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Land Grabbing and Deforestation in the Brazilian Amazon

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Land Grabbing and Deforestation in the Brazilian Amazon*

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Abstract

Brazil's former president Bolsonaro repeatedly encourages land grabbing in the Amazon. This paper investigates whether this rhetoric influences deforestation in the region. Combining information from land registries with satellite images, we construct a panel with information on deforestation of more than 200,000 public and private properties in the region. We then use a differences-in-differences model to examine whether deforestation increased more in public lands compared to private lands after the Brazil's former president took office. Consistent with the president's rhetoric encouraging land grabbing, we find deforestation in public properties increased 0.22 standard deviations more than in private properties after the president took office. This result implies the president's rhetoric was responsible for the loss of 1,900 square kilometers of forests between 2019-2021.

Keywords: *Deforestation; Land Grabbing; Property Rights, Amazon*

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1 Introduction

Property rights are fundamental for economic development. It is only if property rights are well defined that an asset's owner has incentives for making investment decisions, for instance (Besley and Ghatak, 2010).¹ Therefore, the State has an essential role in leveling the playing field by assigning well-defined property rights. Where property rights are not well-defined, there is an increase in uncertainty that hinders economic development. This holds true as it relates to property rights over land, wherein the uncertainty over ownership is conducive to opportunistic behavior such as land grabbing.

The Brazilian Amazon - the most biodiverse ecosystem on the planet in terms of the richness and endemism of its species (Mittermeier et al., 2003) - has historically been a place of intense land grabbing and rural conflicts due to a lack of well-established property rights (Sant'Anna and Young, 2010; Fetzer and Marden, 2017). Indeed, there is an incentive for deforestation among land grabbers since it is easier to claim for a plot of land if it is cleared than forested (Fearnside, 2001). Nonetheless, deforestation rates in the Amazon have soared after Jair Bolsonaro took office in January 2019. The former Brazilian president has always been explicitly against environmental protection. His discourse vocals the ruralist's lobby interests, incentivizing deforestation and land grabbing.

In this paper, we assess the effects of Bolsonaro's pro-landgrabbing discourse on the deforestation of public lands. We analyze the evolution of deforestation at the property level throughout the period 2012-2021. As Bolsonaro took office, in January 2019, with a public and well-known discourse against environmental and conservation policies, it was expected that deforestation would rebound. Moreover, the Brazilian politician has argued against indigenous land rights or the creation of protected areas, and has been in favor of regularizing land grabbers.

¹Property rights are related to use rights, transfer rights and contract rights. That is, an owner can use an asset, transfer it and contract with other parties transactions like renting, mortgaging and so on (Besley and Ghatak, 2010).

Thus, in this paper, we specifically analyze the effects of the former Brazilian government on deforestation in public lands. Since the president's voice and policies were recurrently used to favor land grabbers, we expect that deforestation in public lands should have upsurged relatively more than in private lands. In order to test this hypothesis, we estimate a difference-in-differences model, where public properties in the Brazilian Amazon biome are our treatment group and private properties in the same region are used as our control group.

Our findings corroborate our hypothesis. In our preferred specification, normalized annual deforestation in public lands in the Brazilian Amazon have increased by 0.22 standard deviation due to the incentives for land grabbing after 2019. This result implies an aggregate effect of more than 190 thousand hectares of forest lost since 2019, which is equivalent to a US\$ 470 million loss involving no more than carbon emissions, considering a cost of carbon of US\$ 5/tCO₂.²

Our paper is organized in 6 sections. Section 2 provides a context of the historical link between land grabbing and deforestation in the Brazilian Amazon, as well as how the Brazilian government fostered, after 2019, these activities even more. In Section 3, we describe the construction of our data set and the variables used in this paper. Section 4 discusses our empirical strategy and discusses the validity of our hypothesis of identification. Section 5 provides and discusses the results of our paper. Finally, 6 highlights the main conclusions of our paper.

²If we were to consider a social cost of carbon in the range of US\$14 -US\$152/tCO₂ for 2020 as estimated by the US Interagency Working Group on Social Cost of Greenhouse Gases (IAWG, 2021), the cost of deforestation would vary from US\$ 1.3 billion to US\$ 14.3 billion.

2 Background

In the Brazilian Amazon, an old tradition has taken place in which land grabbers clear the forest on public lands to signal occupation and claim ownership (Fearnside, 2001).³ These operations might become more disseminated as the agents perceive a lower risk due to the weakening of environmental enforcement and a higher probability of acquiring property rights in the future due to a favorable political context. Thus, under low credible commitment to conservation and land management efforts on the government's part, opportunistic behavior towards land grabbing is more likely to arise (Sant'Anna and Costa, 2021).

In this section we present the relevance of land grabbing in the Amazon, and show some of the most remarkable and publicized statements issued during Bolsonaro's campaign, all of which are related to the matters of environmental conservation, and land tenure policy. The campaign pledges that appeared on the candidate's political platform registered at Brazil's Superior Electoral Court (TSE) are also taken into consideration. Finally, to reinforce our argument, some relevant events in the early months of the Bolsonaro's administration, as well as the legislation later proposed, are accounted for.

2.1 Land Grabbing in the Brazilian Amazon

In the Brazilian Amazon, the economic incentives behind land grabbing are a central reason for deforestation and conflict (Alston et al., 1999; Sant'Anna and Young, 2010). This dynamic of contentious land change involves multiple agents and has historical roots (Almeida, 2010). Beginning in the late 1960s, the military government set in motion a series of projects and policies to integrate the Amazon to the rest of the Brazilian economy.

