, 20, Baixa da Colina, 69.901-319, Rio Branco Acre, neste contrato denominada "SOS AMAZÔNIA",

O **INSTITUTO NACIONAL FRANCÊS DE PESQUISA EM AGRICULTURA, ALIMENTAÇÃO E MEIO AMBIENTE (INRAE)**, pessoa jurídica de Direito Público, inscrita no VAT FR 57 180 070 039 – APE 7219Z, localizada em Centre Occitanie-Montpellier, 2 Place Pierre Viala, 34060 Montpellier Cedex 2, França, representado por sua Diretora de Pesquisa, **Julie Subervie**, neste contrato denominado "INRAE", e

_____, devidamente inscrita(o) no CPF sob nº _____ e no RG nº _____ (órgão de expedição _____), com endereço na/no _____, no município de _____ no Estado do Acre, CEP _____, doravante denominado "PROPRIETÁRIO DA TERRA"

Firmam entre si o presente **CONTRATO DE PAGAMENTO POR SERVIÇOS AMBIENTAIS (PSA)**, que será regido pelas seguintes Cláusulas e Condições:

CLÁUSULA PRIMEIRA – DO OBJETO DO CONTRATO

O presente Contrato tem por objeto a conservação da floresta existente na propriedade do provedor de serviços ambientais (PROPRIETÁRIO DA TERRA), de forma voluntária, conforme os objetivos do programa piloto "A Renda da Floresta", implementado pela SOS AMAZÔNIA, em parceria com o Instituto Nacional Francês de Pesquisa em Agricultura, Alimentação e Meio Ambiente (INRAE).

A Renda da Floresta é um projeto de pesquisa, experimental, que tem o objetivo de implementar um programa piloto de Pagamento por Serviços Ambientais (PSA) na Amazônia brasileira. Esse Programa compensará proprietários de terra pelos esforços de conservar suas florestas. Por meio

desse estudo, será analisado se os participantes estão dispostos a receber dinheiro em troca da conservação da floresta e se esse incentivo financeiro trará resultados efetivos na região.

Parágrafo único: O Termo de Consentimento Livre e Esclarecido assinado pelo PROPRIETÁRIO DA TERRA, confirmando seu interesse em participar do estudo, é parte integrante deste Contrato.

CLÁUSULA SEGUNDA – DA ÁREA OBJETO DO CONTRATO

As partes, em comum acordo, definem o modo como será definido o perímetro da área que será objeto do contrato de Pagamento de Serviços Ambientais (PSA):

Parágrafo primeiro: A definição da área objeto do contrato será realizada na visita de assinatura do contrato de Pagamento de Serviços Ambientais (PSA), ocasião em que o proprietário da terra em conjunto com um membro integrante da SOS AMAZÔNIA definirão os limites da propriedade rural através do uso do software de mapeamento QGis, assim como os pontos limítrofes (coordenadas geográficas) através de uma ata. Tal delimitação tomará como base, inicialmente, os limites estabelecidos no Cadastro Ambiental Rural (CAR) da propriedade, porém com possíveis alterações desses limites para que o mapeamento da área do contrato seja condizente com a real delimitação da propriedade, conforme relatado pelo proprietário.

Parágrafo segundo: A definição da área será realizada mediante assinatura de ata, contendo as coordenadas geográficas definidas para a área mapeada, com assinatura das partes envolvidas no presente contrato.

Parágrafo terceiro: Não poderá ser objeto de contestação a definição da área, após assinatura da ata e do respectivo contrato.

CLÁUSULA TERCEIRA – DA PREVISÃO LEGAL

O Pagamento por Serviços Ambientais (PSA) está legalmente previsto na Lei Federal nº 14.119/2021, a qual institui a Política Nacional de Pagamento por Serviços Ambientais (PNPSA).

CLÁUSULA QUARTA – DO PRAZO DO CONTRATO

Este acordo terá a duração de 14 (quatorze) meses, contados da data de assinatura, sendo 12 (doze) meses o período em que o PROPRIETÁRIO DA TERRA deverá cumprir o compromisso voluntário de proteger sua parcela de floresta, e, após esse período, 2 (dois) meses de prazo para que a SOS AMAZÔNIA efetue o pagamento (PSA) do valor acordado, caso verificado o cumprimento.

CLÁUSULA QUINTA – DO DIREITO DE PROPRIEDADE

Este acordo não implica em nenhum direito de propriedade ou expropriação de terra por parte da SOS AMAZÔNIA, do INRAE ou qualquer de seus parceiros do Programa A Renda da Floresta sobre a(o) PROPRIETÁRIO DA TERRA que presta o Serviço Ambiental, sendo o seu direito de propriedade inviolável.

CLÁUSULA SEXTA – DA COMPENSAÇÃO PELA CONSERVAÇÃO DA FLORESTA

Por meio deste acordo, o PROPRIETÁRIO DA TERRA concorda em receber, ao final do contrato, o valor de R$ _____ (_____) pela preservação integral da área de floresta existente em sua propriedade.

Parágrafo primeiro: A SOS AMAZÔNIA penas pagará a compensação financeira caso toda a sua área de floresta seja preservada até o final do Contrato. Ou seja, se for constatado que o PROPRIETÁRIO DA TERRA desmatou parte da área de floresta, mesmo que mínima, o pagamento não será realizado.

