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Research article

Will farmers seek environmental regularization in the Amazon and how? Insights from the Rural Environmental Registry (CAR) questionnaires

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ABSTRACT

The future availability and quality of natural resources essential to life such as ecosystem services and biodiversity depend on the conservation and restoration of native vegetation. The Brazilian Native Vegetation Protection Law (NVPL) requires farmers to conserve a minimum percentage of native vegetation within their properties as Legal Reserves (LR) as well as riparian forests and hilltops as Permanent Preservation Areas (PPAs). To monitor the conservation and facilitate the compliance of these areas, the Rural Environmental Registry (CAR) and the Environmental Regularization Program (PRA) were created. However, so far, little is known about farmers' interest in joining the PRA and the actions they intend to take to correct their past illegal deforestation. This article explores a unique dataset comprising of the individual answers of 97 thousand farmers in the states of Pará and Mato Grosso given to the Brazilian Forest Service in the process of joining at the national rural environmental registry system. We found that the adherence to the PRA is positively correlated with recognition of the LR deficit and the size of the rural property. Also medium and large landowners and crop producers tend to seek compliance by taking actions outside the farm (compensation), while small farmers and squatters are more likely to act inside their own areas (restoration). Understanding farmers' interests and options for LR compliance can contribute for the formulation of more effective implementation strategies for PRA and NVPL.

1. Introduction

The future availability and quality of natural resources essential to life such as ecosystem services and biodiversity depend on the conservation and restoration of native vegetation (Joly et al., 2019). In order to reduce the effects of the loss of ecosystem services caused by the advancement of unsustainable activities on native vegetation, compliance with legislation and agreements that regulate land use and environmental protection is essential and urgent. Thus, Brazilian Native Vegetation Protection Law (NVPL – Law 12,651/2012) plays an important role in biodiversity preservation and climate change mitigation. This legislation has important instruments for conservation and environmental compliance of private lands, which cover ≈44% of Brazilian lands (Sparovek et al., 2019) and have more than half of Brazil's native vegetation (Metzger et al., 2019; Soares-Filho et al., 2014; Sparovek et al., 2012). All individual farms must conserve a minimum percentage of native vegetation within their properties as Legal Reserves (LR) as well as riparian forests and hilltops as Permanent Preservation Areas (PPAs) (Brasil, 2012). These areas provide ecosystem services that benefit both social and environmental common good, as well as agricultural production through biological pest control, regulation of climatic and hydrological systems, maintenance of soil structure and fertility, nutrient cycling, and pollination (Ditt et al., 2010; Kennedy et al., 2016; Metzger et al., 2019; Power, 2010).

Despite the high potential for forest conservation, land clearing on private properties remains the main driver of native vegetation losses in Brazil. By 2008 farmers have deforested illegally 50 ± 6 Mha that should have been conserved as LR and PPAs (Soares-Filho et al., 2014 – see also Guidotti et al. (2017) and Sparovek et al. (2012) for other estimates). Part of the deforested area needs to be restored or compensated[1] – 16.3 Mha of LR and 4.5 Mha of APPs (Soares-Filho et al., 2014). For this, the NVPL created the Rural Environmental Registry (CAR, in Portuguese) and the Environmental Regularization Program (PRA, in Portuguese). CAR is a large environmental registration program in Brazil that

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[1] The other part, about 58% of all the illegally cleared areas prior to 2008 (mostly in LR of small properties) was forgiven under growing pressure from law enforcement agencies, the agribusiness sector lobbied for a major overhaul in the NVPL leading to an amnesty (Soares-Filho et al., 2014).

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combines a monitoring tool based on satellite images and the digital georeferencing of rural properties (Azevedo et al., 2014; Pires and Ortega, 2013; Rajão et al., 2012). It is a mandatory electronic registry where farmers provide personal data, information about their property (e.g. size), and information about its legal status (LR, PPAs, etc.) (Brasil, 2012; MMA, 2014). Based on this information, if necessary farmers must develop actions for compliance with the NVPL inside their own rural property (natural regeneration or tree planting)[2] or outside (compensating)[3] (Brasil, 2012).

Understanding farmers' conservation behavior is the key to increasing efforts to address agri-environmental challenges (Thompson et al., 2015). There is a growing literature on farmer participation in conservation and/or agri-environmental programs, investigating farmers' attitudes and behavior towards the introduction of environmental measures and the factors underlying them (e.g. Reimer and Prokopy, 2014; Thompson et al., 2015; van Dijk et al., 2016; Zhang et al., 2015). In Brazil, the willingness of private landowners to meet NPVL requirements on their properties has been a rising issue for scientific research, since achieving compliance is rife with socioeconomic and political challenges (Azevedo et al., 2017; Santiago et al., 2018; Trevisan et al., 2016). Yet, few studies have attempted to understand the preferences of farmers about the different compliance options offered by the NVPL (Brito, 2020; Coudel et al., 2012; Giannichi et al., 2017; Pacheco et al., 2017; Santiago et al., 2018; Schmidt and McDermott, 2014; Schons et al., 2019; Trevisan et al., 2016). Expanding on this literature we analyze a unique dataset provided by farmers as part of the enrolment at CAR in the states of Pará and Mato Grosso to understand (i) whether landowners are willing to seek compliance, and (ii) what strategy they are most likely to use. More specifically, we aim to answer the following questions: Do farmers intend to adopt the PRA to become compliant with the NVPL? What regularization strategy do the farmers are likely to adopt?