³We define land grabbing or "grilagem" as in Brito et al. (2019), that is all action that intends to obtain the possession or property rights over land through illicit means. Those who clear public forests areas (a crime under the Federal Law n° 9,605 of 1998, in its article 50-A) to demonstrate the use of the land, or those who invade public land with the intent of occupying it, are committing the crime that is commonly referred to as "grilagem", thereafter land grabbing. This crime is defined by the 1966 Federal Law n° 4,947, in its article 20.

Until then, less than 1% of the Amazon area had a formal claim, and deforestation was negligible (IBGE, 1960). In the following decades the in-migration to Amazonian states increased significantly (Brasil, 1997). Newcomers were attracted mostly by the promise of land as a result of a directed colonization effort, that is, the settlement of farmers on formerly public land by official and private projects (Almeida and Santos, 1990). The policies implemented in the 1970s established direct and indirect economic incentives to deforestation (Young, 1998).

In 1976, two provisional acts issued by the Military Government (n°s 006 and 007) established the first legal prerogative for the formalization of property claims over illegally occupied public land. It allowed for the regularization of properties up to 60 thousand hectares, “illegally acquired, but in good faith”.

As described by Almeida (2010), the frontier that emerged in the Brazilian Amazon was, and still is, a territory where social and economic restrictions are hardly truly enforced. The yet pristine environment is simply a means to immediate gains. In the 1980s, land values have soared as a result of large infrastructure projects,⁴ cementing the economic interests that had emerged. This accumulation process was not a result of production, but rather a result of the speculative interest over land (Almeida and Santos, 1990).

This process continues to this day, even after the end of the military rule in 1985 and the introduction of modern environmental and social protection measures. The Constitution of 1988 asserted that the land must serve a social function, that is, it must be made productive according to some criteria. This constitutional rule intended to force the legislators to act on the social problem of landownership inequality. The 1988 Constitution is also the first to legally protect the environment and acknowledge indigenous and other peoples' rights, though it left much of the details on how to achieve social and environmental goals to future legislation.

⁴Such as the Belém-Brasília highway connecting the North-South axis, and the Transamazônica highway, connecting the East-West axis Young (1998).

The 1990s and early 2000s saw a record increase in the rate of deforestation both in public and private lands (Assis et al., 2019). The highest rate was registered in 1995 and second highest in 2004 (respectively, 29,000 and 27,000 km²). On the other hand, with the new Constitution in place, there began the demarcation of reserves of native and traditional peoples and creation of large protected areas for conservation efforts in the Amazon. That is, much of the public land was designated to the purpose of conservation, preventing the speculative undertakings.

In addition, a most relevant program to contain the rise in deforestation was put in place. Launched in 2004, the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm) established, among other things, a law enforcement approach towards combating deforestation in the Brazilian Amazon. Assunção et al. (2013) estimates that observed deforestation from 2007 through 2011 was 75% smaller than it would have been in the absence of command and control policies.

Still there remained strong pressures towards formalizing land grabber's claims. In June 2009, a law (n° 11,959) authorized the registry of illegally obtained properties up to 1,500 hectares in the Amazon, as long as those who claimed ownership proved their presence before 2004. Subsequently, a new legislation in 2017 (n° 13,465), raised this limit to 2,500 hectares and delayed the deadline for regularization from 2004 to 2011. These changes established a public perception of low credible commitment to conservation and land management efforts on the government's part, encouraging land grabbing (Brito et al., 2019).

From 2019 to 2022, we witnessed the resurgence of an old political approach to the Amazon, opposite to past advancements in environmental enforcement and social protection of native and traditional populations. Through discourse and practical actions, the election of Bolsonaro has enhanced incentive for land grabbing.

2.2 The Discourse

As argued before, Brazil's former president has recurrently argued in favor of practices that menace Brazilian biomes. However, Bolsonaro's voice has been employed towards anti-scientific rhetoric as regards policies against COVID-19 as well. [Ajzenman et al. \(2020\)](#) investigates if Bolsonaro's populist and anti-scientific rhetoric over the pandemic induced followers to engage in risky behavior. The authors are able to relate increases of Covid-19 cases in pro-government municipalities after some noticeable speeches made by the president against social distance.

A review of Bolsonaro's speeches exposes an agenda contrary to the environmental and social policies put in place in the past decades ([Revista Piau , 2020](#)). Instead, he brought back the rationale of policies implemented during the military dictatorship (1964 - 1985) ([Barretto Filho, 2020](#); [Ferrante and Fearnside, 2019](#)). Bolsonaro's rhetoric was amplified by the prominent influence of social media content on the Brazilian national political debate, especially during the 2018 campaign ([Ituassu et al., 2019](#); [Murta et al., 2019](#); [Ranzani and Reigota Caram, 2019](#)).

In 2017, Bolsonaro declared that if he became president, he would act to halt the demarcation of indigenous reserves and Quilombos ([Terra, 2019](#)).⁵ This declaration took place at a meeting in Mato Grosso state, Brazil's top soybean grower. In his first interview as an elected President (on November 5, 2018), Bolsonaro reiterated this promise ([Folha de S o Paulo, 2018](#)). In addition, one official campaign pledge⁶ asserted the intention to modify legislation, allowing for the exploit and sell of these protected areas.