Parágrafo segundo: A propriedade rural com a área de floresta a ser preservada durante o estudo está localizada em: _____

Parágrafo terceiro: A área total de floresta existente na propriedade do PROPRIETÁRIO DA TERRA será estimada, pelo INRAE, por imagens de satélite com base no perímetro da área que será objeto do contrato, definida em conjunto entre um membro integrante da SOS AMAZÔNIA e o PROPRIETÁRIO DA TERRA e registrada em ata, conforme CLÁUSULA SEGUNDA.

Parágrafo quarto: A área florestal será monitorada pelo INRAE por meio de imagens de satélite, o que servirá de base para a verificação do cumprimento dos compromissos voluntários do PROPRIETÁRIO DA TERRA. Ou seja, ao final do Contrato, será feita uma análise comparativa da situação da cobertura de floresta da propriedade no decorrer de 12 (doze) meses, para constatar se o Pagamento por Serviços Ambientais será pago e em quais condições.

CLÁUSULA SÉTIMA – DOS COMPROMISSOS VOLUNTÁRIOS DO PROPRIETÁRIO DA TERRA

O PROPRIETÁRIO DA TERRA é a parte provedora de serviços ambientais e deverá cumprir, pelo período de 12 (doze) meses, os seguintes compromissos voluntários para conservar sua área de floresta e, ao final do contrato, poder receber o Pagamento por Serviços Ambientais (conforme definido na CLÁUSULA QUINTA):

1. Tomar as medidas que estejam ao seu alcance para proteger a integridade da área de floresta;

2. Não cortar a área de floresta a ser protegida para o desenvolvimento de atividades econômicas, como agricultura e pecuária;

3. Não fazer uso de fogo na área de floresta a ser protegida, bem como prevenir contra possíveis incêndios florestais; e

4. Informar seus dados bancários e pessoais necessários para que seja possível realizar o pagamento da compensação ao final do Contrato, se for o caso. Se o PROPRIETÁRIO DA TERRA ainda não possuir uma conta bancária em seu nome no momento da assinatura, deverá informar à SOS AMAZÔNIA no prazo de 6 (seis) meses, por e-mail ou telefone.

Nome do titular da conta bancária: _____
CPF: _____ Banco: _____
Agência: _____ Conta: □ Corrente □ Poupança _____

Parágrafo único: O PROPRIETÁRIO DA TERRA poderá continuar desenvolvendo atividades que não geram a derrubada de árvores, como, por exemplo, a coleta de produtos florestais não madeireiros.

CLÁUSULA OITAVA – DAS OBRIGAÇÕES DA SOS AMAZÔNIA

Neste acordo, a SOS AMAZÔNIA é a parte pagadora de serviços ambientais e possui as seguintes obrigações:

1. Realizar o pagamento da compensação financeira à título de Pagamento por Serviço Ambiental no prazo de 2 (dois) meses a contar do término do período de 12 (doze) meses em que o PROPRIETÁRIO DA TERRA deverá preservar sua área de floresta; e

2. Estar à disposição sempre que o PROPRIETÁRIO DA TERRA desejar tirar dúvidas acerca do acordo ou do estudo sendo implementado.

CLÁUSULA NONA – DAS OBRIGAÇÕES DO INRAE

Neste acordo, o INRAE é a instituição de pesquisa parceira na implementação do Programa e possui as seguintes obrigações:

1. Realizar análises por meio de imagens de satélite para estimar a área de floresta existente na propriedade e monitorar a área durante a vigência do contrato;

2. Estar disponível para esclarecer ao PROPRIETÁRIO DA TERRA, sempre que necessário, sobre o andamento do estudo e quaisquer dúvidas que surjam durante a implementação do contrato, reiterando que o vínculo estabelecido pelo presente Contrato se trata de uma pesquisa, de modo a fortalecer a participação, seja por telefone, e-mail ou outro meio de comunicação direto (conforme o Termo de Consentimento Livre e Esclarecido); e

3. Enviar relatórios quando solicitado pelo PROPRIETÁRIO DA TERRA para informar sobre os dados de monitoramento de sua propriedade, onde devem constar as evidências de cumprimento ou não cumprimento dos compromissos voluntários quanto à conservação da floresta.

Parágrafo único: Os dados coletados referentes à área florestal do PROPRIETÁRIO DA TERRA serão usados exclusivamente para subsidiar a pesquisa e este Contrato, sendo mantidos de forma sigilosa, e nenhuma informação será compartilhada com terceiros. Nenhum dos dados coletados e analisados durante o estudo se destinam ao compartilhamento com órgãos de fiscalização ambiental.

CLÁUSULA DÉCIMA – DO NÃO CUMPRIMENTO E DA RESCISÃO DO CONTRATO

1. Caso o PROPRIETÁRIO DA TERRA não realize o serviço ambiental desejado neste Contrato, ou seja, se não cumprir com seu compromisso voluntário de conservar a floresta, não receberá nenhuma compensação financeira.

2. O PROPRIETÁRIO DA TERRA não sofrerá nenhuma penalidade contratual nem terá de arcar com nenhum ônus em razão do descumprimento de seu compromisso, pois este acordo é voluntário e não compulsório. Caso não cumpra o acordo, a depender do descumprimento, apenas não receberá parte ou a totalidade do valor oferecido, conforme a CLÁUSULA QUINTA.

