Environmental Evaluations of Agricultural Multinational's Deforestation Mitigation Efforts in the Amazon[1]

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ABSTRACT

Environmental protection fails to occur in many developing countries even when they have good environmental laws because of limited government ability to monitor and enforce environmental laws. An alternative route to monitoring and enforcing environmental laws is to engage private firms and non-governmental organizations (NGOs). In this paper, we evaluate whether the Responsible Soy Project, a partnership between Cargill and The Nature Conservancy (TNC), was successful in enforcing Brazil's Forest Code, a stringent law to prevent deforestation. Implementation of the Responsible Soy Project, however, was preceded by the opening of a new port facility in the Brazilian Amazon that opened new areas to profitable agricultural production. We develop a profit maximization model to understand farmers' agricultural production and deforestation decisions. We then empirically evaluate whether the Responsible Soy Project had an environmental impact using difference-in-difference (DID) and nearest neighbor covariate matching methods. Theoretical results predict and empirical results show higher deforestation rates for landowners participating in the project (the treatment group) immediately after the port opened compared to other landowners (the control group), but little difference in deforestation rates between the control and the treatment group after the project started. These results emphasize the importance of timing. To be effective, environmental conservation projects should start before economic development activities that encourage deforestation.

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I. Introduction

Agricultural expansion in Brazil has contributed to economic development through increased production of agricultural commodities but has also caused widespread deforestation in the Amazon River basin. Over 750,000 km^2 of total forest area in the Brazilian Amazon (18.9%) had been cleared by 2012 (INPE 2013), which has led to the release of carbon into the atmosphere and the loss of biodiversity. Traditionally, governments are responsible for regulating economic activities to maintain environmental quality, and Brazil is no exception. Brazil has one of the most stringent set of environmental law in the world. The Forest Code, enacted in 1965 and strengthened in 1995, requires 80% of each property in the Amazon be preserved as primary forest. Despite the strict law, however, deforestation continued due to ineffective government monitoring and enforcement. An alternative route to monitoring and enforcement is a market-oriented approach that engages multinational companies and non-governmental organizations (NGOs). Multinationals may have incentives to enforce environmental quality standards because of increased demand for sustainable products, or commitment to corporate social responsibility. Their buying power can force farmers to comply with the environmental law. NGOs can monitor farmers' performance using remote sensing technologies and provide assurance that environmental standards are upheld.

The Responsible Soy Project in Brazil is an example of collaboration between a multinational and an NGO. In 2005, Cargill began working with The Nature Conservancy (TNC) on a pilot project called the Responsible Soy Project in the municipality of Santarém, located where Tapajós River joins the Amazon River, and the site of a newly opened port facility to export soybeans. TNC tracked deforestation through a satellite monitoring system and Cargill agreed to buy soybeans only from farmers who had not deforested their land from the time of the start of the project. The project contributed to the establishment of the Soy Moratorium in 2006, where all major agricultural companies agreed not to buy soybeans from farmers who had deforested their land. NGOs, such as TNC, World Wildlife Fund (WWF), and Greenpeace, were responsible for oversight of this moratorium.

In this paper, we investigate conditions when economic incentives, enforced by multinational agricultural companies and monitored by NGOs is effective in monitoring and enforcing environmental laws. We construct a theoretical model using a farmer's profit maximization framework to understand farmers' deforestation decisions under specific assumptions that attempt to replicate the conditions of the Responsible Soy Project. We use a unique data set from the project to empirically test the hypothesis that conservation projects by private companies and NGOs can significantly decrease deforestation. We use nearest neighbor matching and difference-in-difference (DID) methods to compare deforestation rates between landowners enrolled in the project (the control group) and landowners not enrolled in the project (the treatment group) before and after the port construction in 2003 and before and after the implementation of the Responsible Soy Project in 2005. Empirical estimates show that the opening of the port in 2003 dramatically increased deforestation rates in the region. After the project was initiated in 2005, there was a dramatic decline in deforestation rates. There was a larger decline in deforestation rates in the treatment group than in the control group. It is unclear whether this larger decline is because of the effect of the Responsible Soy Project or a reversion to more typical deforestation rates following elevated deforestation in 2003-2004. The results and implication of this study provide important information not only to multinationals and NGOs that are already engaged in various conservation projects, but also to governments looking to this type of partnership to help enforce and monitor environmental laws.

Review of the Literature

This paper is one of the first quantitative studies to evaluate the impact of market-oriented projects implemented by private companies and NGOs to reduce environmental degradation. The relevant literature can be divided into: a) political and business literature, andb) conservation and economics literature. The former literature uses mostly qualitative analysis to study causes and consequences of environmental governance by private companies engaging other institutions including NGOs and governments. The latter literature, in many cases, estimates the impact of market-oriented projects implemented by both the government and NGOs. This paper ties these two literatures together by quantitatively estimating the impact of a project that was initiated by a private company and an NGO.

Many studies in the politics and business literature conduct qualitative analyses of the causes and consequences of collaborations for environmental conservation among different stakeholders, including private companies, NGOs, government, and civil society (Büthe 2010). Fuchs and Kalfagianni (2010) claim that the power of private governance in the food industry originates from the organizational strength of firms in the industry and the legitimacy of the regulations imposed by the firm. In addition, they argue that the impact of private governance in the food industry on the sustainability of the food system is currently “ambiguous”. On the other hand, Mayer and Gereffi (2010) contend that private regulations can be effectively sustained with institutionalization by the government in the long run.

The conservation and economics literature has extensive studies that quantitatively estimate the impact of market-oriented approaches that create economic incentives for land owners to minimize the environmental impacts of their economic activities and conserve their land. This market-oriented approach includes the creation of markets for environmental services: payments for ecosystem services (PES) and sustainability certification systems. There have also been studies that review various types of PES programs and sustainability certification systems around the world (Landell-Mills and Porras 2002; Pattanayak et al. 2010). Some of those studies suggest ways to improve current programs and others call for more evidence on the effectiveness of PES programs and sustainability certification systems. Wunder et al. (2008) provide a comprehensive review of case studies evaluating PES programs by comparing features, payment types, efficiency, and welfare effects. They discussed ways for the programs to be more efficient by being able to distinguish people who are in compliance to properly compensate them and by designing the program so that it is financed by the users of environmental services instead of by the government. Blackman and Rivera (2011), on the other hand, reviewed studies that examined economic and environmental benefits of sustainability certification systems. They found that there is insufficient evidence of benefits to the environment and to the producers from the certification systems due to a lack of rigorous quantitative studies with credible counterfactuals. Miteva et al. (2012) conclude that there is limited evidence on the effectiveness of protected area (PA), PES, and decentralization measures. They discuss how we can improve current evaluation studies by connecting theoretical with empirical studies, using better methods, such as considering the spatial spillover effects, and increasing interdisciplinary work that engages natural scientists, who understand the spatial data, with economists. The economics and conservation literature indicates that we still do not understand the effectiveness of market-oriented approaches, such as PES programs and sustainability certification system, because of a lack of rigorous studies that have good data and long span of the programs (Blackman and Rivera 2011; Pattanayak et al. 2010).

This study extends previous empirical studies of the impact of market-oriented approaches to conserve the environment. In the Responsible Soy Project, an agricultural multinational, Cargill, uses its purchasing power to enforce environmental regulations, with the oversight of conservation done by an NGO, TNC. This paper contributes to expanding our knowledge of the effectiveness of market-oriented approaches by evaluating the impact of a private company's enforcement of environmental regulations, which is relatively new in the field. The data set from the Responsible Soy Project has never been used before and provides a unique opportunity to evaluate the impact of a market-oriented approach that uses the purchasing power of a company as an enforcement mechanism.

II. Background

Brazilian Amazon and Deforestation in the Municipality of Santarém

The Brazilian Amazon is the largest tropical rainforest on the planet with the richest biodiversity in the world, comprising at least 10% of the world's amphibians and mammals and 17% of all bird species (FAO 2006). The Amazon biome constitutes 49.3% of Brazil's territory. Legal Amazon, which is a socio-geographic division in Brazil, is found in the northern part of Brazil and includes the entire states of Acre, Amapá, Amazonas, Pará, Rondônia, Roraima, and Tocantins in the North Region, part of the state of Mato Grosso and Maranhão in the Central-West Region and in the Northeast Region, respectively.