Another pledge consisted in ascribing some of the land management and environmental enforcement attributions to the Agriculture Ministry, despite possible conflicts of interest.

⁵Quilombos are historical rural settlements, organized by African descent peoples. Both Indigenous and 'Quilombolas' territories are recognized and protected by the Constitution in its articles n  231 and 68, respectively.

⁶The official government program is available here: http://divulgacandcontas.tse.jus.br/candidaturas/oficial/2018/BR/BR/2022802018/280000614517//proposta_1534284632231.pdf

The original proposition was to extinguish the Environmental Ministry altogether. He also promised to withdraw from the Paris Climate Agreement and expand agricultural and mining activities especially in the Amazon (Mongabay, 2019a). Ferrante and Fearnside (2019) summarize this agenda that the president shares with one of his key political bases, the so called “ruralista” or ruralists - large landholders and their representatives in the Brazilian Congress.⁷

In December 2018, during a live streaming, the president-elect promised to end the issuing of fines as penalties to crimes against the environment.⁸ Indeed, in 2019, the number of fines issued were the lowest in at least 11 years, in spite of the rise in deforestation (Mongabay, 2019b).

2.3 Onset of a New Administration

Indigenous leaderships declared that invaders interested in occupying indigenous territories became more aggressive as soon as the electoral result became known. Dina-man Tuxá, the executive coordinator of the Articulation of Indigenous People of Brazil (Apib) at the time, predicted that “there will be an increase in deforestation and violence against indigenous people” (The Guardian, 2019). In one episode (on January 30, 2019), armed land grabbers invaded the Uru-Eu-Wau-Wau Indigenous Reserve, announcing Bolsonaro’s electoral victory and threatening a hostile invasion (O Globo, 2019). According to CIMI (Missionary Indigenous Council), after three months into the new administration, reported cases of invasions to indigenous lands rose 150%.

In April 2019, an invasion of illegal loggers took place at the Jamari National Forest in the state of Rondônia, a public area under concession for sustainable exploitation of native,

⁷However, as can be seen by his long-run discourse against conservation policies as well as indigenous rights, we argue that Bolsonaro’s policies are not only related to interests but also on his very deep ideas about these issues. On the relation of ideas and interests in shaping political equilibrium, see Rodrik (2014).

⁸This declaration can be seen here: <https://videos.bol.uol.com.br/video/bolsonaro-diz-que-quer-acabar-com-industria-da-multa-do-ibama-04028C9B336EDCA96326>

high-quality timber. The environmental monitoring and enforcement agency (IBAMA) was called to act. The operation resulted in the destruction of equipment used by the illegal loggers.⁹ The following day, president Bolsonaro made a statement condemning the operation and verbally deauthorizing the agency to destroy equipment used to commit such crimes ([The Intercept, 2019](#)).

On July 4, 2019, in a meeting with congressmen that form the ruralist's political base (Frente Parlamentar do Agronegócio), Bolsonaro stated that "this government is yours". He also has repeatedly and publicly shared the desire to weaken environmental licensing and oversight ([Ferrante and Fearnside, 2019](#)). Even the NGO's that act on the Amazon combating the degradation of the forest became a target. As such, the appointed Environmental Ministry was quick to derange the Amazon Fund ([The Guardian, 2019](#); [Exame, 2019](#)).

Also in July 2019, Bolsonaro claimed that the Brazilian Amazon Rain-forest Monitoring Program (PRODES) - a product of the National Space Research Institute (INPE) - was providing false information on the current rates of deforestation ([Extra, 2019](#)). The PRODES program is well recognized by the scientific community ([Adami et al., 2017](#); [Fearnside, 2019](#)) and the rates of deforestation it produces serves as an official estimate for negotiations on carbon emissions carried out by the Brazilian government.¹⁰ T

2.4 Perverse Incentives

A study conducted by [Brito et al. \(2019\)](#), discusses how the Brazilian landownership legislation incentivizes land grabbing through deforestation. The authors list some of the 'perverse incentives' derived from federal and state legislation that helps sustain such territorial dynamics. State laws are important since about 60% of undesignated areas belong

⁹The agencies are authorized to destroy heavy equipment that cannot be easily retrieved from remote areas during an operation. This measure is authorized by the 2008 presidential decree nº 6,514.

¹⁰See: <http://redd.mma.gov.br/en/monitoring>

to Amazonian states governments. Overall, most state legislation do not establish a deadline date to regularize previous illegal occupations, and when it does this is prone to future modifications. In the absence of a commitment to a fixed deadline it remains the possibility of future privatization of public lands. This is what these reoccurring new legislation seem to pursue, i.e., not only to give property rights, but to serve as prerogative for future privatizations of public land, weakening the credibility of stricter environmental policies.

In 2017, another legislation (n° 13,465) revised the country's rules on land tenure regularization. This revision reinforced the mechanism through which contentious deforestation and land use change lead to ownership claims. The new law gives amnesty to those who illegally occupied public lands between 2005 and 2011, granting the possibility of purchasing up to 2,500 hectares, in some cases with discount prices. According to Brito et al. (2019), the estimated area affected may cover 28.2 million hectares, more than one million of which may overlap with indigenous lands. The authors also estimated that total revenue losses, due to price discounts, may reach US\$32 billion (considering the conversion rate of R\$ 3.72 to US\$, as of 2019).