2. Background

Most farmers consider LR an impediment to economic development as their maintenance involves foregone benefits (i.e. opportunity costs) from agricultural production (Azevedo et al., 2017; Bernasconi et al., 2016; Stickler et al., 2013). At the same time, understanding the motivations for complying (or not) to the NVPL and identifying the factors behind them is an essential starting point for promoting forest conservation and restoration on private lands.

For instance, using an econometric approach, Schons et al. (2019) suggest that the non-compliance of landowners with the NVPL is correlated with proximity to highways (−), tenure time (+), property size (−), and the ability to change the land use from cattle ranching to higher yield agriculture. Santiago et al. (2018) agree that property size is an important indicator of the likelihood of restoration (see also Stefanes et al., 2018), but add that crop diversity, as well as the presence of water sources, also contributes to compliance with LR regulations. Although this suggests at least some awareness of the benefits that forests provide (i.e. ecosystem services), some landowners still prefer non-compliance (Trevisan et al., 2016). The reasons why farmers do not engage in reforestation are diverse, such as lack of government incentives (law enforcement, financial and technical support), lack of knowledge but bureaucracy also remains an important barrier (Coudel et al., 2012). Meanwhile, the motivating factors for seeking compliance outside the farm via compensation are often reported as high opportunity cost of land use and forest area with low prices in land market (Brito, 2020; Holland et al., 2016; Pacheco et al., 2017), as well as the percentage of illegal deforestation up to 2008 (+) (Brito, 2020).

Finally, landowner perceptions about law enforcement seem to have a strong effect on their behavior. More specifically, the likelihood of compliance decreases with frequent policy changes (e.g. law revisions), weak and inconsistent law enforcement (Schmidt and McDermott, 2014), and also with the current and growing loosening of government inspection and penalization measures, while it increases with engagement in environmental licensing and exposure to technical support (Santiago et al., 2018). Other studies argue that CAR could prompt landowners to comply with LR regulations (e.g. Laudares et al., 2014), but empirical evidence suggests that, so far, its effectiveness is limited at best, due to the lack of law enforcement (Azevedo et al., 2017; Costa et al., 2018).

Although these studies underscore that compliance with LR regulations is ultimately a conscious choice by landowners, there is scant evidence of the level of farmers' information about the need to seek regularization or not. Furthermore, the diversification of compliance options introduced by the NVPL, particularly the introduction of compensation possibilities, not only raised questions about whether landowners would comply with LR regulations but also how they would do so. Some studies have estimated the demand as well as the equilibrium price of forest certificates (CRA, in Portuguese) under different regulatory scenarios (Brito, 2017; Freitas et al., 2017; Giannichi et al., 2017; May et al., 2015; Nunes et al., 2016; Soares-Filho et al., 2016). While others have looked at the costs and challenges related to forest restoration (Nunes et al., 2017; Santiago et al., 2018). Yet, very little is still known about how different profiles of farmers may seek to comply with the NVPL.

3. Methods

Our study was conducted in the states of Pará (PA) and Mato Grosso (MT), located in the Brazilian Amazon region. Pará is the 2nd largest state in Brazil (124.59 Mha) and Mato Grosso is the 3rd (90.32 Mha). Both states are pioneers in the creation of CAR, even before it became a legal obligation at the national level (Azevedo et al., 2014; Rajão et al., 2012). So far, Pará and Mato Grosso have about 222,669 and 145,140 registries in the CAR, respectively, which mostly come from small farms (PA 89.89% and MT 78.05%), followed by medium (PA 6.69% and MT 12.99%) and the remaining are large farms (PA 3.42% and MT 8.96%) (SFB, 2020). More importantly, both states encompass the Amazon agricultural frontier known as the deforestation arc, where deforestation rates have ranked among the highest in the Brazilian Amazon in the last 30 years (INPE, 2019), even though they have been striving to reduce deforestation in the last decades (Nepstad et al., 2014; Nunes et al., 2016). Finally, they have a large number of LR areas that demand recovery to comply with NVPL regulations, yet there is also a significant portion of LR assets that may be used for the compensation of other farms (Nunes et al., 2016; Soares-Filho et al, 2014, 2016; Sparovek et al., 2012).

Mato Grosso is one of Brazil's main agribusiness powerhouse. It is the largest cattle producer in Brazil with an estimated 31.97 million head in 2019 (15% of Brazil's herd) (IBGE, 2019a). In agriculture, the state of Mato Grosso also leads the ranking in soybean and corn production with 32.24 M/t (28%) and 31.24 M/t (31%), respectively (IBGE, 2019b). There was an expansion of the cattle slaughter infrastructure during 2000–2016 (+29% in the density of plants), and by 2016 operated in the state 72 slaughterhouses through 52 different companies (Vale et al., 2019). Pará has more than 20.88 million cattle (10% of Brazilian herd – 4th position) (IBGE, 2019a), also has about 1,88 M/t of soybeans and 0.83 M/t of corn (IBGE, 2019b). Concerning slaughterhouses, Pará has 20 federally inspected plants (Gibbs et al., 2016).