The modern history of deforestation in the Amazon begins in the late 1800s and early 1900s when about 300,000 hectares of forest land in the region of Santarém were cleared for rubber plantations and for the production of rice, corn, and other crops. The "Rubber Boom" accelerated after 1900 with the development of the automobile industry. The Brazilian rubber boom, however, was short-lived because of competition from Asian rubber suppliers and the invention of synthetic rubber. Many rubber plantations were subsequently abandoned. Some rubber plantations were reverted to secondary forest and some farmers grew corn and rice on abandoned plantation land. In the 1970s black pepper plantations were developed and the federal government started to make investments in transportation infrastructure. This increase in economic activity caused renewed deforestation. Extraction of mineral resources in the 1980s brought additional population and economic activity to the Santarém region (Moraes 2010). By 2000, the cumulative deforestation rate in Santarém was 16% (3,756 km^2) and as of 2010 the cumulative deforestation rate had reached 20% (4,586 km^2).

The Responsible Soy Project

Cargill opened a grain terminal at the port of Santarém, located on the confluence of the Amazon and Tapajós Rivers in northern Brazil, in 2003 (see Figure 1). Cargill built the facility because of increased congestion in southern Brazilian ports and to have an Amazonian port closer to European markets. Santarém has become a regional center for trade and finance in western Pará and has waterway, road, and air transportation links. According to the Brazilian Institute of Geography and Statistics (IBGE) census, the population of Santarém was 294,774 in 2010, a 12.3% increase from 2000 (IBGE 2010). The Santarém port exports mostly soybeans from the state of Mato Grosso; 95% of the soybean production exported through the Cargill facility comes from Mato Grosso. The opening of the Santarém port also made soybean production in the Santarém area more attractive because there was now a ready export outlet.

Shortly after the grain terminal at Santarém opened in 2003, The Nature Conservancy (TNC) began talking with Cargill about how to ensure that Cargill operations did not increase deforestation in the area around Santarém. Though it was illegal to deforest more than 20% of land area in each property under the Forest Code, Cargill did not have a way to distinguish between farmers who were in compliance with the Forest Code and those had violated the law.

In 2004, TNC and Cargill held an initial exploratory meeting to discuss a potential project in Santarém. Cargill and TNC had substantive discussions about the impact of road construction from the state of Mato Grosso to the Santarém municipality and a possible compliance tracking scheme for soybeans (Cleary 2004). This initial meeting led to the creation of the Responsible Soy Project, which was launched in December, 2004.

Cargill and TNC staff agreed on four main criteria that farmers would have to comply with in order to receive financing and be able to sell soybeans to the Cargill grain terminal in Santarém: i) have no deforestation of their property; ii) be in a legal process of compliance with the Forest Code (environmental licensing process); iii) have soy areas located in areas indicated for consolidation or expansion of agricultural activities according to ecological economic zoning (EEZ) of the state of Pará system; and iv) be registered in the rural environmental registration (CAR) system.

Starting in 2005, farmers in the Responsible Soy Project were subject to a zero deforestation requirement. Any observed deforestation on a property made the property ineligible and Cargill would not buy any soybeans grown on that property. The rule provides a clear and simple standard for soy sourcing. There were 15 properties out of 383 total properties in the project area that did not meet the requirement and were excluded from the project in 2008.

Observance of the Forest Code also requires restoration of Areas of Permanent Preservation (APP). Restoration of APP has been set as one of the key elements of the Responsible Soy Project because of the ecological importance of APP for water resources and biodiversity. TNC, working with the Forest Ecology and Restoration Laboratory (LERF) from the University of São Paulo, has been training farmers on how to restore APP. Starting in 2005, TNC held seminars and meetings to provide technical assistance to farmers on how to comply with the restoration of APP land and chose 12 pilot farms to demonstrate land restoration and monitoring mechanisms.

To monitor whether farmers are satisfying zero deforestation and APP restoration requirements, TNC monitors properties every year by satellite imagery and field inspection. Yearly observation allows TNC to compare the differences in forest cover on the property. The first version of the database was established in June 2005. It covered the entire areas of the municipalities of Santarém and Belterra (S&B). These two municipalities have a combined area of 27,285km^2. The database was later extended to the neighboring municipalities outside of S&B (96,256 km^2) in order to cover farmers outside of S&B that supply soybeans to the Santarém terminal (Cleary 2007). The initial assessment was used to create a map showing stands of primary forest in S&B as well as farm locations. Updated maps were completed in May 2007 and December 2008.

The other two rules of the Responsible Soy Project are that soy areas to be located within areas identified for consolidation or expansion of agricultural areas according to the ecological economic zoning (EEZ) and to be registered in the Integrated System for Environmental Licensing and Monitoring (SIMLAM), which is the system for rural environmental registration (CAR). EEZ involves strategic planning and management by the state government and considers physical and socioeconomic conditions for sustainable development. More specifically, EEZ establishes protected areas within a state. Farmers are prohibited from undertaking agricultural activities in these protected areas. CAR is a mandatory property registration system to promote identification and regularization of properties in each state. CAR stores spatial data on property boundaries to monitor and control farmers' economic activities in their fields. To register, farmers need to hire a technician to geo-reference their property along with environmental diagnosis and recovery planning for degraded areas. TNC has been helping farmers register their properties in the state environmental registration system. After farmers, along with TNC, submit the data and documentation they are classified as "provisional" until they are reviewed and approved to be "confirmed" by the state environmental agency (SEMA). The properties become registered to the Pará state system of environmental monitoring and licensing for rural properties (SIMLAM).

III. Theoretical Model

In this section, we develop a simple conceptual model to explain farmers' production and deforestation decisions. We specifically model a case where farmers have an increased opportunity to sell their products followed by a project designed to prevent deforestation, as in the case of the Responsible Soy Project. We use this simple model to explore how farmers' deforestation decisions change under different circumstances and investigate whether the model can explain what actually happened in the field.

There are three periods in the model. At the start of period 1, farmers clear land for agricultural production, which they can then produce and sell in periods 1, 2 and 3. In period 1, the only option for farmers is to sell agricultural output to Firm 1. Firm 1 may be thought of as a local buyer that pays a low price and does not impose environmental standards on farmers. Firm 2 enters in period 2. Firm 2 may be thought of as a multinational that exports agricultural output. Assume that Firm 2 pays a higher price for agricultural output than does Firm 1: $P_2 > P_1$. In period 3, Firm 2 introduces a strict environmental standard and will only buy from farmers who do not engage in deforestation in period 3. For simplicity, we assume prices are constant through time and that there is no discounting.

We assume that farmers do not anticipate future changes. Prior to period 2 farmers do not anticipate the entry of Firm 2 in period 2. Prior to period 3, farmers do not anticipate the imposition of the environmental standard in period 3. We assume that farmers maximize profits in each period given the conditions they face in that time period.

Let $d_i^t \geq 0$ denote the proportion of land deforested in period *t* by farmer *i*. Let $D_i^t \in [0,1]$ represent the cumulative proportion of farmer *i*'s property deforested in period *t*: $D_i^t = \sum_{s=1}^{t} d_i^s$. We assume there is a constant cost of deforestation per unit area: C_D. Define farmer *i*'s agricultural production function in period *t*, $f_i^t(A_i^t)$, to be a function of the proportion of area in cultivation, A_i^t. Production costs of farmer *i* in period *t* are a function of the proportion of land in cultivation, $C_i^t(A_i^t)$. Assume that both the production function and cost function are twice differentiable such that:

Assumption 1. $f_i^t(.)$ is increasing and concave ($f' > 0, f'' < 0$)

Assumption 2. $C_i(.)$ is increasing and convex ($C' > 0, C'' \geq 0$)

As long as net revenue of agricultural production does not decline through time, a profit maximizing farmer will set the proportion of area of cultivation equal to the cumulative amount of deforestation, $A_i^t = D_i^t$.