3. Assim, o PROPRIETÁRIO DA TERRA, se desejar, poderá rescindir este Contrato a qualquer momento. Neste caso, a SOS AMAZÔNIA solicita que seja informada por e-mail ou telefone, preferencialmente, em até 7 (sete) dias após a decisão ser tomada.

CLÁUSULA DÉCIMA PRIMEIRA – DA PROTEÇÃO DE DADOS

A SOS AMAZÔNIA e o INRAE, por si e por seus colaboradores, obrigam-se a atuar neste Contrato e no bojo do estudo em conformidade com a Legislação vigente sobre Proteção de Dados Pessoais e as determinações de órgãos reguladores/fiscalizadores sobre a matéria, em especial a Lei 13.709/2018, além das demais normas e políticas de proteção de dados de cada país onde houver qualquer tipo de tratamento dos dados do PROPRIETÁRIO DA TERRA. O Termo de Consentimento para Coleta e Uso de Dados deve ser assinado pelo participante e é parte integrante deste Contrato.

CLÁUSULA DÉCIMA SEGUNDA– DAS DISPOSIÇÕES GERAIS

Tendo em vista que este acordo consiste em um projeto de pesquisa experimental, sendo todas as obrigações dele provenientes meramente voluntárias, sem contraprestação e por tempo determinado, não há qualquer vínculo entre as partes para fins da legislação trabalhista e tributária, bem como não há uma prestação de serviço propriamente dita, mas somente o compromisso voluntário de não desmatar a área de floresta, com o objetivo de promover serviços ecossistêmicos.

E assim, as partes assinam o Contrato em duas vias, na presença de duas testemunhas, para que produza efeitos, almejando que este acordo traga benefícios para ambas as partes, bons resultados para o estudo e leve mais consciência ambiental para todos que o conhecerem ou dele se beneficiarem.

_____ -AC, _____ de _____ de 2021

INRAE SOS AMAZÔNIA A RENDA DA FLORESTA

Appendix B: A simple model of WTA with a BDM procedure

We consider a group of landowners of size 1 (agents of deforestation, agricultural firms, landowners,...), who get some benefit from deforestation.

With $i \in [0,1]$, agent i's expected net payoff from deforestation is:

$$\pi_i(d_i) = b_i d_i - \frac{c}{2} d_i^2 \tag{9}$$

with $b_i d_i$ the income from deforestation d_i and $\frac{c}{2} d_i^2$ the cost of deforestation. For simplicity, we consider that b_i is our indicator of opportunity cost, and our only source of heterogeneity among landowners.

We first consider the business-as-usual scenario, which constitutes the reference level under no intervention. Then two types of contract to reduce deforestation are to be presented.

B.1. Business-as-usual

First we consider the BAU situation, what would happen if no REDD+ project was implemented. In the empirical section, the BAU situation refers to the outcome of the control group C.

In the case, landowners would choose their level of deforestation to maximise their net payoff described in equation (9) . The first-order condition gives the level of deforestation and the net payoff in the BAU: $d_i^{BAU} = \frac{b_i}{c}$ and $\pi_i^{BAU} = \frac{b_i^2}{2c}$.

B.2. BDM auctions

landowners are offered two types contracts (that we call A and B) to incentivize deforestation reduction. The contracts take the form of BDM auctions, as presented before. Under BDM auctions:

- landowner i states her bid w_i for contract A or B;
- A random payment a_i is drawn [13];
- If the random payment is larger than or equal to her bid, $a_i \geq w_i$, she is enrolled in the PES scheme, at the random payment drawn;
- If the random payment is smaller than her bid, $a_i < w_i$, she is not enrolled.

If we (and the landowner) assume a uniform distribution of the random payments, we have: $E(a) = \frac{\overline{a}}{2}$, $P(a_i < w_i) = \frac{w_i}{\overline{a}}$, and $P(a_i \geq w_i) = 1 - \frac{w_i}{\overline{a}}$.

[13] The interval $[0, \overline{a}]$ on which the draw is made is not known to the landowner. Yet her bid is made upon her belief on that interval. As a matter of simplicity, we assume that $\overline{a}$ is both the maximum potential draw and the landowner's belief.

B.3. Contract A: fixed

If she is enrolled under contract A (hence with probability $1 - \frac{w_i}{\overline{a}}$), landowner i receives a payment of the amount of the draw, for the full conservation of her forest cover: she has to set $d^B = 0$. If any deforestation is observed, she receives zero. If she is not enrolled, she can have her BAU deforestation level and payoff.

Her participation constraint to contract A is thus: $\pi_i^A = w_i \geq \pi_i^{BAU} \equiv \overline{w_i}^A$. $\overline{w_i}^A$ describes the minimum payment the landowner is willing to accept in order to participate to contract A. landowner i will thus make a bid equal to her opportunity cost.