[2] 'Natural regeneration' is restoration of native vegetation resulting from natural processes, i.e. a passive restoration that consists of removing disturbing factors and isolating the area. 'Tree planting' consists of planting species of native vegetation and may include exotic species up to 50% of the total area to be recovered (Brasil, 2012).

[3] 'Compensation' is an offsetting mechanism that can be, for example, by forest certificates trading (CRA), LR surplus, areas in conservation units (UC) pending expropriation (Brasil, 2012).

As part of its environmental registration procedure, the National Rural Environmental Registry System (SICAR) includes a questionnaire about the environmental regularity of the property that must be filled by the farmers while joining the system. This questionnaire involves multiple choice close-ended questions about the farmers' perception of the compliance level of the property (i.e. existence of LR deficit or surplus[4] and environmental fines), and farmer's intentions concerning the regularization process (i.e. join PRA and how eventual deficits will be solved) (SFB, 2016). The data contain different sources of noise that generate uncertainties about the results of the analysis, namely, the binary (yes or no) approach of the questionnaire, farmers' lack of knowledge about the legislation, and the fact that quite often specialists in geoprocessing and employees of rural trade unions and non-governmental organizations fill the form on behalf of the farmers. But despite these limitations, the dataset provides an important source of knowledge about farmers' preferences about the environmental regularization process.

In addition to the SICAR questionnaire dataset (SFB, 2017), this study included an analysis of the rate of land area covered by agriculture (soybean, corn and/or cotton) (Agrosatélite, 2017) and the estimated LR status from the vegetation area declared in the CAR (Soares-Filho et al., 2016). In total, we explored 97,782 properties with CAR[5] (SFB, 2017), comprising 27% of CAR registries in Pará and Mato Grosso. These datasets were analyzed from two perspectives:

(i) *An assessment of the farmers' willingness to adhere to PRA* – a descriptive analysis was performed that crossed the declarations made by farmers on adherence to PRA, the declarations of the existence of LR deficits on their properties, and estimated LR status. Also, we used a logistic model in order to understand the profile of farmers wishing to participate in the regularization process (*PRA model*: 0 = no, 1 = yes); and

(ii) *A diagnosis of the declared preference of compliance alternatives* – a logistic model was used to verify the likely choice of farmers and whether the farmers are interested in the compliance inside (=0) or outside (=1) the rural property (*ALT model*), considering the characteristics of rural properties and their owners as determining factors (Table S1).

The fitted models assume that its outcome (Y) follows a binomial distribution (logit as link function):

$$Y_i = log(\frac{\pi_i}{1-\pi_i}) = \beta_0 + \sum_{j=1}^{p} \beta_j X_{ji} \quad (1)$$

where i is each property of a sample size n and π is the probability that $Y = 1$ (*PRA model:* farmers will adhere to the PRA; *ALT model:* they will regularize the LR outside their properties). $(1-\pi)$ is the probability that $Y = 0$ (*PRA model:* farmers will not adhere to the PRA; *ALT model:* farmers will regularize the LR inside their properties), $(\pi/\ 1-\pi)$ is the odds that $Y = 1$, and Y is the log odds or logit. β_0 is the model constant, β_j are the regression coefficients and X_j are the predictor variables (Table S1). The models were adjusted using 10-fold cross-validation in R (R Core Team, 2018). Instead of one model per state, we decided to estimate models including both areas, because individually we would have an imbalanced response class (e.g. 77% of one class against 23% of another), that would have to change model and/or use some techniques such as resampling (oversampling, undersampling) or generate synthetic samples.

[4] While the 'LR surplus' is the area of native vegetation above the percentage required by law, 'LR deficits' is the opposite.

[5] Since SICAR did not require farmers already enrolled in the old state-based CAR to reinsert their data, we exclude the dataset involves farmers that registered their properties in the CAR before the data migrated from the state level to the national model, which did not have a questionnaire.

To verify the discriminatory capacity of the models, i.e. the response of the logistic regression models, we used the receiver operating characteristic (ROC) curve (Bradley, 1997). The ROC curve calculates the accuracy in predicting the occurrence of an event by taking into account the cases where it actually occurred (i.e. true positive rate – the proportion of correct answers from observations regarding answer Y = 1) in relation to instances it where did not occur (i.e. false positive rate – the portion of correct observations regarding answer Y = 0). The closer the response estimated by the logistic response model observed, the larger the area under the curve (AUC) (Costa, 2019).

4. Results

4.1. Farmers' stated preferences

About 55% (12,279) of the analyzed farmers stated that they would choose an option to comply with LR inside the rural property. Of these farmers, more than 70% (8662) prefer to allow 'natural regeneration', while others stated that they prefer 'tree planting'. Although the remaining 45% (10,080) of the farmers stated a preference for 'compensating' their LR deficit (Fig. 1), a portion of them (17% | 1740) did not give further details on how they intend to compensate. This may indicate respondents' lack of knowledge and/or limitation of the CAR's questionnaire.