Finally, we assume that there are two types of farmers, those close to Firm 2 (e.g., close to the port) and those that are far away. Farmers of Type 1 have a high transport cost per unit of output in order to sell to Firm 2, C_1. Farmers of Type 2 have a low cost per unit of output in order to sell to Firm 2, C_2. For simplicity, we assume that $C_2 < P_2 - P_1 < C_1$ so that Type 2 finds it advantageous to sell to Firm 2 when possible ($P_2 - C_2 > P_1$), while Type 1 finds it advantageous to sell to Firm 1 ($P_2 - C_1 < P_1$).

Given the assumptions above, farmer *i* decides on the amount of deforestation in his farm (d_{ij}^t) to maximize his profit selling to Firm *j*:

$$\max_{d_i \in (0,1]} \pi_i(d_{ij}^t) = P_j f_i(d_{ij}^t) - C_{ij}(d_{ij}^t)$$

Below, we proceed by optimizing farmers' deforestation level under the two scenarios and compare maximized profits in each scenario to obtain conditions for choosing to sell to Firm 1 or Firm 2. Given that farmers did not know that Firm 2 will initiate the project in the post-project period, which is the nature of the Responsible Soy Project, we assume that farmers are not forward looking.

Period 1

The farmer expecting to sell agricultural production in periods 1, 2, and 3, to Firm 1 and with production and cost functions defined above solves the following problem to decide how much forest to clear initially:

$$Max \sum_{t=1}^{3} [P_1 f_i^t(D_i^t) - C_i^t(D_i^t) - C_D\, d_i^t]$$

Given that deforestation in period 1 generates cleared land that can be used for agricultural production in all three periods, the farmer anticipates that deforestation will occur in period 1 and not in periods 2 and 3. Let D_i^* represent the profit maximizing choice of deforestation for farmer i. The farmer will produce on all cleared land with production of $f_i^1(D_i^*)$ and net revenue of $P_1 f_i^1(D_i^*) - C_i^1(D_i^*) - C_D D_i^*$.

Type 1 Farmers in Periods 2 and 3

As there is no change in circumstances in periods 2 and 3 relative to period 1, there will be no further deforestation among these farmers. They will continue to produce on cleared land D_i^* and have the same level of output.

Type 2 Farmers in Periods 2 and 3

Each farmer now has the option of selling to Firm 2 in period 2 and given that $P_2 - C_2 > P_1$ Type 2 farmers will find it profitable to do so. Since marginal profit on further production is higher by selling to Firm 2, Type 2 farmers may find it profitable to clear more land in period 2. They will do so if

$$\sum_{t=2}^{3}(P_2 - C_2)\frac{\partial f_i^t(D_i^*)}{\partial D_i^t} - \frac{\partial C_i^t(D_i^*)}{\partial D_i^t} - C_D > 0 \quad (1)$$

In period 3, the farmer would not choose to clear more land.

Summary

Farmers that do not plan to sell to Firm 2 will not have an incentive to deforest their land in either period 2 or 3. Farmers that plan to sell to Firm 2 will have an incentive to deforest their land in period 2 assuming that the condition in equation (1) holds. No farmer will choose to deforest their land in period 3. The environmental standard imposed in period 3 to prevent further deforestation has no impact on deforestation behavior.

IV. Empirical Model

The Responsible Soy Project is a non-randomized experiment because farmers can choose whether to participate in the project. Consequently, farmer characteristics that make a farmer more likely to enroll in the project may be correlated with the deforestation rate on the property.

Even if we were able to control for all the observable characteristics that affect farmer choice, there may still be unobservable characteristics that are correlated with the participation decision and property deforestation rates, such as a farmer's environmental conscience. This correlation between unobservable farmer characteristics and the decision to participate will bias coefficient estimates in regression analysis (Imbens and Wooldridge 2009). There are four common econometric methods to deal with this problem: instrumental variable (IV) methods, regression discontinuity design (RD), matching method, and DID method. We use matching and DID methods to estimate the impact of both the port opening and the project implementation on deforestation. Unfortunately, we do not have a suitable instrument for IV estimation nor a threshold variable that determines participation in the project that can be used for RD estimation. Matching and DID methods have been widely used in recent years to evaluate the impact of policies and projects.

Nearest Neighbor Covariate Matching Method

The matching method matches each observation in the treatment group with one or more observations in the control group that have similar observable characteristics. We match each observation in the treatment group ($\mathrm{P}=1$) to the observations in the control group ($\mathrm{P}=0$) based on the observed set of variables, Z, given the "strong ignorability" assumptions below (Abadie and Imbens 2011; Rosenbaum and Rubin 1983):

(1) $E[Y_P|Z, P=1] = E[Y_P|Z, P=0]$

(2) $c < Prob(P=1|Z) < 1-c, for\ some\ c > 0$

where Y_P represents deforestation level of a farm in group P. The first assumption implies that the participation is not correlated with Y_P after conditioning on the observed factors Z that affect project participation, i.e., conditional independence assumption (Dawid 1979). This is a strong assumption because it means that participation is random for farmers with similar characteristics. The second assumption requires that the probability that a farmer participates in the project conditional on observed characteristic Z is not equal to zero or one.

As was shown in the theoretical model, farmers' firm choices are affected by prices, farmers' production functions, and cost functions:

$$Firm = F^{FC}\left(P_j, f_i(\cdot), C_{ij}(\cdot)\right), \qquad j \in \{1,2\}.$$

Given that there is no price difference among farmers selling to the same firm in this region, each farmer's firm choice decision depends on factors affecting production and cost. We use five pre-port or pre-project observed variables, Z, for determining farmers' firm choice decisions: percentage of forested area before the port opens or before the project started, distance to the soybean delivery facility and to major roads, total property area, and land quality. The percentage of forested area and land quality affect production, and distance to a major road, distance to the soybean delivery facility, and total property area affect the farmgate cost of production. These five variables are used to find the nearest neighbors to match each property in the treatment group to one or more properties in the control group.

We estimate the impact of the port and the project on deforestation using the matching estimator in years 2003 and 2004 to evaluate the impact of opening the port facility in 2003 and in the years from 2005 to 2012 to evaluate the impact of the Responsible Soy Project, which started in 2005. We match properties in the treatment group based on the five pre-port or pre-project observed variables both to their single nearest neighbor and to their four[4] nearest neighbors (Abadie and Imbens, 2011). The inverse of the variances of each element in Z is used for the distance metric. We correct for bias that can remain after matching by adjusting the

[4] Abadie and Imbens (2011) suggest to use four nearest neighbors because the model with four neighbors performed better with less mean-squared error in their simulation.

differences in matched control and treatment properties for the differences in covariates (Abadie and Imbens 2011; Abadie et al. 2004). We estimate heteroskedastic-robust asymptotic variance (Abadie and Imbens 2006; Abadie et al. 2004) because the bootstrap standard error method is not valid for nearest neighbor matching using a fixed number of neighbors with replacement (Abadie and Imbens 2008). The heteroskedasticity assumption relaxes the assumption of constant treatment effect and constant variance conditional on treatment and covariates, Z.

Difference in Differences (DID)

The DID method is useful for disentangling the impacts of a specific project that affects only those participating in a project from more general trends that affect everyone. The DID estimator removes unobserved time-invariant farmer characteristics that affect selection in the project participation by double differencing in and between control and treatment groups. This method controls for other effects that cause changes through time and attempts to isolate the effect of project participation on outcomes. We use the DID method to compare the deforestation rate for farmers participating in the project to other farmers not participating in the project before and after the port opened and before and after the start of the project. The DID is estimated using the following regression, as suggested by Imbens and Wooldridge (2009):

$$Y_{it} = \alpha + \sum_{t=2001}^{2012} \beta_t \cdot 1[T_i = t] + \gamma_1 G_i + \tau_{DID} P_{it} + \delta X_{it} + \varepsilon_i$$

where Y_{it} is the deforestation rate of property *i* at time period *t*; T_i is a time variable indicating years from 2001 to 2012; G_i is a participation dummy variable equal to 1 if the property is eventually in the project and 0 otherwise; P_{it} is an indicator for property *i* being in the project after the project started in 2005; X_{it} are other control variables that affect the deforestation rate in property *i*; and ε_i is an error term that is assumed to be independent of both *G* and *T*. The initial time period $t = 2000$ and control group of $G_i = 0$ coefficients have implicitly been normalized to zero. This model assumes that the policy effect is the same for all years.