Already into Bolsonaro's administration, two legislation proposals (n° 2,633/2020 and n° 510/2021) were proposed, with the intention to further modify the conditions for formalization in benefit of land grabbers, extending the possibilities of privatizing public lands. However, the Law of Public Forests Management (n° 11,284 of 2006) does not allow for the sale of public forests in the Amazon, even when they are yet undesignated. Public Forests must be designated to conservation, sustainable exploit under temporary concession, or the demarcation of native and traditional peoples reserved areas (Brito et al., 2019).

3 Data and Descriptive Analysis

For our analysis we utilize georeferenced data on land tenure from Imaflora's Agricultural Atlas (Freitas et al., 2018) and on deforestation increments from the Brazilian National

Institute for Space Research's (INPE) monitoring system. The latter is referred to as the Brazilian Amazon Rain forest Monitoring Program by Satellite or PRODES (Souza et al., 2019). Our study focuses on the Brazilian Amazon biome. A vector file of such area is also provided by INPE. All data sets used are publicly available.

3.1 Land Tenure

The Brazilian land tenure system map is a product of Imaflora's "Atlas - The geography of Brazilian agriculture", an initiative to disseminate knowledge about Brazilian agriculture. It covers the Brazilian national territory and makes publicly available a picture of the whole of registered public and private lands in Brazil.

It is important to highlight that this tenure map uses only official public databases, from the following governmental institutions: the Brazilian Institute for Geography and Statistics (IBGE), that provides data on military areas and others, such as infrastructure and urban areas; the Brazilian Forest Service (SFB), that accounts for the forests inventories; the National Foundation for Indigenous People (FUNAI), responsible for the indigenous territories demarcation; the Ministry of Environment (MMA), that provides data on national and state-level protected areas; the National Institute for Colonization and Agrarian Reform (INCRA), that offers a database on rural properties and settlements; and the Rural Environmental Registry (CAR), that consists of a self-declared property boundaries database on private rural properties (for properties registered until June 09, 2018).

Since there is overlapping among different layers (different property registry systems), Freitas et al. (2018) proposed a hierarchical order of priorities that guide the prevalence of one layer over another. The decision to resolve the overlapping considers the legal certainty of the registry, if the geospatial information is precise, and the possibility of changes in tenure. Together, these registries, after treatment, account for 82.6% of the Brazilian territory with 4,519,223 different properties. For the Legal Amazon area (5,018,636 km²),

after our own processing (see details in Appendix), there remains a total of 468,158 unique properties, covering 4,453,553 km² or 88.7% of the total area.

Figure 1 displays the map of Brazilian Amazon by land tenure.

FIGURE 1 - HERE

3.2 Deforestation

The annual increase of deforestation (PRODES) for the Brazilian Amazon is composed by the accumulated deforested area, from the beginning of the program in 1988 up until 2007 and consolidated annual rates between 2008 and 2021.¹¹ This program accounts for clear-cut deforestation, defined as the complete removal of the forest cover, larger or equal to 6.25 hectares, and it only considers pristine forests when looking for changes in forest cover (Souza et al., 2019). Once it registers a deforested area, it excludes such area of subsequent monitoring. That is, the program does not account for reoccurring deforestation on regenerated forests.

For our analysis, we utilize the normalize annual deforestation by property, defined as:

$$Deforest_{it} = \frac{Deforestation_{it} - \bar{Deforestation}_{it}}{sd(Deforestation_{it})} \quad (1)$$

Where $Deforest_{it}$ is the normalized annual deforestation increment for municipality i and year t ; $Deforestation_{it}$ is the annual deforestation increment measured in municipality i between the 1st of August of $t - 1$ and the 31st of July of t , and $\bar{Deforestation}_{it}$ and $sd(Deforestation_{it})$ are, respectively, the mean and the standard deviation of the annual deforestation increment calculated for each i over the 2012 through 2021 period.

¹¹The 2021 rate is made up only of 106 priority satellite scenes, out of a total 229 scenes that cover the entire Brazilian Legal Amazon. These priority scenes cover the regions where at least 90% of deforestation alerts occurred.

4 Empirical Model

As discussed in section 2, the former Brazilian government, led by Bolsonaro, stimulates deforestation in the Amazon. However, the incentives were even more important for land grabbing in public land. Therefore, we expect to see a relative increase in deforestation in public lands after Bolsonaro’s election, as a signal of the upsurge in land grabbing activity.

In this paper, we test this hypothesis by estimating a difference-in-differences model, where our treatment group is composed by public plots of land in the Brazilian Amazon. Our sample comprises a balanced panel of 218,878 public and private properties between 2012 and 2021 which had positive forested area throughout the whole period. Our identifying assumption is that deforestation had similar trends before Bolsonaro took office. In other words, we rely on parallel trends before the treatment, as usual in DiD estimates. Therefore, our benchmark equation to be estimated is:

$$Y_{it} = \beta_0 + \beta_1 D_{it} + \alpha_t + \lambda_i + \epsilon_{it} \quad (2)$$

Where Y_{it} is the annual normalized deforestation by property i , at year t . The coefficient - β_1 - is our coefficient of interest and measures the average treatment effect on the treated. D_{it} is a dummy variable that assumes value equal to one after 2018 if the property i is public. The term α_t is a time fixed effect, which captures yearly shocks common to all rural properties, λ_i is the property fixed effect, which captures effects of unobservable and invariant variables in time. The model error term is ϵ_{it} .