Most farmers in Pará stated that 'natural regeneration' (65% | 3527) would be the preferred means of compliance, while 'compensation' is the second most voted alternative (23% | 1265). Farmers who indicated 'compensation' as the preferred strategy for compliance, more often chose to purchase CRA (39% | 493) and the registration of an equivalent area of the same owner with native vegetation (38% | 475). In Mato Grosso, 'compensation' predominates with 52% (8815) of farmers, mostly preferring to buy and donate to the government an area located inside a protected area pending expropriation (46% | 4089). Unlike Pará, 'natural regeneration' in Mato Grosso is the second most frequent response (30% | 5135). The least cited alternative in both states is 'tree planting' (11% in PA and 18% in MT) (Figure S1).

Farmers wishing to adopt 'natural regeneration' or 'tree planting' as the main alternative to regularize the LR deficit declared the second choice if they were to switch to 'compensation' (Table S2). In Pará, the registration of equivalent native vegetation area in another farm of the same owner is highlighted as first and second among farmers who stated that they would adopt 'natural regeneration' and 'tree planting', respectively. In Mato Grosso, this option is in second and third place among farmers of the same groups (Table S2). Thus, if farmers adopt the options declared in the CAR and if the declared vegetation area is considered as the basis for the PRA, ≈1.38 Mha are expected to be restored (in 10,672 rural properties) and ≈2.70 Mha (in 8,651 rural properties) are likely to be compensated outside the farm in the states of Pará and Mato Grosso. This suggests that on average every farm would restore 129 ha or seek compensation of 312 ha outside the property.

Regarding the environmental regularization program, 81% (79,659) of the farmers stated that they wish to adhere to the PRA while 19% (18,123) claimed that they do not wish to adopt the program. The intentions of not joining the PRA do not define the non-adhesion of options to comply with the NVPL, since the farmer may do so independently, as indicated by the legislation (Brasil, 2012). There are some differences in preferences between farmers in Mato Grosso and Pará states. While 74% of the farmers stated they are willing to join PRA in the state of Pará, 84% of the farmers in Mato Grosso answered positively to this question. Among the farmers who agreed to adhere to the PRA, approximately 23% in both states also recognized the existence of an LR deficit within their properties. Of this group, only 15% (646) of rural properties in Pará and 76% (10,686) in Mato Grosso have LR deficits, estimated through declared vegetation (Fig. 2). This suggests that farmers are often more pessimistic about their compliance status, and are probably unaware of the different types of aminesty provided by the NVPL that reduce the