The resulting coefficient of τ_{DID} estimates the difference in the average outcome of the treatment group before and after the treatment minus the difference in the average outcome of the control group before and after the treatment. This double-differencing method controls for the time trend and differences in Y_i caused by time-invariant characteristics and thus isolates the effect of project participation on deforestation.

One potential problem with this DID estimation is that, because we use panel data, the error term might be correlated to group or time specific characteristics. Bertrand et al. (2004) estimate DID rejection rates for placebo laws under various sampling methods and Monte Carlo simulations using Current Population Survey (CPS) data. They show significance of serial autocorrelation and how it can overestimate t-statistics and significance levels. They also show that the result is robust for different number of observations and time periods. To correct for this serial correlation we use a robust clustered variance-covariance matrix, which clusters all observations in different years by county.

V. Data

Constructing Variables

The deforestation rate in each year is calculated for the properties in the control group and in the treatment group. Data for the analysis were gathered from TNC and Brazilian government sources. Data on deforestation from 2001 to 2012 come from the Brazilian National Institute for Space Research (INPE). The deforestation rate is defined as the percentage of deforested area over the remaining forest cover in each farm. We do not use the percentage of the deforested area over the total area because this would give very low deforestation rates in a given year for properties that deforested in the past with little remaining forest cover. In this dataset, only properties with more than 6.25 hectares of forest cover are recorded as having forest cover, which is the minimum area that can be detected through satellite imagery system.

ArcMap GIS software was used to create property polygons from the boundary information and to calculate the other control variables, including the total area of each property, distance to soybean delivery facility, distance to major roads, and land quality variables. Distance to Cargill's soybean delivery facility and distance to major roads are calculated from the coordinates of Cargill's soybean delivery facility and from road shape files from Brazilian Agricultural Research Corporation (Embrapa 2013). Distances are measured as Euclidean distance from a point to the nearest edge of a feature. Land quality is calculated for each farm by assigning proportional area weights using data from Embrapa (Embrapa 2013). The description and statistics of variables used in the model are given in Table 1.

Constructing Treatment and Control Groups

The treatment group is defined as farmers participating in the project, while the control group is defined as farms not participating in the project but within the S&B region. Data on individual property boundaries comes from TNC for the treatment group, and from the Environmental Registry System (CAR) of the Pará State Environmental Agency (SEMA) for the control group.

For properties in the treatment group, we exclude properties with zero recorded forest cover in any given year: 65 properties out of 383 properties in the treatment group. Because the focus of this study is on whether the port and the project had an impact on deforestation, it is reasonable to exclude these properties because there is no forest cover for them to clear. We also excluded 15 properties after 2008 and 8 properties after 2010 that were dropped from the project because they failed to meet project criteria. Finally, we restrict my analysis to farms that were in the project since its implementation in 2005 which results in an additional 40 farms being dropped because they did not join the project until 2011-2012. This data restriction makes it easier to detect project affects if the impact of the project is not assumed to be shown in a short time period (Arriagada et al. 2012; Blackman and Rivera 2011). To check the robustness of the results, we also run the analysis including the 23 properties that were dropped from the project and the 40 properties that entered the project in 2011-2012 and found that the main findings were robust to different inclusion and exclusion assumptions.

The control group is constructed using the SIMLAM system (SEMA 2012), which is the database for the CAR. We downloaded boundary files of farms that are in the region of S&B. We kept only farms in the S&B region that were located south of the Tapajós and Amazon rivers, where the farms in the treatment group are located, to minimize bias that can occur because of geographic mismatch (Heckman et al 1997; 1998). In addition, we used only farms that have been reviewed and confirmed by SEMA. As a result, there are 235 properties in the control group.

Table 2 shows the means and standard deviations of covariates in the treatment and control groups, differences in the mean of covariates in each group, and the significance of the differences in the mean of covariates before and after matching for the port effect and project effect estimations. On average, properties in the treatment group tend to be closer to the soybean delivery facility and to major roads, have smaller forest cover, larger total area, and better land quality compared to the properties in the control group. The differences between the means of covariates in the treatment and control groups are all significant except total area variable before matching. The significant differences between the mean of covariates in the treatment and control groups disappear after matching each property in the treatment group to the property in the control group in both estimations of port and project effects.

VI. Results

The main environmental question of interest is the effect of the Santarém port facility and the Responsible Soy Project on deforestation. The model showed that the increased deforestation rate in the treatment group is higher than that in the control group during the post-port period and that in the post-project period there should be no additional deforestation in either group. If the rate of deforestation in the treatment group is larger than the deforestation rate of the control group after the port opening in 2003 and if the two groups have equivalent levels of deforestation after the project started in 2005 then the empirical results would support the theoretical model. Here, we first present evidence using descriptive statics from deforestation calculations and government statistics, and then we present econometric estimates based on the theoretical model.

Evidence from Descriptive Statistics

Table 3 and Figure 2 present evidence on the rate of deforestation in the treatment group and control group over the time period from 2001 to 2012. The treatment group began in 2001 with less remaining forest cover (41.7%) compared to the control group (53.0%), i.e., the treatment group had incurred greater deforestation prior to 2001. The average rate of deforestation was higher in the control group compared to the treatment group in 2001-2002, while the average rate of deforestation became higher in the treatment group before the project started in 2005 than in the control group. In particular, there appears to be a large spike in deforestation in 2003 and 2004 with much higher spike of deforestation in the treatment group in 2004. Figure 2 highlights the dramatic nature of the spike in deforestation rates, particularly for the treatment group in

2004. The average deforestation rate of the treatment group increased 311% from 2002 to 2003 and 170% from 2003 to 2004. The average deforestation rate of the control group increased 145% from 2002 to 2003 and 38% from 2003 to 2004. Starting in 2005 with the beginning of the Responsible Soy Project, the rate of deforestation in the treatment group immediately dropped and it has remained relatively low thereafter; the average deforestation rate dropped from 17.8% in 2004 to 1.7% in 2005. Deforestation rates also dropped in the control group starting in 2005 though the decline was not as dramatically as in the treatment group (from 5.8% in 2004 to 2.3% in 2005). Since 2006, the average deforestation rate has been relatively steady with a decreasing trend for both the treatment and control groups. The average deforestation rate was slightly higher in the treatment group between 2007 and 2010 than in the control group. Since 2011, the deforestation rate in the treatment group has been lower compared to that of the control group.

The timing of these changes in deforestation rates is important. The port facility opened in 2003. The Responsible Soy Project started in 2005. The period after the port opened but before the project started (2003-2004) had far higher deforestation rates then either the period prior to the port opening or the period after the project began. The opening of the port appeared to push deforestation rates higher in the S&B region, especially for the treatment group. The start of the Responsible Soy Project appeared to reduce deforestation rates to deforestation rates experienced prior to the opening of the port. Figure 3 shows the percentage of land planted with soybeans over total cropland area for S&B, the surrounding municipalities,[5] Pará state, and Brazil, from 2001 to 2011. The percentage of land planted with soybeans in S&B increased from just 0.9% in 2002 to 28.1% in 2005. In Brazil as a whole, the same percentage increased from 30% in 2002 to 36.4% in 2005. The significant increase in land planted with soybeans in S&B

[5] Surrounding 10 municipalities include Alenquer, Aveiro, Curuá, Juruti, Monte Alegre, Óbidos, Placas, Prainha, Rurópolis, and Uruará. The total area of these 10 municipalities is 136,443 km^2, making it 5 times larger than the combined area of S&B.

between 2003 and 2005 is consistent with the fact that the new port opened up opportunities for producing and exporting soybeans from the area. Following 2005, soybean percentages have stayed relatively unchanged in both S&B and in Brazil as a whole.