As Brazilian municipalities can have important differences in environmental policy, especially in the Amazon, we add, in our preferred specification, municipality specific time shocks. Therefore, our benchmark specification is:

$$Y_{it} = \beta_0 + \beta_1 D_{it} + \alpha_t + \lambda_i + \alpha_{mt} + \varepsilon_{it} \quad (3)$$

As discussed, a main restriction to our identifying hypothesis is that control and treatment groups must have parallel trends before the law revision. To anticipate part of the discussion, Figure 2 includes deforestation by group of properties before and after Bolsonaro. Albeit this is not the variation used in our identification, Figure 2 illustrates a pattern of similar deforestation, before Bolsonaro was elected, and a significant change afterwards. This is quite similar to the pattern which arises in our regression setting.

FIGURE 2 - Here

We also conduct two complementary exercises to validate our empirical strategy. Our main goal is to show that the effect we document is indeed related to the government's incentives for land grabbing. Hence, we test for parallel trends in deforestation by estimating an event-study, which allows for a better trace of the timing of the estimated impact. We also allow for non-linear time shocks as a function of initial characteristics of the properties (time dummies interacted with initial deforested area and geographical coordinates of the property's centroid). For the event-study, we estimate the following model:

$$Y_{it} = \sum_{k=-K+1}^{-1} \gamma_k^{lead} D_{it}^k + \sum_{k=1}^L \gamma_k^{lag} D_{it}^k + \alpha_t + \lambda_i + \varepsilon_{it} \quad (4)$$

Where D_{it}^k is our dummy of treatment that assumes value equal to 1 if the treated unit is k periods from the time of treatment.

5 Results

In this section, we first report our main results on deforestation. We then explore heterogeneity by category of public land, provide robustness checks and discussion.

5.1 Main results

Table 1 presents the effect of the enhanced incentives for land grabbing induced by the Brazilian government stance on deforestation in the Brazilian Amazon. In the first column we include only property and year fixed effects. We add an interaction of state and year fixed effects in the second column and municipality and year fixed effects in the third column. Finally, on column (4), we add an interaction of geographic coordinates and year fixed effects in order to allow for specific non-linear trends for each property.

In the first column, we find a positive coefficient of 0.188. As we add state non linear trends, the estimated coefficient remain stable. When we allow for Municipality FE x Year FE and Geo Coordinates x Year FE, results from columns (3) and (4) increase to 0.22. Overall, the estimated increase in deforestation is approximately 0.2 standard deviation of the deforestation increment.

TABLE 1 - HERE

To give some sense of the magnitude of our results, we compare it to some papers that use the same dependent variable and analyze policies to curb deforestation in the Brazilian Amazon. TAssunção et al. (2015) estimate a coefficient between -1.1 and -1.4. However, the authors analyze all the policies under the PPCDAm. Our results are similar to those found by Assunção et al. (2020) - 0.216 - which estimate the effects of a restriction in access to rural credit for farmers that were not in compliance with environmental regulation and legal titling requirements. The policy of blacklisting municipalities that had a higher risk for deforestation led to an estimated effect of 0.55, higher than our estimates (Assunção

and Rocha, 2019). Finally, Assunção et al. (2013) estimate an effect of 0.06 of the policy of deforestation alerts by satellite.

5.2 Event Study

A fundamental assumption for the validity of our results is that treated and control groups have parallel trends before the treatment. In other words, we must verify whether deforestation in public and private properties had similar trends before 2018.

Hence, in order to evaluate the parallel trends assumption, we conduct an event-study estimation. In this analysis, the treatment dummy - *PublicLand_i* - is interacted with year dummies (with the coefficient of 2018 being normalized to zero). The results of the event-study analysis are shown on Figure 3.

The results from the event-study reassure the identification hypothesis, since the difference in the estimated coefficients of public and private land is not different from zero before 2018 and is positive thereafter.

FIGURE 3 - HERE

5.3 Robustness and Heterogeneity

A central point to our argument is that the surge in deforestation in public land was a result of Bolsonaro's discourse and policies and not to some other event that might have affected the odds of being successful with land grabbing. This indeed a caveat since there was the 2017 law that provided new incentives for land grabbing. However, as the event study results from Figure 3 show, deforestation in public lands in 2018 did not increase and is statistically equal to difference between deforestation in public and private lands in 2017 and in the years before. Therefore, as we observe positive effects only after 2019 reassure our confidence that results are driven by the current government's lack of disposition to engage in command and control policies especially against land grabbing.

Moreover, Table 2 presents some robustness tests and a heterogeneity analysis for distinct types of public land. In column (1), we use our benchmark specification, but weight the regression according to property area. As such, we recover the effect of the government's incentives to land grabbing on normalized deforestation by hectare. In addition, the weighted regression provides confidence that our results are not driven by small properties. Again, the estimated coefficient is positive and robust. Column (2) explores a different dependent variable. We measure deforestation as the inverse hyperbolic sine of deforestation. Results are in line with our previous findings.

In the following, column (3) displays the estimated coefficients by type of public land. We split public land into six different types: (i) rural settlements; (ii) undesignated forests; (iii) indigenous land; (iv) untitled Terra Legal Program; (v) Protected Areas; and (vi) military land. Results point an increase in deforestation among all kinds of public land. Point estimate is not so robust for military land. This might be related to the small number of military land - 65 - which increases standard errors. Another important feature is the size of the estimated coefficient for untitled lands in the Terra Legal Program.