Her expected payoff is:

$$\pi_i^A = \frac{1}{\overline{a}}(\frac{b_i^2}{2c})^2 + [1 - \frac{1}{\overline{a}}\frac{b_i^2}{2c}]\frac{\overline{a}}{2} \tag{10}$$

Expected enrollment, payoffs and individual deforestation levels thus take the form:

$$\begin{cases} \pi_i^A = \frac{\overline{a}}{2} \\ d_i^A = 0 \end{cases} \quad \forall i \in [0, \bar{i}^A] \tag{11}$$

$$\begin{cases} \pi_i^A = \pi_i^{BAU} = \frac{b_i^2}{2c} \\ d_i^A = d_i^{BAU} \end{cases} \quad \forall i \in [\bar{i}^A, 1] \tag{12}$$

$$\bar{i}^A \ s.t. \ \pi_{\bar{i}^A}^{BAU} = \frac{b_{\bar{i}^A}^2}{2c} = \frac{\overline{a}}{2} \tag{13}$$

Proposition 1: *Under fixed contract A, landowners make a bid equal to their opportunity costs. Enrolled is such that:*

1. ***Enrolled landowners:*** *landowners with low opportunity costs, i.e. lower than the expected draw, are expected to be enrolled and completely cease deforestation;*

2. ***Non-enrolled landowners:*** *landowners with high opportunity costs, i.e. higher than the expected draw, are expected not to be enrolled and adopt a deforestation behavior as in BAU.*

The number of non-enrolled landowners is larger when more landowners have large opportunity costs with respect to the expected draw.

In proposition 1, bidders are supposed to make an bid equal to their opportunity cost in order to have a positive net payoff if enrolled. Another possibility for those bidders is to make a random bid and not respect the zero deforestation condition if the draw is lower than their opportunity cost. In this case, those bidders can get out of the contract at no cost and perform their BAU deforestation level.

Expected total avoided deforestation from the project is:

$$AD^A = \int_0^{\bar{i}^A} d_i^{BAU} f(i) di \tag{14}$$

Figure 13: **Contract A: bids w_i^A and enrollment as a function of opportunity cost b_i**

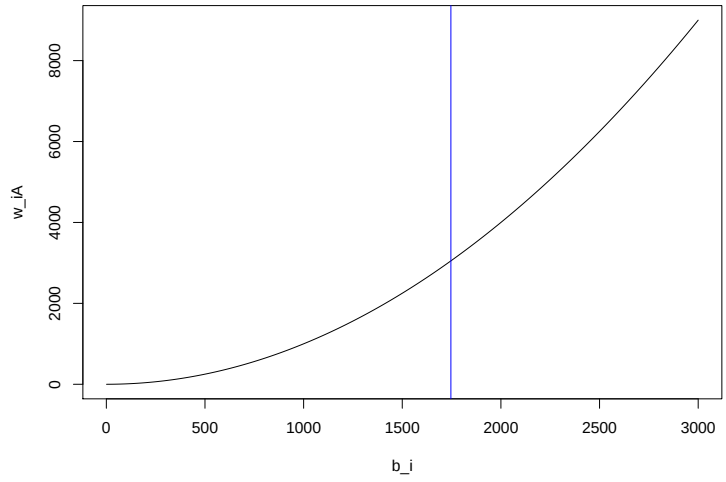


Figure 14: **Contract A: deforestation d_i^A as a function of opportunity cost b_i**

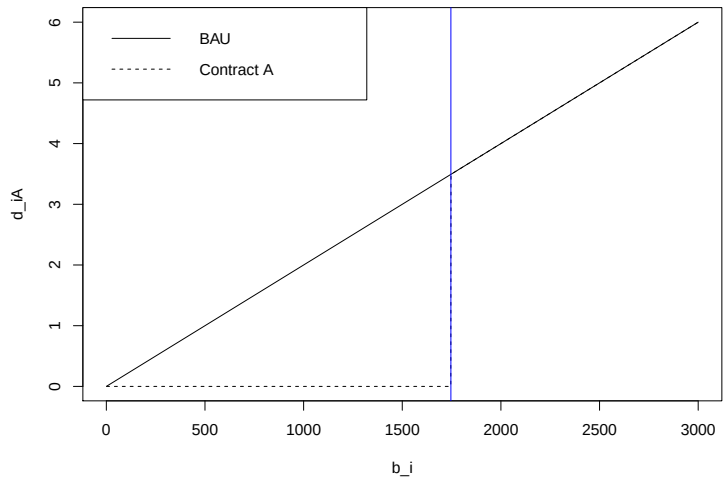
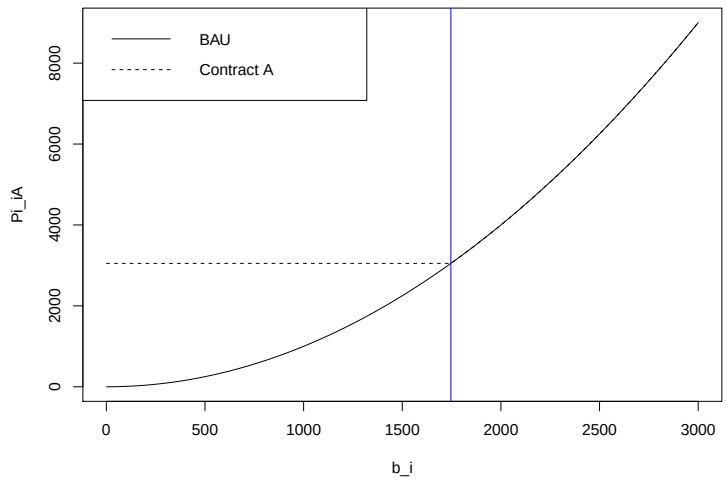


Figure 15: **Contract A: expected payoff π_i^A as a function of opportunity cost b_i**



B.4. Contract B: flexible

The second type of contract is a more flexible version than contract A. In contract B, the full payment is received if no deforestation is observed, but a penalty $\gamma(d_i)$ decreases the payment for any deforestation observed on the holder's land. The penalty is increasing and convex in the deforestation level: $\gamma(d_i) = \gamma d_i^2$. Hence the expected payment made to the landowner is: $(1 - \gamma d_i^2)E(a)$.