Figure 4 and 5 show total area planted in soybeans and in all crops, respectively, from 2001 to 2011. The two figures show whether the increase in the percentage of soybean planted area after the port opening between 2003 and 2005 results from expanding agriculture or from a shift in crops. In S&B, total area planted in soybeans increased by 35,150 hectares, from virtually zero 350 hectares in 2002 to 35,500 hectares in 2005. Total crop planted area in S&B increased by 87,121 hectares, from 39,245 hectares in 2002 to 126,366 hectares in 2005. In Pará state, total area planted in soybeans increased by 65,753 hectares, from 2,648 hectares in 2002 to 68,401 hectares in 2005. Total crop planted area increased by 183,328 hectares, from 1,119,417 hectares in 2002 to 1,302,745 hectares in 2005. The increase in soybean planted area over the increase in total crop area was 40% in S&B and 36% in Pará state between 2002 and 2005. It is plausible that soybean expansion caused more deforestation in S&B compared to the deforestation in Pará state between 2002 and 2005. It is clear that the period 2002 to 2005 was a period of rapid expansion of soybean production, and agricultural production in general, in S&B.

The subsequent decline, on average, of the deforestation rate in 2005 and the relatively steady low deforestation rate after 2005, shown in Table 3 and Figure 2, are consistent with several plausible hypotheses. This evidence is consistent with the view that the Responsible Soy Project was effective at slowing deforestation. It is possible that without the Project there would have been continued high rates of deforestation after 2005 because of profitable opportunities to produce soybeans given the existence of the port facility. Yet this evidence is also consistent with the view that the deforestation that was going to occur with the opening of the port largely occurred in 2003 and 2004 and would have dropped in any event soon thereafter. The decline in deforestation rates in the control group and the steady percentage of soybean planted area in all of Brazil indicate that the motive to plant soybeans may have been lower in 2005 and thereafter. The decline in deforestation after 2005 may also have been the result of changes in federal policies, such as increased enforcement of the Forest Code by the government, or changes in international agricultural markets, such as the drop in the price of soybeans in 2005. The real price of soybeans dropped by 13%, and that of maize dropped by 14%, from 2004 to 2005 (World Bank 2013). The following subsection further investigates which hypothesis best describes the impact of the port and the project by using nearest neighbor matching and DID methods.

Evidence from empirical models

Table 4 shows the results of the nearest neighbor matching estimator. A positive (negative) coefficient indicates that the properties in the treatment group had a higher (lower) average deforestation rate compared to the properties in the control group that have been matched based on the pre-port characteristics listed in Table 1. The results show that there was positive and significant port effect on deforestation in 2004 and no effect of the project between 2005 and 2012, except for the year 2011, at 5% level of significance. The positive and significant coefficients of 7.1 using one neighbor and 8.2 using four neighbors indicate that the port opening had an impact of increasing deforestation by 7.1% and 8.2% for the treatment group compared to the control group in 2004.

The results of the DID regressions are shown in Table 5. Table 5 shows the impact of port opening and the project in the region. The key coefficient in the DID regression is the coefficient on the Port or project time period*Treatment variable. This variable measures the difference in the effect of the port and the project on deforestation rates of the treatment and control groups. A positive coefficient in the port effect DID regression indicates that the treatment group had an increase in deforestation in the period 2003-2004 compared to the period 2001-2002 than did the control group. The result indicates a positive and significant coefficient of Port time period*Treatment variable. The coefficient of 7.6 indicates that the treatment group had a higher deforestation rate by 7.6% than did the control group after the port opening. This number is similar to the effect of 7.1% from results of the matching estimator using four nearest neighbors.

The effect of the project on deforestation is also shown in Table 5 and it provides several checks of the robustness of the result. In the project effect, we show coefficients for a regression with data for all years, a regression excluding 2004, and a regression excluding 2003 and 2004. We exclude 2003 and 2004 because deforestation rates in those years reflect the positive effect of port opening on deforestation, which is a temporary shock and can overestimate the impact of the project on deforestation. A negative coefficient indicates that the treatment group had a larger decline in deforestation in the period 2005-2010 compared to the period 2001-2004 than did the control group. The results using data from all years indicate a negative and significant coefficient of Project time period*Treatment variable (Column 3 of Table 5). This negative and statistically significant coefficient, however, is due almost entirely to the high rates of deforestation in the treatment group in 2003-2004 (as shown in Table 3 and Figure 2). When the DID regression is run without year 2004 or without both 2003 and 2004 there is a statistically insignificant effect of Project time period*Treatment variable (Column 4 and 5 of Table 5). There is a larger decline after 2005 in deforestation rates in the treatment group than in the control group. But whether this larger decline is because of the effect of the Responsible Soy Project or a reversion to more typical deforestation rates following elevated deforestation in 2003-2004 is less clear.

These results from the matching estimator and the DID regressions show that there was a positive and significant effect of the port opening on deforestation rates of the properties in the treatment group. However, there has been little difference in deforestation rate between the control group and the treatment group after the project for preventing deforestation started in 2005. These results are consistent with the results of the model showing positive impact of the port but no impact of the project on deforestation.

A difficult issue with interpreting the DID regression results occurs when there is a temporary change in outcomes for the treatment versus the control group (Ashenfelter, 1978). This pre-treatment shock causes an artificially inflated impact of the training program in the DID estimates. In the case of the Responsible Soy Project, the high rates of deforestation in the treatment group in 2003 and 2004 as compared to the control group, are the reason that the coefficient on Project time period*Treatment variable is negative and statistically significant in the DID regression. One way to address the temporary individual specific effect is to exclude the data that cause the temporary change (Ashenfelter 1978). This was done as the results are shown in the column 4 and 5 of the Table 5 excluding 2004 data and both 2003 and 2004 data. When this was done, the Project time period*Treatment variable became not statistically different from zero.

It is also possible to try to control for temporary effects by including additional covariates in the DID model (Abadie 2005). We included four control variables that can explain the differences in the characteristics of control and treatment groups. The regression results show that the distance to soybean delivery facility near the port and total area variables are negative and significant for all using data from all years, using data without 2004, and using data without the years 2003 and 2004. Properties closer to the soybean delivery facility tend to have higher deforestation rates. This result is not surprising as one would expect places closer to the port to have lower transportation costs and be more willing to invest in soybean production. The coefficient for total area is negative and significant for all regressions, which indicates that properties with larger areas tend to have lower deforestation rates. This might be because the cost for deforestation is lower for farmers with smaller properties. It might be easier for farmers who have smaller properties to manage when they deforest. Land quality is positive and significant for all regressions. Higher land quality means higher yield and more profit from agricultural crop production, resulting in higher deforestation. The distance to a major road is statistically insignificant. Most of the properties in the region are fairly close to federal and state roads, which may explain why this variable does not appear to be much of a factor. Even when controlling for these additional factors, we still find that coefficient of the time period*treatment variable is negative and statistically significant in the regression results for all years but statistically insignificant when data from 2004, and from 2003 and 2004 are excluded.

VII. Conclusion

Thoughtful economic development coupled with enforcement of environmental laws to protect natural capital offers the best hope for achieving a decent standard of living to all people while maintaining the natural capital on which future prosperity depends. Often some type of government regulation is needed to achieve an efficient level of development and conservation because of environmental externalities. In many cases, however, especially in developing countries, governmental regulations fail to achieve both goals of development and conservation due to lack of monitoring and enforcement. An alternative route to monitoring and enforcement is engaging multinational agricultural companies and NGOs. In this paper, we used data from The Responsible Soy Project, a pilot project between Cargill and TNC to prevent deforestation from soybean production, to evaluate whether this type of partnership can have a positive impact for conserving the environment.

The theoretical model showed that a project such as the Responsible Soy Project will not have a beneficial environmental impact if it is implemented after opportunities for environmentally destructive activities have occurred in the field. Land owners adjust their production decisions when they are given economic incentives to do so. Enforcing strict regulation to prevent deforestation after deforestation has occurred is too late. Descriptive statistics and empirical results of nearest neighbor matching and DID models support the findings of the theoretical model. Governmental statistics showed extensive expansion of soybean planted area compared to other crops during the period between the opening of the port and the start of the project in S&B. In the same period, there was a large spike of deforestation, especially in the treatment group in the period 2003-2004. The nearest neighbor matching and DID estimators showed that deforestation rates of the treated group are significantly higher by 7-8% compared to the control group after the port opening, supporting the hypothesis of the port's effect on increasing deforestation. The evaluation of the project's impact on deforestation using the nearest neighbor matching and DID showed that there has been little difference in the deforestation rate between the control group and the treatment group except during the period 2003-2004. Although there is a larger decline after 2005 in deforestation rates in the treatment group than in the control group, it is less clear whether this larger decline is due to the effect of the Responsible Soy Project or to a reversion to more typical deforestation rates following elevated deforestation in 2003-2004. The results indicate the importance of timing. To prevent environmentally unsustainable activities from occurring, projects to monitor and enforce environmental laws must be in place prior to proceeding with economic development that presents opportunities for environmentally destructive outcomes rather than being put in place after such activity is already underway.