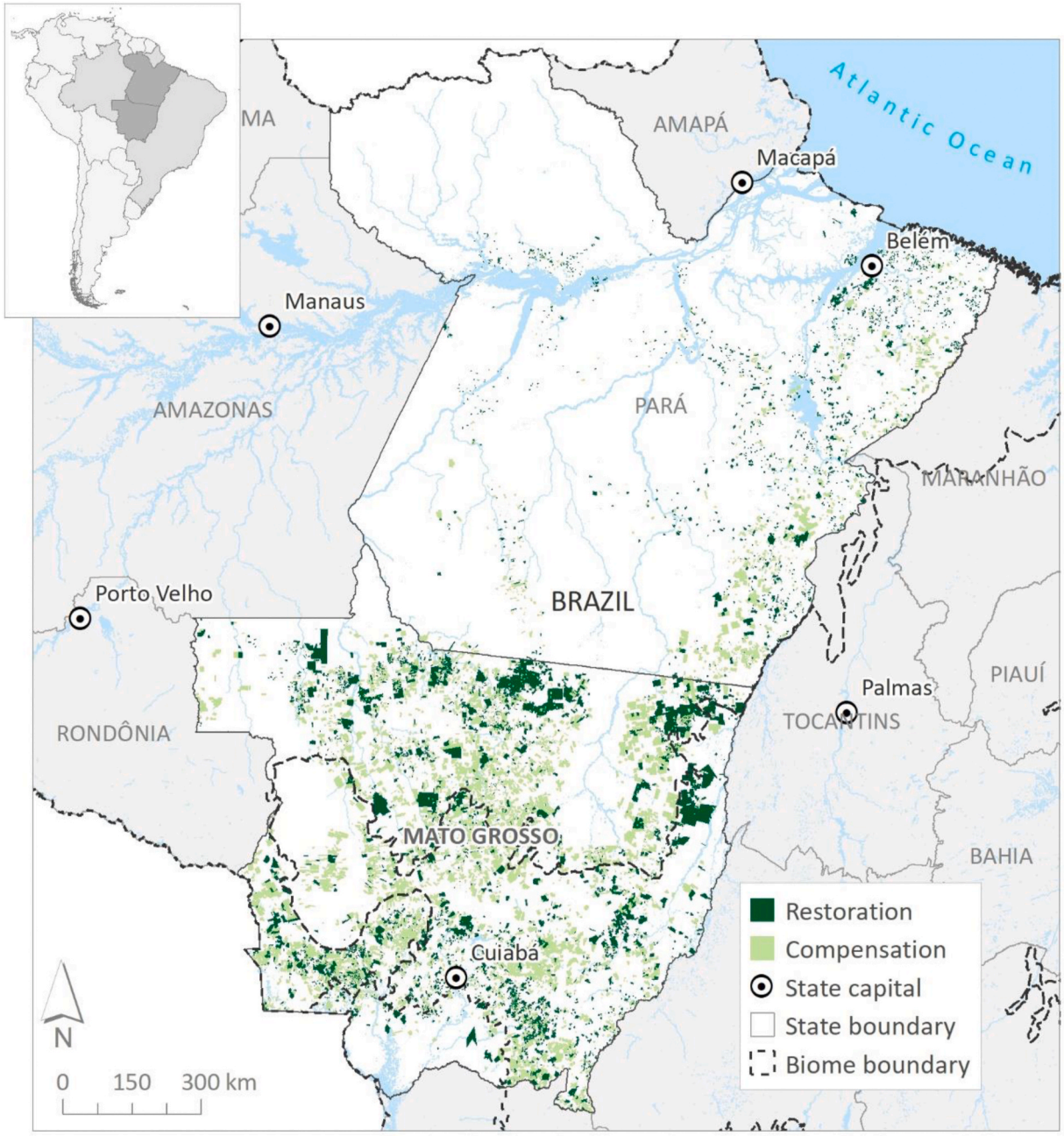

Fig. 1. LR deficit compliance options stated in the CAR, in the states of Pará and Mato Grosso, Brazil.

need to restore or compensate LR.

4.2. LR compliance choice model

The probability of adherence to the PRA increases on average by 16.53% (ranging from 8.26 to 25.49%) when the farm is large (>15 FM[6]) in relation to small (up to 4 FM). Farmers who reported not having an LR deficit are 79.51% less likely to adhere to the PRA than those who reported having an LR deficit. In addition, the estimated LR situation from the declared native vegetation area indicates that farmers with LR surplus (−41.73%) or null (−37.72%) are less likely to join the PRA compared to those with a deficit of estimated RL. Farm owned by a company also presented a negative effect (on average −29.47%) on adherence to PRA. The odds also increase by 4.26% when the farmer has a land title (Table 1). The size of the declared vegetation area had little effect on PRA adhesion. By contrast, the medium category of farm size was not significant to explain the interest of farmers to participate in the environmental regularization program in Pará and Mato Grosso.

Regarding the alternatives of regularization, the adjusted model suggests that the probability of a farmer choosing compensation as the preferred strategy for LR compliance reduces by 0.63% for each increase in the farmer's age (Table 1). This effect is smaller (−0.02% to −0.01%) when it comes to increasing the native vegetation area declared in the CAR. By contrast, the probability of adopting the regularization outside the farm is reduced, on average by 45.85%, when farmers have a land title. Farmers are also less likely to seek off-farm compliance when the

[6] Fiscal Module is a unit of measure in hectares set by Brazilian Institute of Colonization and Agrarian Reform (INCRA) for each municipality. In the state of Pará, the fiscal module varies from 5 to 75 ha and in Mato Grosso from 22 to 100 ha (INCRA, 2013).