Note here that the payment has to be non-negative, which implies: $d^{max} \equiv \frac{1}{\gamma^{1/2}}$. d^{max} represents the level of deforestation that makes landowners default the contract and get no payment. When the penalty rate γ goes to infinity, contract B gets similar than contract A: when $\gamma \to \infty$, $d^{max} \to 0$. When the penalty rate goes to zero, contract B is very flexible and does not bring any constraint to the landowner when $\gamma = 0$, $d^{max} \to \infty$.

landowner i's participation constraint is:

$$\begin{aligned} \pi_i^{BAU} &\leq \pi_i^B(w_i, d_i) = b_i d_i - \frac{c}{2} d_i^2 + w_i[1 - \gamma d_i^2] \\ &\iff \\ w_i &\geq \frac{\pi_i^{BAU} - (b_i d_i - \frac{c}{2} d_i^2)}{(1 - \gamma d_i^2)} \equiv \overline{w_i}^B(d_i) \end{aligned} \tag{15}$$

$\overline{w_i}^B(d_i)$ describes the minimum payment the landowner is willing to accept in order to participate to the bid. It has to compensate for the landowner's opportunity cost of reducing deforestation from d_i^{BAU} to her actual deforestation level under contract B.

The expected payoff under contract B (equation (15)) is larger than the one in contract A (w_i) if the level of the penalty is lower than the payoff of non participation: $w_i \gamma d_i^2 > b_i d_i - \frac{c}{2} d_i^2$. It follows that there is a penalty level $\overline{\gamma}(b_i)$ above which the willingness to accept contract B will be higher than the one of accepting contract A.

If she is enrolled, she can choose a positive level of deforestation such that:

$$\max_{d_i} b_i d_i - \frac{c}{2} d_i^2 + \frac{\overline{a}}{2}[1 - \gamma d_i^2] \tag{16}$$

which gives: $d_i^B = \frac{b_i}{c + \gamma \overline{a}}$.

Integrating the individual deforestation level into the bid brings:

$$\overline{w_i}^B = \pi_i^{BAU} \frac{(\gamma \overline{a})^2}{(c + \gamma \overline{a})^2 - \gamma b_i^2} \tag{17}$$

Overall, contract B brings the following expected outcome:

$$\begin{cases} \pi_i^B = \pi_i^{BAU} \frac{c}{c+\gamma\overline{a}} + \frac{\overline{a}}{2} \\ d_i^B = \frac{b_i}{c+\gamma\overline{a}} \end{cases} \quad \forall i \in [0, \bar{i}^B] \tag{18}$$

$$\begin{cases} \pi_i^B = \pi_i^{BAU} = \frac{b_i^2}{2c} \\ d_i^B = d_i^{BAU} = \frac{b_i}{c} \end{cases} \quad \forall i \in [\bar{i}^B, 1] \tag{19}$$

$$\bar{i}^B \ s.t. \ \pi_{\bar{i}^B}^{BAU} = \frac{c+\gamma\overline{a}}{2\gamma} \tag{20}$$

Proposition 2: *Under flexible contract B, increasing the penalty level* γ *:*

- *increases the individual deforestation level of enrolled landowners :* $\frac{\partial d_i^B}{\partial \gamma} < 0$.
- *decreases the number of enrolled landowners:* $\frac{\partial \bar{i}^B}{\partial \gamma} < 0$.
- *decreases the expected payoff of enrolled landowners:* $\frac{\partial \pi_i^B}{\partial \gamma} < 0$.

Figure 16: **Contract B: larger flexibility (lower γ) increases individual levels of deforestation**

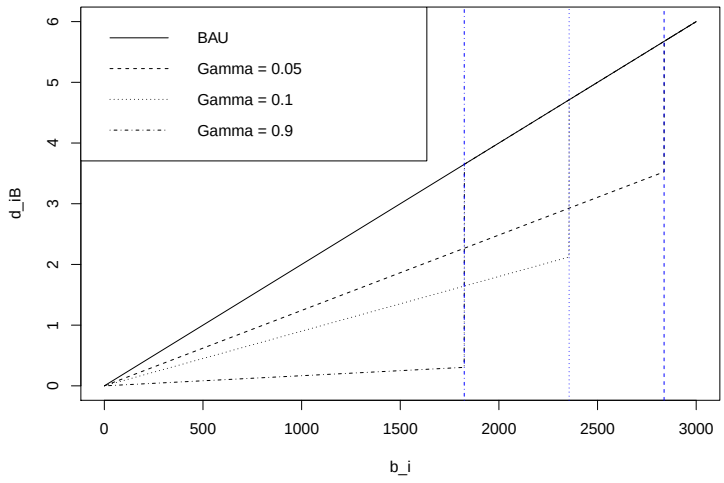


Figure 17: **Contract B: larger flexibility (lower γ) increases participation (lowers willingness to accept w_i^B)**