In other respects, there is evidence of positive effects of the project that may be important but hard to quantify. It was observed through a visit to the project properties and a series of semi-structured interviews with farmers, governmental officials, and TNC and Cargill staffs. The project has been highly successful in getting properties enrolled in the registration system, an essential component to being able to do monitoring and enforcement of actions at the individual property level. The project also has increased the farmers' knowledge about the Forest Code and improved the means for compliance. The project has had notable successes, particularly in forging relationships among important stakeholder groups and in demonstrating techniques for registering land, monitoring and enforcement of the Forest Code. The quantification of the project's impact on increasing farmers' knowledge about the Forest Code and sustainable farming or forging relationships among different stakeholder groups may be more challenging. The amount of deforestation in Brazil as a whole has declined significantly after the highest annual total in 2004 since 1990. While it is unclear how much this project can claim as success it is clear that enforcement and monitoring have improved and deforestation has declined.

Other evidence of positive effects of the project include success in the restoration of APP (see Figure 6), which can be quantified using InVEST (Integrated Value of Ecosystem Services and Tradeoffs) tools with required data including land use land cover, watersheds, and elevation data. Future research can focus more on quantification of the success that has not been able to be measured in this paper.

The business environment in Brazil and other countries has been changing significantly, with governments now more willing to involve the private sector and NGOs in enforcement of environmental laws and more generally in its decision making process for sustainable development. Multinational businesses and local farmers respond to changes in the market. A partnership such as that between Cargill and TNC, demonstrated in the Responsible Soy Project, can change incentives and produce results on the ground. The project provides an example of how a multinational corporation and an international conservation NGO can address the issue of environmental degradation in the process of economic development using market incentives and involving all stakeholders. With further attention to issues of timing as well as other important details of the project design, such projects have the potential to achieve both economic development and environmental conservation goals.

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Table 1. Variable descriptions, means, and standard deviations (S.D.)

Variable	Description	Mean (S.D.)		
		Total	Control group	Treatment group
		(N=553)	(N=235)	(N=318)
Deforestation rate in each year between 2001 and 2012 (%)	The percentage of deforested area over remaining forest cover			
Forest cover in 2002 (%)	The percentage of forested area over total area in a property in 2002 before the port opened, which is used to find the nearest neighbor to measuring the port impact	45.80 (30.39)	52.01 (30.63)	41.21 (29.42)
Forest cover in 2004 (%)	The percentage of forested area over total area in a property in 2004 before the project started, which is used to find the nearest neighbor to measuring the project impact	39.84 (31.23)	48.69 (31.17)	33.31 (29.68)
Distance to the soybean delivery facility (km)	Euclidean distance from a property to Cargill's soybean delivery facility	49.22 (25.04)	52.20 (23.37)	47.01 (26.02)
Distance to a major road (km)	Euclidean distance from a property to the nearest federal or state road	4.37 (5.47)	6.45 (7.07)	2.84 (3.10)
Total area (ha)	Total area of a property	379.48 (676.35)	369.68 (447.87)	386.72 (805.22)
Land quality	Area-weighted land quality based on the classification of Ramalho and Pereira (1995). Scores range from 0 (no production capability) to 7 (most productive soil)	5.23 (1.89)	4.60 (2.09)	5.70 (1.58)

Table 2. Covariate balance between treatment and control groups before and after matching

Variable	Unmatched			Matched			
	Mean (S.D.)		Diff. in mean (S.E.)	Mean (S.D.)		Diff. in mean (S.E)	
	Treatment group	Control group		Control group - port	Control group- project	Port	Project
Forest cover in 2002 (%)	41.21 (29.42)	52.01 (30.63)	10.81*** (2.58)	41.94 (1.67)		0.73 (2.35)	
Forest cover in 2004 (%)	33.31 (29.68)	48.69 (31.17)	15.39*** (2.61)		34.29 (1.66)		0.99 (2.35)
Distance to the soybean delivery facility (km)	47.01 (26.02)	52.20 (23.37)	5.19** (1.06)	46.78 (1.24)	46.37 (1.25)	-0.23 (1.91)	-0.64 (1.92)
Distance to a major road (km)	2.84 (3.10)	6.45 (7.07)	3.61*** (0.45)	2.69 (0.16)	2.63 (0.16)	-0.15 (0.24)	-0.21 (0.24)
Total area (ha)	386.72 (805.22)	369.68 (447.87)	-17.04 (58.23)	337.79 (31.00)	331.67 (30.80)	-48.93 (54.77)	-55.05 (54.66)
Land quality	5.70 (1.58)	4.60 (2.09)	-1.11*** (0.16)	5.62 (0.09)	5.62 (0.09)	-0.08 (0.13)	-0.08 (0.13)

***, **, and * indicate 1% and 5% level of significance, respectively

Table 3. Total number of properties, average deforestation rate, total area, and forest cover of the control group and treatment group

Year	Control group				Treatment group			
	# properties	Average			# properties	Average		
		Deforestation rate (%)	Area (ha)	Forest cover (%)		Deforestation rate (%)	Area (ha)	Forest cover (%)
2001	235	1.19	369.68	53.03	318	0.53	386.72	41.70
2002	235	1.70	369.68	52.01	318	1.60	386.72	41.21
2003	235	4.17	369.68	50.53	318	6.58	386.72	39.17
2004	235	5.76	369.68	48.69	318	17.78	386.72	33.31
2005	235	2.30	369.68	47.31	318	1.73	386.72	32.69
2006	235	3.61	369.68	46.22	318	2.55	386.72	32.13
2007	235	1.18	369.68	45.67	318	1.76	386.72	31.63
2008	235	1.35	369.68	44.96	318	2.16	386.72	31.09
2009	235	1.84	369.68	44.62	303	2.37	323.23	28.58
2010	235	0.87	369.68	44.36	303	1.04	323.23	28.38
2011	211	1.43	372.07	45.10	295	0.19	330.22	28.70
2012	211	0.90	372.07	44.68	295	0.55	330.22	28.50

Table 4. Nearest neighbor matching estimator results on the effects of port and the project on the treated group compared to the control group

Year	Average effect on the Treated using one neighbor	Average effect on the Treated using four neighbors
The port effect		
2003	1.32	1.31
	(1.57)	(1.46)
2004	7.12**	8.20***
	(3.10)	(2.86)
The project effect		
2005	-0.48	-0.46
	(1.07)	(0.96)
2006	-2.77	-1.69
	(1.72)	(1.60)
2007	0.66	0.88
	(0.70)	(0.55)
2008	0.83	0.94
	(0.72)	(0.73)
2009	0.43	-0.82
	(2.77)	(1.60)
2010	-0.19	-1.20
	(0.80)	(1.24)
2011	-2.00**	-2.32**
	(0.99)	(1.19)
2012	0.11	-0.32
	(0.38)	(0.92)

***, **, and * indicate 1% and 5% level of significance, respectively

Table 5. DID regression results for the effect of port opening and of the project on deforestation with all years, without 2004 observations, and without 2003 and 2004 observations

Variables	Port effect	Project effect		
	2001-2012	2001-2012	Without 2004	Without 2003 and 2004
Intercept	2.99***	3.79***	2.55***	1.33***
	(0.83)	(0.58)	(0.50)	(0.41)
Distance to the soybean delivery facility	-0.09***	-0.04***	-0.02***	-0.01**
	(0.01)	(0.01)	(0.00)	(0.00)
Distance to a major road	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.02)	(0.01)
Total area (100ha)	-0.05**	-0.05***	-0.04***	-0.04***
	(0.03)	(0.01)	(0.01)	(0.01)
Land quality	0.74***	0.37***	0.21***	0.14***
	(0.17)	(0.08)	(0.06)	(0.06)
Port or Project time period	3.52***	-1.49***	-0.65	0.26
	(0.76)	(0.43)	(0.43)	(0.36)
Treatment	-1.57***	2.83***	0.22	-0.59
	(0.56)	(0.68)	(0.56)	(0.41)
Port or Project time period*Treatment	7.60***	-3.64***	-0.73	0.22
	(1.28)	(0.70)	(0.61)	(0.48)