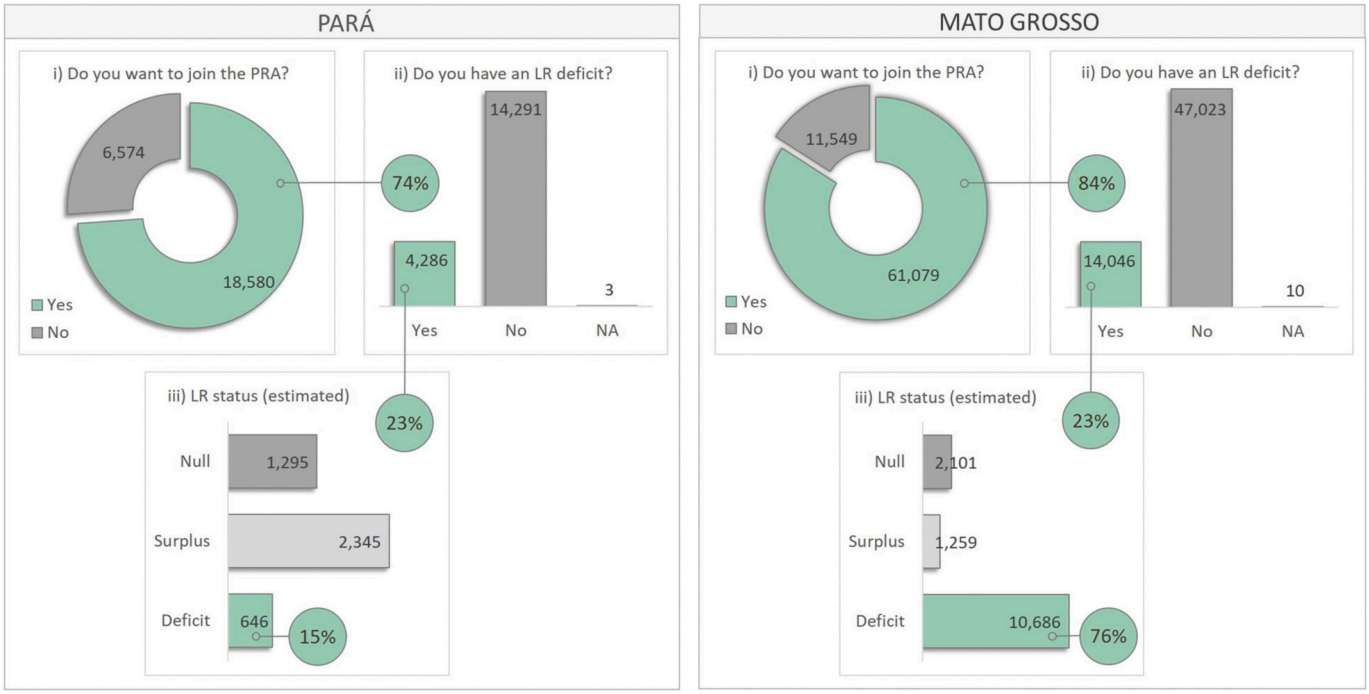

Fig. 2. Classification of farmers who declared to join the Environmental Regularization Program (PRA) in the states of Pará (left) and Mato Grosso (right), Brazil. NA – Not Available. LR status – Legal Reserve (LR) status estimated from the vegetation area declared in the CAR.

Table 1
Results of the PRA adherence (PRA model) and alternatives to regulate LR deficit (ALT model) in Pará and Mato Grosso, Brazil.

Variable	PRA Model (n = 97,782)						ALT Model (n = 19,323)					
	Coef.	Pr(>|z|)		OR	CI		Coef.	Pr(>|z|)		OR	CI	
					2.5%	97.5%					2.5%	97.5%
(Intercept)	2.989	<2e-16	***	19.859	17.991	21.937	−0.284	0.00018	***	0.753	0.649	0.874
Ownership:												
Individual	(base)						(base)					
Company	−0.349	1.3e-13	***	0.705	0.643	0.774	0.631	4.1e-10	***	1.880	1.545	2.295
Document:												
property	(base)						(base)					
land title	0.042	3.6e-02	*	1.043	1.003	1.084	−0.614	<2e-16	***	0.541	0.498	0.589
Age	0.003	3.2e-06	***	1.003	1.002	1.004	−0.006	3.2e-07	***	0.994	0.991	0.996
LR deficit:												
yes	(base)											
no	−1.585	<2e-16	***	0.205	0.191	0.220						
NA	−0.644	5.4e-01		–	–	–						
Vegetation area	<0.001	2.1e-08	***	1.000	1.000	1.000	< −0.001	4.6e-06	***	1.000	1.000	1.000
LR situation:												
deficit	(base)						(base)					
surplus	−0.540	<2e-16	***	0.583	0.559	0.607	−0.546	<2e-16	***	0.579	0.526	0.638
null	−0.474	<2e-16	***	0.623	0.594	0.654	−0.328	2.8e-11	***	0.721	0.654	0.794
Agricultural							1.858	<2e-16	***	6.410	5.532	7.445
Farm size:												
small	(base)						(base)					
medium	−0.034	2.3e-01		–	–	–	1.445	<2e-16	***	4.240	3.876	4.640
large	0.153	4.9e-05	***	1.165	1.083	1.255	1.941	<2e-16	***	6.967	6.126	7.940

Significance levels (***$p \leq 0.001$, *$p \leq 0.05$); OR – odds ratio; CI – confidence interval; Base – reference category adopted in the models.

estimated LR situation, considering the area of declared native vegetation indicates a forest surplus (−42.09%). The probability of choosing LR compensation increases on average by 87.96% when the farm is owned by a company (Table 1). The chances increase even more for medium and large farms, and when farms have a high percentage of agricultural coverage.

In terms of the discriminatory capacity, the *PRA model* has AUC = 0.641 and the sensitivity = specificity at 0.606 (Fig. 3), this indicates that the adjustment can distinguish about 60% of farmers who want to join the program or not. The *ALT model* has better performance, AUC equal to 0.788 and sensitivity = specificity at 0.712 (Fig. 3). This means that the model has about 70% chance to distinguish between cases of choosing compensation (compliance outside the property) and restoration (compliance inside the property), i.e. it indicates that the model's ability to discriminate between farmers wishing to adopt an alternative of compliance outside or inside the property is not random.

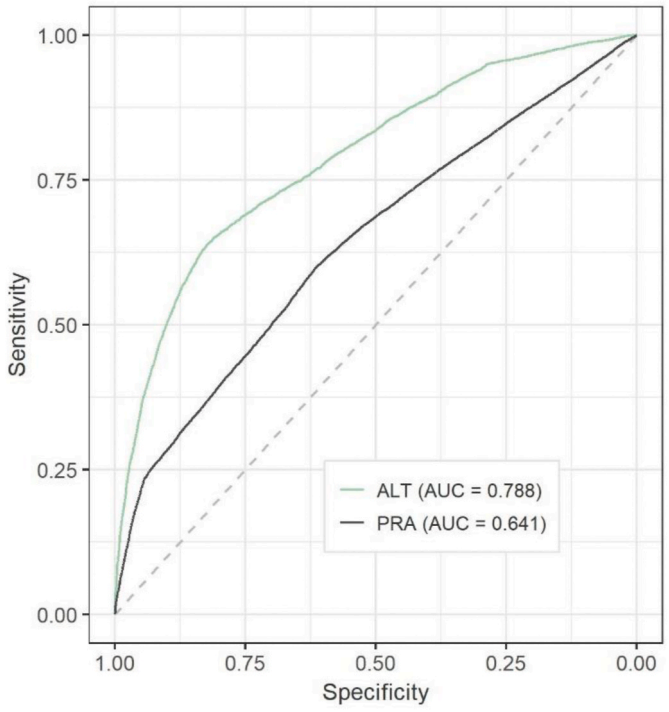

Fig. 3. Receiver operating characteristic curve of ALT and PRA models. AUC – area under the curve.