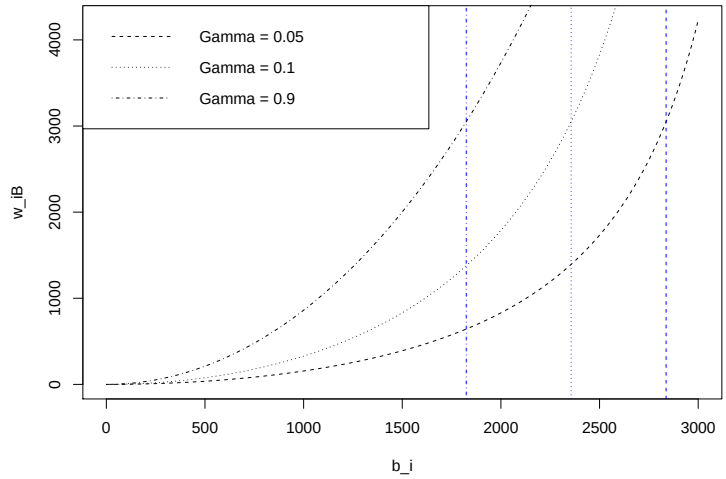
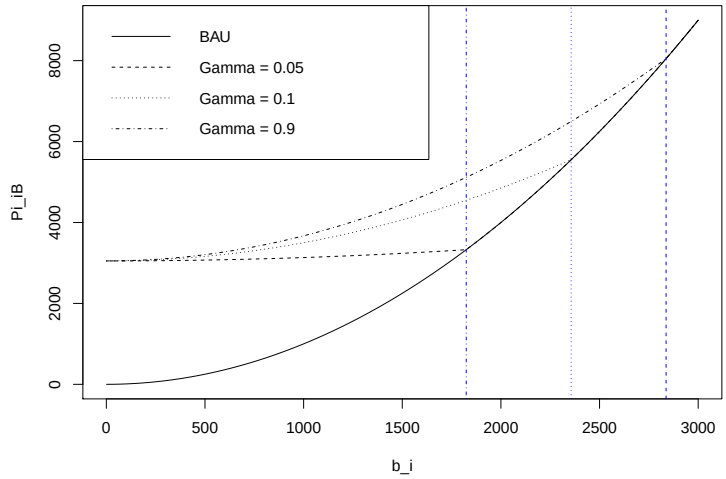


Figure 18: **Contract B: larger flexibility (lower γ) increases expected payoffs**



Expected total avoided deforestation from the project under contract B is:

$$AD^B = \int_0^{\bar{i}^B} d_i^{BAU} - d_i^B f(i)di = \int_0^{\bar{i}^B} b_i \frac{\gamma \overline{a}}{c(c+\gamma \overline{a})} f(i)di \tag{21}$$

B.5. Default risk in the case of an income shock

Our simple model underlines the mechanisms behind adding some flexibility to a PES contract in a BDM framework. In the model, landowners have perfect knowledge of their opportunity cost of reducing deforestation. In real life, some positive shocks, increasing b_i, can influence the landowners' opportunity costs once the contract has been implemented. As landowners can generally decide to exit from avoided deforestation contracts at no cost, those unexpected shocks can create a default risk of contract A and B. It can be the case, for instance, if there is a boom in commodity prices, that makes a contract exit more profitable.

In contract A, landowner i decides to exit the contract if the increase in b_i implies a switch from condition (3) to condition (4). In contract B, landowner i decides to exit the contract if the increase in b_i implies a switch from condition (10) to condition (11); but she can also adapt her deforestation level (and have a penalty) to the shock if the increase in b_i does not imply this switch of conditions. Therefore it is trivial to say that a larger default risk can be expected in contract A than B, as it is more rigid, that we can write: $Df_i^A > Df_i^B$.

More precisely:

- Small shocks do not impact the default risk, but increase the level of deforestation for landowners enrolled in contract B.
- Medium shocks increases the default risk in A but not in B, and the level of deforestation for landowners enrolled in contract B.
- Large shocks increase the default risk in A and B and the level of deforestation of landowners complying to contract B.

Note that a positive shock may not be homogeneous among landowners. Depending on their activity portfolio, some landowners may be impacted by such a positive shock while others are not.

B.6. Comparing contract A and B

The participation and bid of contract A and B can be compared.

		Contract A	Comparison	Contract B
Bid	$w_i^{A,B}$	π_i^{BAU}	$> \iff \gamma < \frac{c^2}{b_i^2 - 2c\overline{a}}$	$\pi_i^{BAU} \frac{(\gamma\overline{a})^2}{(c+\gamma\overline{a})^2 - \gamma b_i^2}$
Enrollment	$\int_0^{\bar{i}^{A,B}} f(i)di$	$\int_0^{\bar{i}^{A}} f(i)di$	$<$	$\int_0^{\bar{i}^{B}} f(i)di$
Default	Df_i	Df_i^A	$>$	Df_i^B
Individual deforestation	$d_i^{A,B}$	0	$<$	$\frac{b_i}{c+\gamma\overline{a}}$
Total avoided deforestation	$AD^{A,B}$	$\int_0^{\bar{i}^{A}} d_i^{BAU} f(i)di$	$>$ or $<$	$\int_0^{\bar{i}^{B}} b_i \frac{\gamma\overline{a}}{c(c+\gamma\overline{a})} f(i)di$
Average avoided deforestation	$\frac{AD^{A,B}}{\int_0^{\bar{i}^{A,B}} f(i)di}$	$\frac{AD^{A}}{\int_0^{\bar{i}^{A}} f(i)di}$	$>$ or $<$	$\frac{AD^{B}}{\int_0^{\bar{i}^{B}} f(i)di}$
Individual payoffs	$\pi_i^{A,B}$	$\frac{\overline{a}}{2}$	$<$	$\pi_i^{BAU} \frac{c}{c+\gamma\overline{a}} + \frac{\overline{a}}{2}$