***, **, and * indicate 1%, 5%, and 10% level of significance, respectively, using standard errors adjusted for individual property

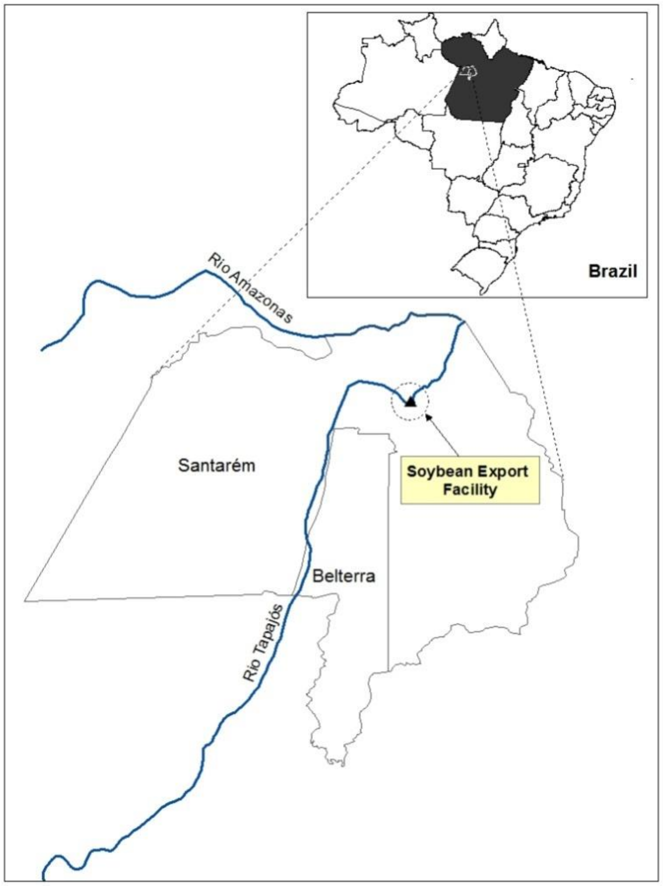
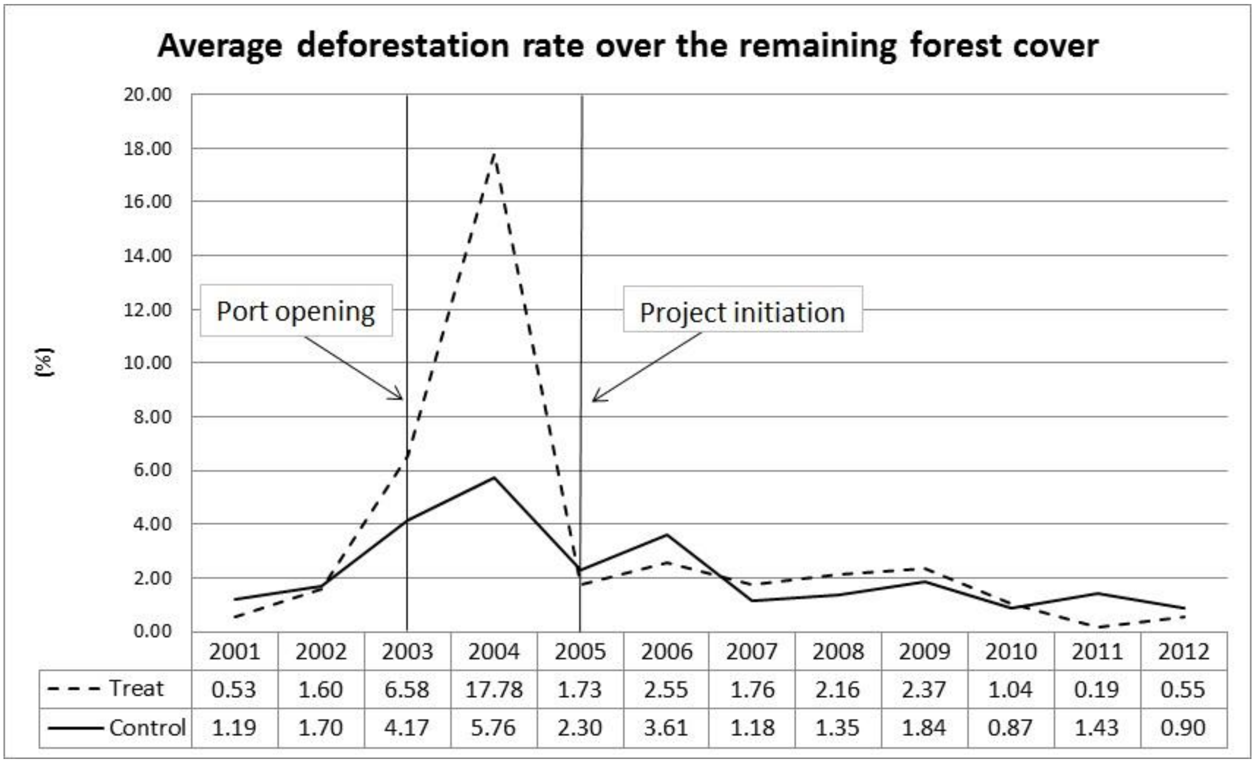
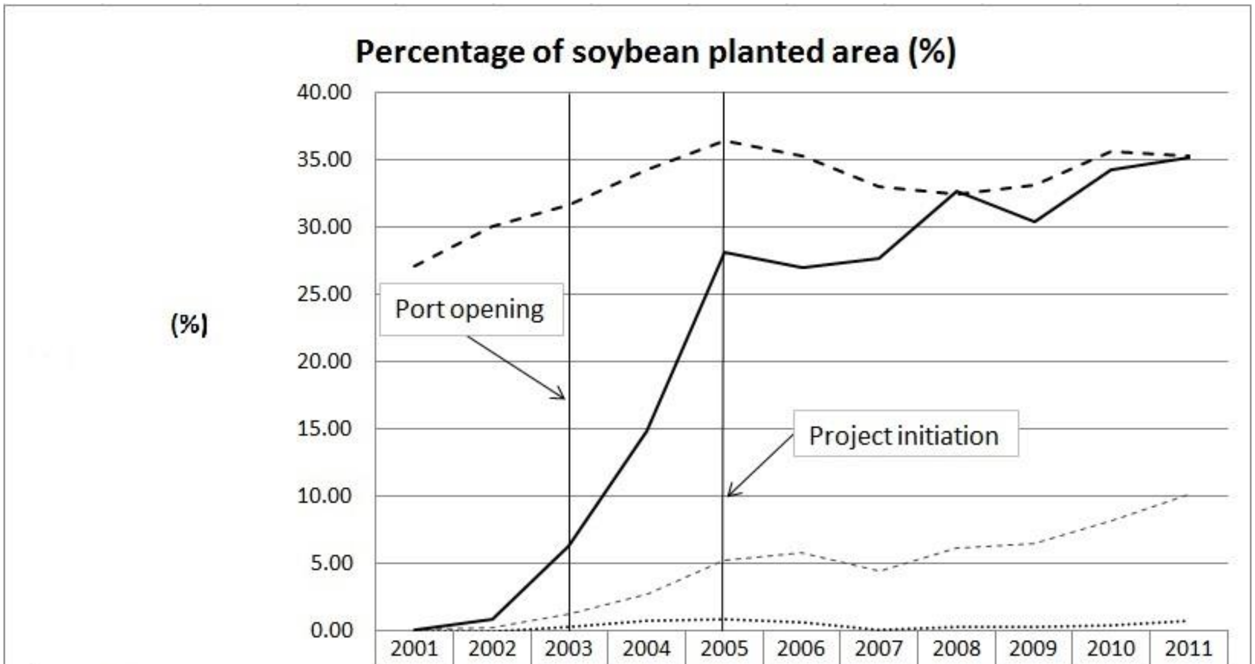


Figure 1. The location of Cargill soybean export facility in Santarém near the confluence of the Amazon and Tapajós Rivers in northern Brazil.