This program was created in 2009 with the aim of regularizing public land occupied in the Brazilian Amazon. However, as of 2016, there were still 1,240 farms under the program that were still untitled. Our results point that the incentives for land grabbing were even more important where property rights were especially weak.¹²

TABLE 2 - HERE

5.4 Cost-effectiveness analysis

In this section, we perform a partial cost-benefit analysis considering no more than the cost related to the emissions of carbon and where the cleared land is entirely directed to cattle ranching. To assess these impacts, we conduct a counter-factual analysis based on

¹²Assunção et al. (2019) show that *de jure* titling under the Terra Legal Program have led to a reduction in deforestation rates among titled properties.

the coefficient of our preferred estimation (Table 1, Column (4)).

TABLE 3 - HERE

Column (1) from Table 3, displays observed yearly deforestation from 2012 to 2021 in the Brazilian Amazon biome. Total deforestation in the period 2019-2021 has amounted to 3.0 million hectares, an area of the same size as that of Belgium. More than half (1.6 million ha) of this deforestation occurred in public land, as can be seen on column (B). In column (C), we have the predicted deforestation in public land if the current government did not foster land grabbing in public land. The difference between the observed deforestation in public lands and its counterfactual gives the excess deforestation due to enhanced land grabbing - a total of 194 thousand hectares or 6.4% of the total deforestation in the period 2019-2021.

To conduct our partial cost-benefit analysis, we consider that the whole extension of cleared land is devoted to cattle ranching. Young et al. (2016) estimate that cattle ranching in the Brazilian Amazon yields profits of BRL 160 (in 2013 prices) per hectare. Using 2013 average exchange rates, we assume that profitability of cattle ranching in the Brazilian Amazon is USD 71/ha/year.

According to the Brazilian Ministry of Environment, the average hectare of forest in the Brazilian Legal Amazon has 485.1 tCO_2 present in its biomass.¹³ Thus, the deforestation of the 194 thousand hectares have led to emissions of 94.3 million tonnes of CO_2 .¹⁴ If we consider a price of carbon of US\$ 5 per tCO_2 , which was used as the reference for transfers to the Amazon Fund, for instance, we reach a cost of US\$ 1.3 billion.

Alternatively, we can calculate the implicit value of carbon by equating its value to the profit from economic activities. In order to compare a flow of annual profits with the

¹³See: http://www.fundoamazonia.gov.br/export/sites/default/pt/.galleries/documentos/ctfa/Nota_Tecnica_2018.pdf

¹⁴We do not consider the methane that is emitted from cattle ranching activities, nor the carbon captured by trees from the atmosphere.

once and for all loss of carbon, we calculate the present value of cattle ranching profits estimates using two different discount rates: 5% and 8%. Respectively, the present values of these profits by hectare are: US\$ 1,420 and 887, which is less than the value of 2,425 US\$/ha which could be received implicitly under a carbon price of 5 U\$/tCO₂. Moreover, we have taken into account no more than the costs related to carbon emissions, neglecting several environmental services provided by the tropical forest, including water resources, soil erosion and biodiversity. If we were to consider these additional services, the ineffectiveness of the policy would be even wider.

6 Final remarks

Deforestation rates in the Brazilian Amazon have soared between 2019 and 2022, global concerns about Brazil's environmental policies have appeared. It is notorious that the former government is against strict environmental policies. Instead, the main discourse and policies regarding conservation policies were towards increased mining, logging and deforestation. It can indeed be said that, at that time, the Brazilian Executive adopted a clear pro-land-grabbing stance.

Given this framework, we have shown that deforestation increased relatively more in public lands after Bolsonaro took office. We argue that this represents a signal that land grabbing is being fostered and leading to a significant part of deforestation after 2019.

Our results point that almost 200 thousand hectares of Amazonian forest have been cleared due to land grabbing's response to incentives. This amounts to a loss of almost 100 million tCO₂, which could represent a loss of almost US\$ 500 million considering no more than carbon emissions under a price of US\$ 5 tCO₂. This is much more than profits from cattle raising are able to gather.

The increase in land grabbing and deforestation generate several negative externalities.

Moreover, it represents inequality increasing, since land grabbing requires capital and political connections. Therefore, it is fundamental to adopt command and control policies to curb deforestation as well as design an effective way of assigning property rights that reduces uncertainty and the incentives to deforest as a way to claim land rights.

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Main Tables and Figures

Table 1: Effects on Deforestation in Public Lands

	(1)	(2)	(3)	(4)
	Normalized Deforestation	Normalized Deforestation	Normalized Deforestation	Normalized Deforestation
Post 2018 x Public Land	0.188 (0.029)***	0.187 (0.027)***	0.223 (0.025)***	0.221 (0.025)***
Observations	853,800	853,800	853,630	853,630
Year and Municipality FE	Y	Y	Y	Y
State x Year FE	N	Y	N	N
Municipality x Year FE	N	N	Y	Y
Geo Coordinates x Year FE	N	N	N	Y
Cluster	Municipality	Municipality	Municipality	Municipality

Notes: Robust standard errors in parentheses are clustered at the municipality level. All specifications include property and year fixed effects. Column (2) adds State x Year FE. Column (3) considers Municipality x Year FE and Column (4) adds GeoCoordinates x Year FE. Significance: *** p<0.01, ** p<0.05, * p<0.1