Proposition 3:

1. ***Bid:*** *the bid made by landowner i in contract A is larger than the bid made in contract B, if the penalty level is low enough: $\gamma < \overline{\gamma}(b_i) = \frac{c^2}{b_i^2 - 2c\overline{a}}$. Then, for a given set of contracts A and B, landowners with low opportunity costs have a willingness to accept contract A larger than contract B, and landowners with high opportunity costs have a willingness to accept contract A lower than contract B (see figure 19).*

2. ***Enrollment:*** *expected enrollment is larger in B than in A.*

3. ***Default:*** *default risk is larger in A than in B, in particular related to medium shocks. Small shocks do not impact the default risk, while large shocks impact both landowners in contract A and B.*

4. ***Individual Avoided deforestation:*** *avoided deforestation from landowners complying to the contract is smaller in B than in A. landowners not complying with the contract provide their BAU deforestation levels.*

5. ***Total avoided deforestation:*** *the difference between contract A and B in terms of total avoided deforestation is undetermined. It is also a matter of participation and distribution of avoided deforestation effort: in contract A, due to lower enrollment and larger default risk, fewer landowners (with lower opportunity costs) make all the avoided deforestation effort. In contract B, more landowners provide some avoided deforestation effort.*

6. ***Average Avoided Deforestation:*** *the difference between contract A and B is not determined. However, it is important to distinguish the average avoided deforestation of enrolled landowners (as in the table) from the average avoided deforestation from complying landowners (that would take the default risk into account).*

7. ***Payoffs:*** *expected payoffs of enrolled landowners are larger in contract B than A. Further, since enrollment is larger, contract B bring an increase in expected payoffs for a larger number of landowners.*

Proofs in appendix C.

Which contract is the most effective to reduce deforestation is not determined in the model, and depends on the distribution of the population of landowners. However, the distribution of effort between contract A and B can be assessed: in contract A, fewer landowners completely stop their deforestation; in contract B, more landowners reduce their deforestation. It follows that in contract A, all the avoided deforestation effort is carried by lower income landowners; while in contract B, the avoided deforestation effort is spread between a larger number of landowners.

The same is true about the costs of the two contracts. Three components can be distinguished: first, direct costs from the payments; second, transaction costs related to the number of enrolled landowners; third, fixed costs. Overall, we have:

$$TC_A = \sum_{i=0}^{\bar{i}^A} \frac{\overline{a}}{2} + TC(\sum_{i=0}^{\bar{i}^A}) + FC \tag{22}$$

$$TC_B = \sum_{i=0}^{\bar{i}^B} \frac{\overline{a}}{2}(1 - \gamma(\frac{b_i}{c + \gamma\overline{a}})^2) + TC(\sum_{i=0}^{\bar{i}^B}) + FC \tag{23}$$

Proposition 4:

1. ***Direct costs****: individual direct costs are lower in contrat B than A:* $\frac{\overline{a}}{2} > \frac{\overline{a}}{2}(1-\gamma(\frac{b_i}{c+\gamma\overline{a}})^2)$*; but contract B implies more participants (and lower default risk); the net effect is undetermined.*

2. ***Transaction costs****: transaction costs are larger under contract B, since more landowners are enrolled. Transaction costs from enrolled landowners could be distinguished from transaction costs of complying landowners. However, since the default risk is also larger in contract A, the two types of transaction costs go in the same direction.*

3. ***Fixed costs****: fixed costs are obviously the same under the two contracts; however, the average fixed costs are lower in contract B:* $AFC_A = \frac{FC}{\int_0^{\bar{i}^A} f(i)di} > AFC_B = \frac{FC}{\int_0^{\bar{i}^B} f(i)di}$

4. ***Total costs****: Overall which contract is the least costly is not determined.*

Figure 19: **Willingness to accept in contract A is larger than in contract B for low enough value of the penalty level**

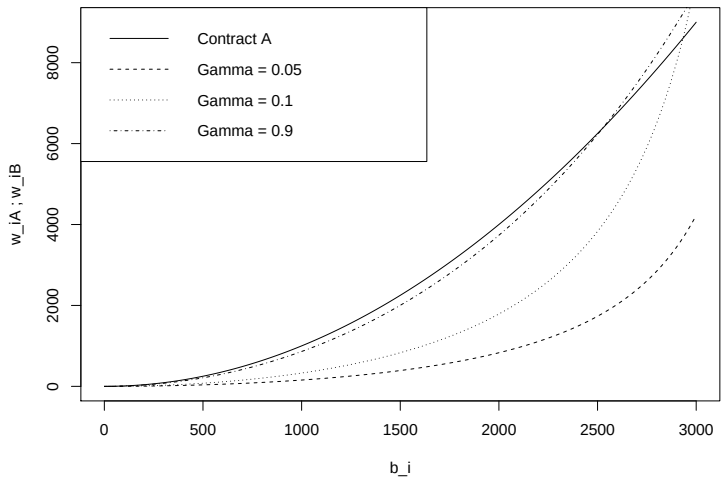


Figure 20: **Enrollment and Individual deforestation of enrolled landowners is larger in contract B than A**