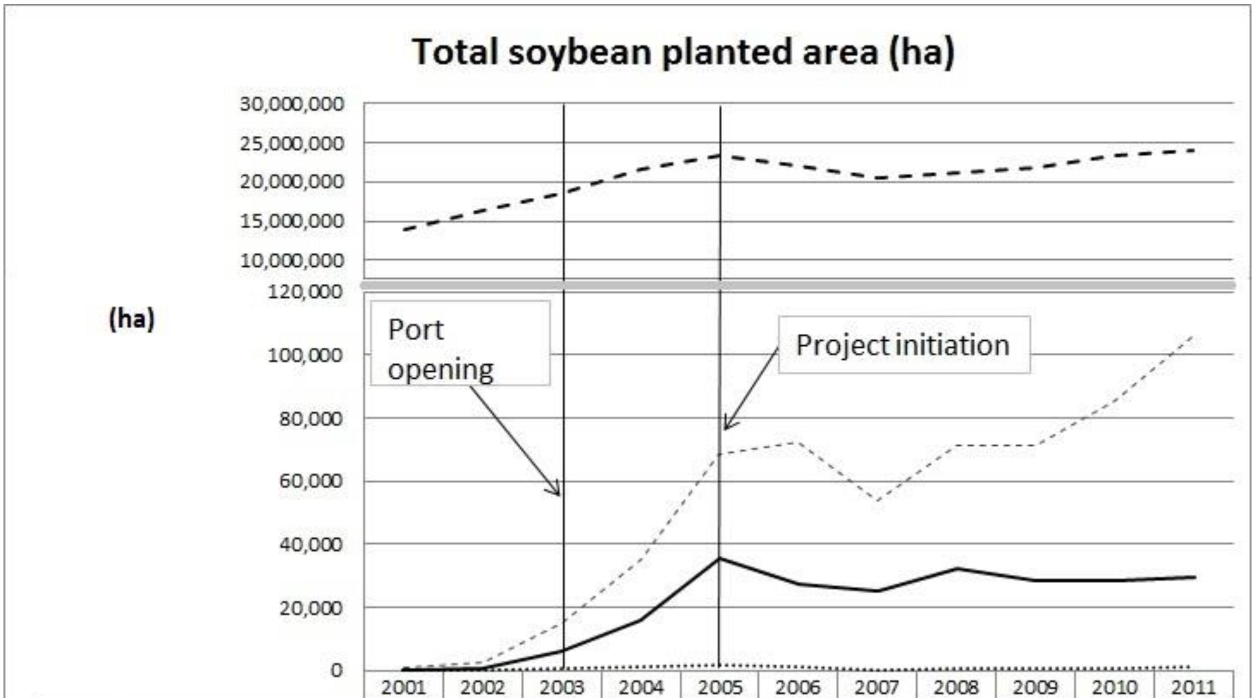
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
- - - Treat	0.53	1.60	6.58	17.78	1.73	2.55	1.76	2.16	2.37	1.04	0.19	0.55
—— Control	1.19	1.70	4.17	5.76	2.30	3.61	1.18	1.35	1.84	0.87	1.43	0.90

Figure 2. Comparison of the average percentage of deforested land over the remaining forest area in the control group and in the treatment group by year from 2001 to 2012



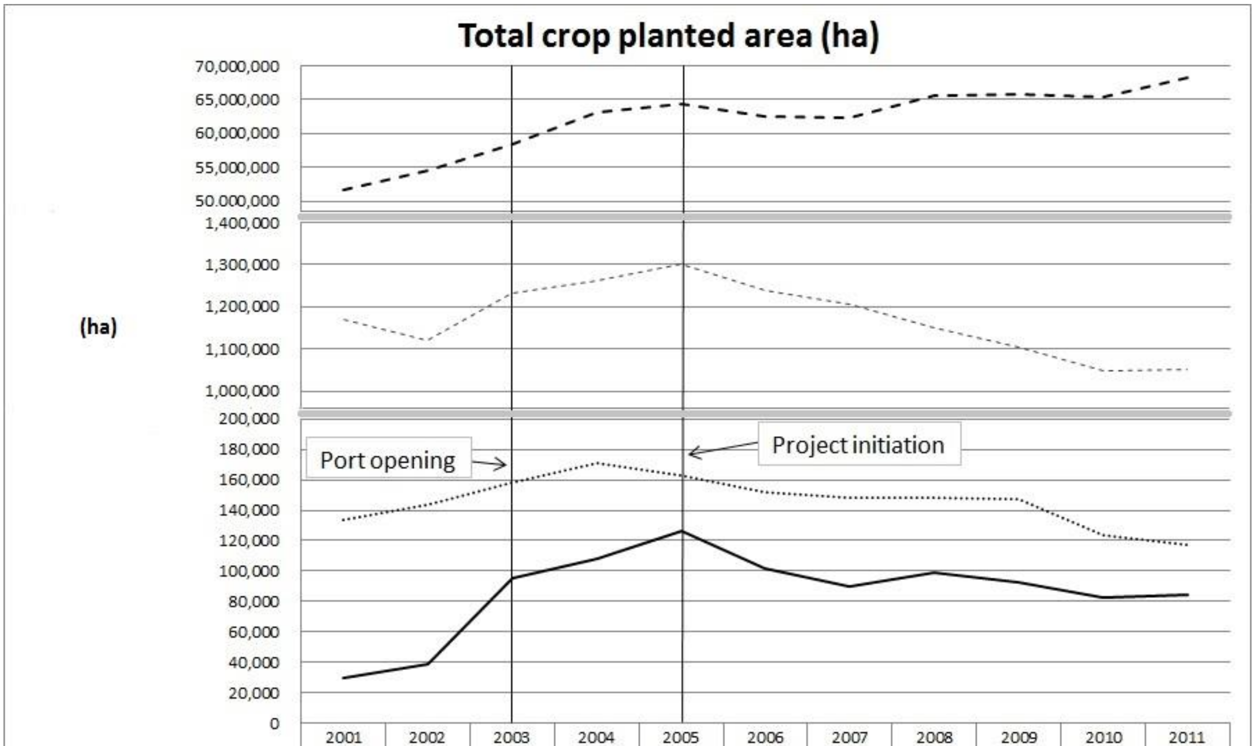
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Brazil	27.09	30.04	31.69	34.27	36.42	35.30	33.00	32.43	33.11	35.70	35.26
Pará	0.09	0.24	1.24	2.79	5.25	5.84	4.44	6.19	6.47	8.14	10.08
S&B	0.08	0.89	6.31	14.85	28.09	27.05	27.70	32.66	30.42	34.32	35.17
Surrounding Municipalities	0.00	0.00	0.26	0.78	0.89	0.60	0.11	0.33	0.28	0.41	0.74

Figure 3. Percentage of soybean planted area over total cropland area in Brazil, Pará, S&B, and surrounding municipalities



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Brazil	13,988	16,376	18,527	21,601	23,426	22,082	20,571	21,252	21,761	23,339	24,032
Pará	1,005	2,648	15,310	35,219	68,410	72,335	53,553	71,060	71,410	85,450	106,01
S&B	25	350	6,000	16,000	35,500	27,500	25,000	32,250	28,150	28,500	29,600
Surrounding Municipalities	0	0	410	1,325	1,450	905	160	490	415	510	870

Figure 4. Total soybean planted area (ha) in Brazil, Pará, S&B, and surrounding municipalities



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Brazil	51,637,16	54,511,62	58,460,98	63,036,96	64,319,31	62,563,90	62,338,73	65,527,80	65,721,59	65,374,59	68,160,51
Pará	1,169,643	1,119,417	1,233,147	1,263,017	1,302,745	1,239,015	1,205,822	1,148,344	1,103,914	1,049,384	1,051,399
S&B	29,831	39,245	95,074	107,761	126,366	101,647	90,260	98,737	92,526	83,034	84,157
Surrounding Municipalities	133,235	143,984	158,316	170,706	162,929	151,457	148,201	147,931	147,496	123,438	117,578

Figure 5. Total crop planted area (ha) in Brazil, Pará, S&B, and surrounding municipalities

Figure 6. Restored APP in the middle of a property (left) and fresh water protected inside of APP (right)