Table 2: Robustness and Heterogeneity results

	(1) Normalized Deforestation	(2) IHS of Deforestation	(3) Normalized Deforestation
Post 2018 x Public Land	0.349 (0.078)***	0.236 (0.033)***	
Post 2018 x Rural Settlements			0.169 (0.036)***
Post 2018 x Undesignated Forests			0.165 (0.032)***
Post 2018 x Indigenous Land			0.215 (0.070)***
Post 2018 x Untitled Terra Legal Program			0.461 (0.044)***
Post 2018 x Protected Areas			0.288 (0.071)***
Post 2018 x Military Land			0.218 (0.171)
Observations	853,630	853,630	853,630
Year and Municipality FE	Y	Y	Y
State x Year FE	N	N	N
Municipality x Year FE	Y	Y	Y
Geo Coordinates x Year FE	Y	Y	Y
Cluster	Municipality	Municipality	Municipality

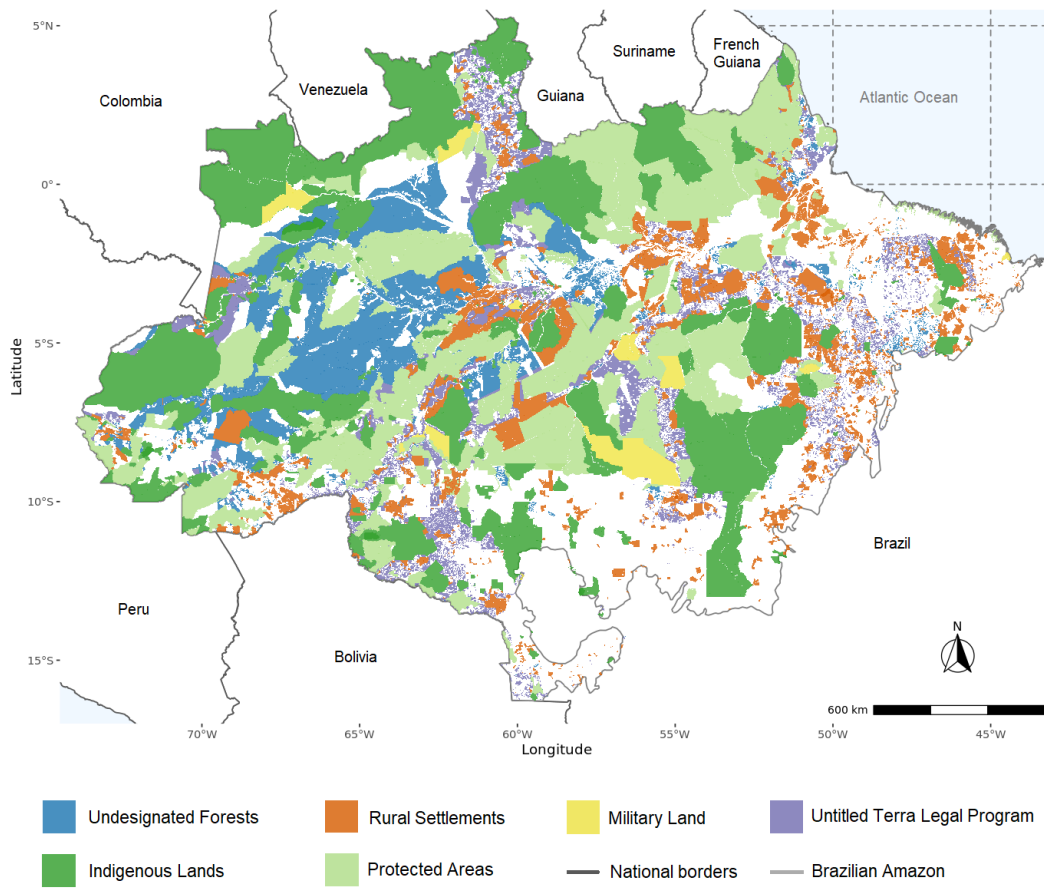
Notes: Robust standard errors in parentheses are clustered at the municipality level. Column (1) presents weighted-regression results. Column (2) considers an alternative dependent variable - IHS of deforestation. Column (3) presents heterogeneity results by type of public land. Significance: *** p<0.01, ** p<0.05, * p<0.1

Table 3: Counter-factual deforestation

	Observed Deforestation Total (A)	Observed Deforestation Public Land (B)	Predicted Deforestation Public Land (C)	Difference (D)=(B)-(C)	% difference w.r.t total deforestation (E)=(D)/(A)
2012	403,880	213,355			
2013	493,505	261,867			
2014	465,138	240,489			
2015	560,692	269,610			
2016	653,509	331,942			
2017	633,387	330,012			
2018	638,858	322,181			
2019	987,552	524,200	459,909	64,291	6.5%
2020	957,944	517,785	452,804	64,981	6.8%
2021	1,095,994	587,029	521,825	65,204	5.9%
Total 2019-2021	3,041,490	1,629,013	1,434,538	194,476	6.4%