5. Discussion

5.1. Who will regularize or not?

The adjusted model indicates that the chances of farmers adopting the PRA in Pará and Mato Grosso, increase among the older farmers, large rural property and/or those who recognize that they have an area of LR to regularize. Conversely, farmers who do not recognize having LR deficits, have small properties and/or are companies have greater resistance to adhering to the PRA. Possibly more farms owned by companies will regularize outside the program than the ones owned by individuals.

In another state of the Amazon region (Rondônia), Santiago et al. (2018) also identified a greater propensity to adopt restoration plans among large landowners and those with knowledge about the requirements of the NVPL. But the lack of knowledge about the NVPL compliance mechanisms is common, other studies that interviewed farmers in the Brazilian Amazon and Cerrado have pointed out (Coudel et al., 2012; Giannichi et al., 2017; Pacheco et al., 2017; Rasmussen et al., 2017). In the state of Pará, Schons et al. (2019) identified that the size of the property reduces non-compliance with the NVPL, this indicates the compliance trend of large properties. Just as we found that 80% wish to join PRA, Coudel et al. (2012) also demonstrated that about 80% of the landowners interviewed in the municipalities of Paragominas and Santarém, state of Pará, are willing (or maybe) to participate in a reforestation project.

A greater resistance of farmers to adhere to the environmental regularization of rural properties is associated with the perception of pending issues to be solved (e.g. LR deficit). It has not yet been possible to notice the presence of farmers who declared that they do not wish to join PRA in the questionnaire, and that later officially jointed the programme in Mato Grosso (Table S3), probably because the PRA is still in its early stages and, therefore, few farmers have entered. On the other hand, it was possible to observe some farmers who reported not having LR deficit later signed a commitment term to compensate a LR deficit (Table S3).

5.2. Which strategy will likely be chosen and why?

Our analyses indicate that the probable profile is: (i) outside the rural property (compensation) – company-owned farms, soybean, corn or cotton producers, and medium and large farmers; and (ii) inside the rural property (natural regeneration or tree planting) – small farmers with a land title. These results are in line with other studies indicating that agricultural producers will compensate their LR deficit depending on the opportunity costs, current land use, suitability for grain crops, and restoration costs (Azevedo et al., 2017; Brito, 2020; Freitas et al., 2017; Soares-Filho et al., 2016). Our results go further when we show statistical significance of farmer's profiles based on stated preference for specific LR deficit compliance options.

In Paragominas (Pará), farmers' motivation for choosing compensation over restoration as renting forest land, purchasing forest land specifically for the LR compensation, or using forest land they previously owned is related to a local model for charging compensation, soil suitability for grain crops and some farmers believe it is more advantageous to buy a forest area than to rent it (Brito, 2020). Furthermore, the opportunity cost of agricultural areas makes compensation more attractive instead of restoration (Brito, 2017, 2020; Freitas et al., 2017; Micol et al., 2013; Soares-Filho et al., 2016). In some cases, it is possible 'that the compensation price costs only 3% of the gains in 1 ha of soy crop' (Brito, 2020, p. 5). Thus, possible the 'farmers with forest deficits may prefer to buy a forest area instead of renting for compensation if they have enough capital to invest' (ibid., p. 1).

A high opportunity cost is also expected of the medium and large farmers, who possibly have profitable activities. It may cost more to restore a large area than to buy another to compensate, for example. 'The market land values indicate that deforested lands are worth on average three times more than forestlands, reaching six times more when comparing the price of low-value forest areas with deforested areas suitable for agriculture' (Brito, 2020, p. 7). It is also common for farmers to have another farm with a forest that can be used to compensate for the deficit of a productive area (Pacheco et al., 2017). Thus, it is likely that the demand for outside regularization will be greater than inside, as those farmers who would choose the restoration (small farmers) have obtained a large amnesty from the new NVPL (Brasil, 2012). Furthermore, farmers' decision to reforest is strongly influenced by their perception of the economic and ecological impacts of restoration, and the policies that promote it (Trevisan et al., 2016), which are still insufficient.