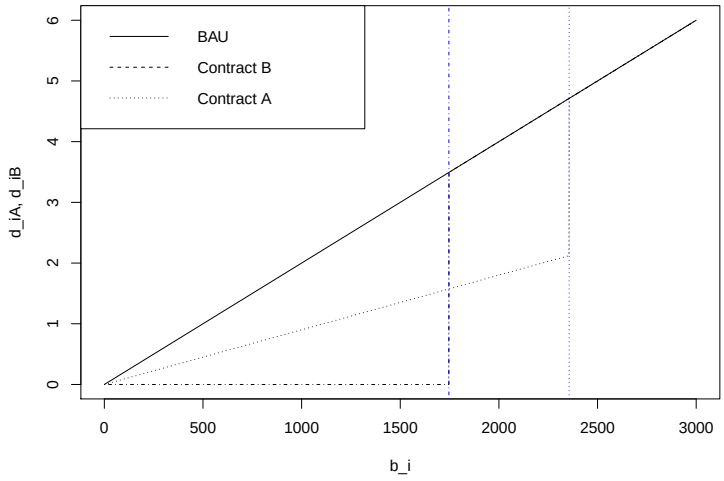
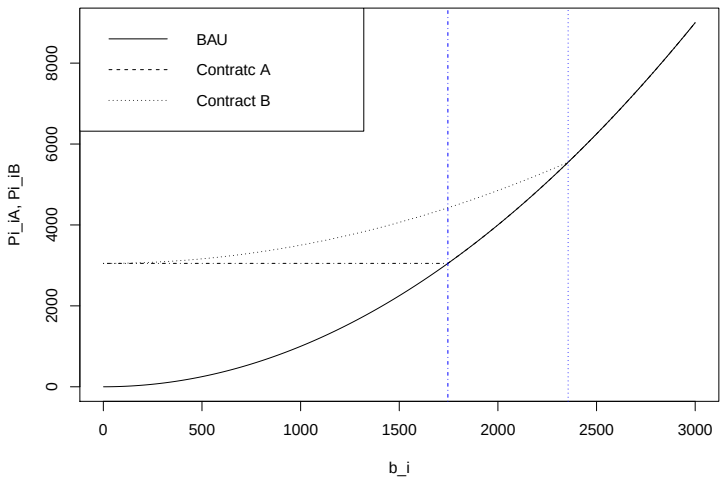


Figure 21: **Payoffs of enrolled landowners is larger in contract B than A**



B.7. Parameters values and numerical examples results

Parameter	Value
b	$\in [0, 3000]$
c	300
$\overline{a}$	6100
γ	[0.05, 0.1, 0.8]

Contract	BAU	A	B		
			$\gamma = 0.05$	$\gamma = 0.1$	$\gamma = 0.9$
Participation		58 %	94 %	78 %	61 %
Deforestation	9003	5953	5952	5954	5952
Avoided deforestation		3050	3051	3049	3051
Payoff	9 004 500	12 554 040	14 772 050	13 793 191	12 712 222
Surplus		3 549 539	5 767 554	4 788 691	3 707 722

B.8. Proof of proposition 2

We have the individual level of deforestation that is decreasing with the penalty level:

$$\frac{\partial d_i^B}{\partial \gamma} = \frac{-b_i \overline{a}}{(c+\gamma\overline{a})^2} < 0 \tag{24}$$

Enrollment decreases when the penalty level increases :

$$\frac{\partial \bar{i}^B}{\partial \gamma} < 0 \tag{25}$$

$$\Longleftrightarrow$$

$$\frac{\partial \pi_{\bar{i}^B}}{\partial \gamma} = \frac{-c}{2\gamma^2} < 0 \tag{26}$$

The payoff of enrolled landowners decreases with the penalty level:

$$\frac{\partial \pi_i^B}{\partial \gamma} = -\frac{-\overline{a} b_i^2}{2(c+\gamma\overline{a})} < 0 \tag{27}$$

B.9. Proof of comparisons

1. The bid made in contract A is larger than the bid made in contract B if:

$$\overline{w_i}^A = \pi_i^{BAU} > \pi_i^{BAU} \frac{(\gamma\overline{a})^2}{(c+\gamma\overline{a})^2 - \gamma b_i^2} = \overline{w_i}^B \tag{28}$$

$$\Longleftrightarrow$$

$$\gamma < \frac{c^2}{b_i^2 - 2c\overline{a}} \equiv \overline{\gamma}(b_i) \tag{29}$$

2. Enrollment is larger under contract B than A:

$$\bar{i}^B > \bar{i}^A \tag{30}$$

$$\iff$$

$$\frac{c+\gamma\overline{a}}{2\gamma} > \frac{\overline{a}}{2} \tag{31}$$

$$\iff$$

$$c > 0 \tag{32}$$

3. It is straightforward to see that individual deforestation levels of enrolled landowners are lower in A than in B: $d_i^A = 0 > d_i^B = \frac{b_i}{c+\gamma\overline{a}}$. Hence individual avoided deforestation is larger in A than in B.

4. The net effect on total avoided deforestation is undetermined: enrollment is larger in B than in A, while individual deforestation levels are lower in B than in A.

5. In terms of payoffs, it is straightforward to see that for enrolled landowner: $\pi^B = \pi_i^{BAU\frac{c}{c+\gamma\overline{a}}} + \frac{\overline{a}}{2} > \frac{\overline{a}}{2} = \pi^A$.

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