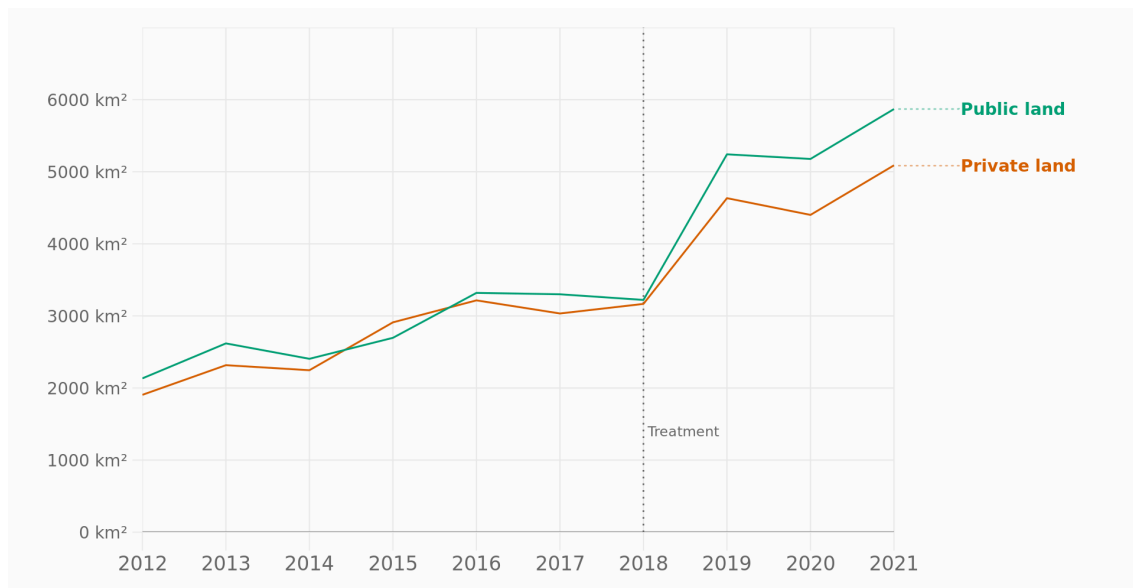
Notes: Counter-factual simulations are conducted using estimates from our preferred specification (Table 1, Column (4)). Values of deforestation are in hectares.

Figure 1: Land tenure in the Brazilian Amazon



Notes: The map displays public land by type.

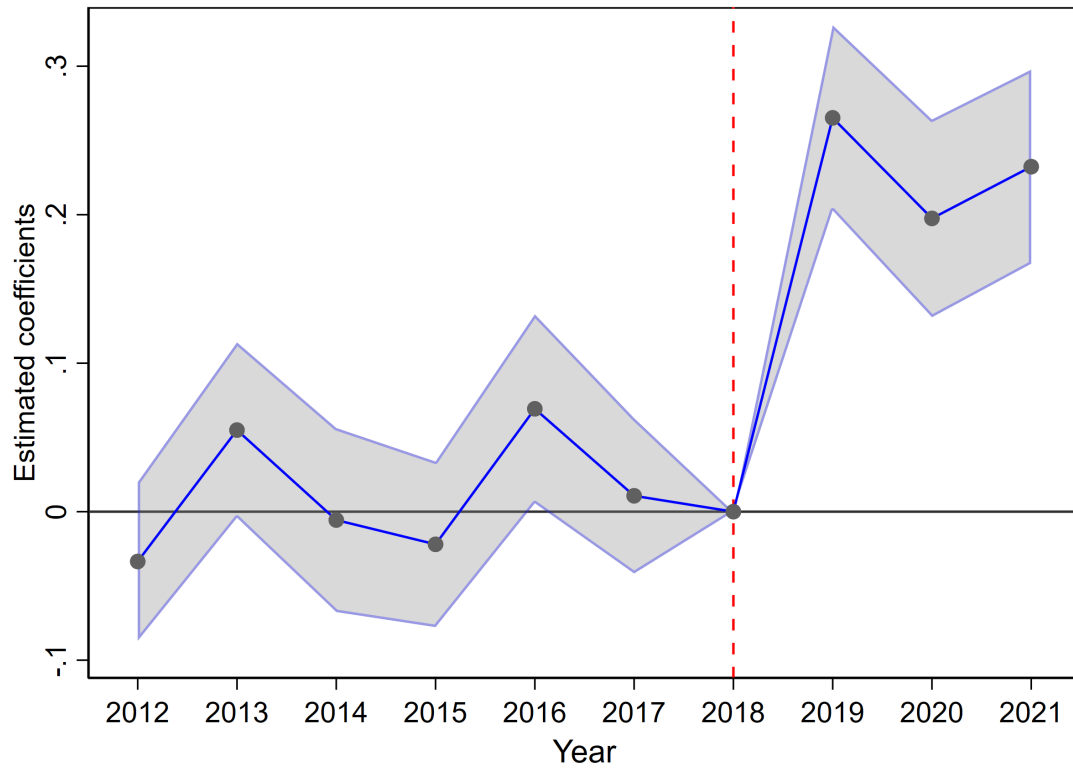
Figure 2: Deforestation in the Brazilian Amazon by public and private properties



Notes: The figure above depicts observed deforestation in the Brazilian Amazon grouped by public and private properties.

Source: Elaborated by the authors with data from PRODES/INPE (2021) and Atlas/Imaflora (2018).

Figure 3: Effects on Deforestation from the Event Study model



Notes: The figure above depicts the estimated coefficient for the interaction Year*Public Land. We control for property and year fixed effects, geo coordinates interacted with year fixed effects and municipality FE x Year FE. Errors are clustered at the municipality level