Effective compliance of the LR deficit, whether inside the rural property (allowing natural regeneration or tree planting) or outside (offsetting), has many local and regional benefits (see Ditt et al., 2010; Metzger et al., 2019; Sparovek, 2012). The first alternative is a potential ally of forest restoration, but it depends on incentives, such as policies that will induce farmers to restore (Nunes et al., 2019; Trevisan et al., 2016). The regularization inside the property can be facilitated among the farmers with a positive perception of forests, e.g. those who do not see a forest as a barrier to production and understand that it has a positive impact on the property (Alves-Pinto et al., 2017). However, this positive view does not necessarily guarantee the implementation of restoration, but it is a point that can be exploited to motivate farmers (Alves-Pinto et al., 2017). If regularization inside the property is an option that would probably be carried out by small farmers, as indicated in our results, it is important that the restoration does not affect the production of family agriculture in order not to reduce the income of these small farmers. This requires more efficient strategies than compulsory restoration and payments for environmental services (PES) which has not been very effective. These strategies may include the promotion of agroecological practices, and the sustainable economic use of LR and APP within the limits defined by the legislation (Trevisan et al., 2016). For this reason argue that restoration should include not only PES but also technical support, and an education program that details the direct and indirect economic benefits of restoration.

In the case of medium and large farms, strategic planning for the recovery of degraded areas must be careful with competition for areas, for example, adopting an area of low agricultural productivity and a strategic location for connecting/forming green corridors (Brancalion et al., 2012; Latawiec et al., 2015; Smith et al., 2010). Likewise, investments in the recovery of degraded areas should go hand in hand with improving agricultural production (e.g. technologies for increasing productivity per area, sustainable intensification) to reduce/minimize the loss of commodities that may expand in other areas (e.g. conversion of forest to production areas) if demand for these commodities remains high (Alves-Pinto et al., 2017; Latawiec et al., 2015; Smith et al., 2010). The regularization outside the rural property decreases the impact of conservation on agricultural production and preserves native vegetation on private land not protected by the NVPL (i.e. surpluses that can be deforested) (Soares-Filho et al., 2016; Sparovek, 2012).

5.3. What is missing for compliance to actually happen?

Certainly, important steps still need to be taken in two ways. First of all, the government environmental agencies need: (i) to proceed with CAR validation to verify declared information and the existence of LR deficits and surplus; (ii) to define terms and procedures for implementation and monitoring of the PRA, including restoration and CRA (e.g. ecological identity); (iii) to offer technical support to small landowners; and (iv) to mobilize all farmers and require compliance, and to ensure sufficient human and technological resources to assist the demand. Second, the farmers need to engage with the compliance process and understand the benefits that conservation can bring to their properties. Another challenge is to overcome the political pressure to remove LR as an institution (see Metzger et al., 2019). In view of this, there is a clear need for a strategy to promote the implementation of environmental compliance in Brazil involving all stakeholders (e.g. governments, regulatory agencies, farmers, and the commodities market).

Given the high costs of maintaining native vegetation in private areas are directed only at landowners, the effective monetary value assignment to standing forests could probably reduce the effects of the cost of conversion. For this, several existing mechanisms, such as compensation and the forest carbon market, need to be disseminated and maintained. The environmental quota certificates market (CRA) has the potential to reduce NVPL compliance costs (Brito, 2017; Freitas et al., 2017; Micol et al., 2013; Soares-Filho et al., 2016) and could also be used as a low cost infrastruture for the implementation of PES related to other services (e.g. biodiversity conservation and carbon). For this, it is important that the compensation mechanism be disseminated via advertisement and technical support among potential buyers and sellers in order to overcome the current mistrust among farmers regarding its potential (Giannichi et al., 2017; Pacheco et al., 2017; Rasmussen et al., 2017).

6. Conclusion

Our analyses show that a large number of farmers intend to regularize their LR deficit, despite all challenges. Most of the farmers evaluated in Pará and Mato Grosso stated that they would adopt the PRA if any deficit were identified, with large landowners more likely to take action. This is good news because resolving the irregularity of these large properties would solve a significant portion of the deficits. We also noted strong intention from farmers to seek regularization by compensating their LR deficit off-farm. This further reinforces the need to design CRA's regulatory procedures and spread knowledge for successful implementation. As expected, the demand for compensation tends to come from medium and large landowners, and crop producers. Despite the declared positive intention, certainly, the farmers will not willingly fully comply with the NVPL unless a strong signal comes from the market, government and society.

Yet, there are still substantial challenges ahead related to the validation of CAR, and the definition of the procedures for the implementation and monitoring of PRA. Both require political support and the strengthening of the institutional capabilities of state governments and the support from the Ministry of Environment and Brazilian Forestry Service. Unfortunately, both are currently lacking especially at the federal level. The Brazilian Forest Service has ensured the states that in early 2019 it would provide them with a new system to support the validation of CAR, but by the beginning of 2021, this system has not yet been implemented. As state-level agencies wait for the tools from the federal government, in most states validation proceeds slowly or has not even started. The political signals are also contributing to reduce the interest of farmers in seeking environmental regularization. With political leaders openly criticizing and delegitimizing the current legislation, deforestation is going up, and a growing number of farmers likely to become reluctant in making investments towards regularization (Rajão et al., 2020). Therefore, the current situation suggests that even though Brazil has all the means to start one of the largest restoration and conservation programs in the world prompted by the demand for regularization, this is not likely to happen in the next few years unless a major political change takes place.

Author contribution

Rayane Pacheco: Methodology, Software, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. Raoni Rajão: Methodology, Validation, Resources, Writing – original draft, Writing – review & editing. Richard Van der Hoff1: Writing – original draft, Writing – review & editing. Britaldo Soares-Filho: Validation, Resources, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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