Limits of Brazil's Forest Code as a means to end illegal deforestation

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Edited by Emilio F. Moran, Michigan State University, East Lansing, MI, and approved May 24, 2017 (received for review March 23, 2016)

The 2012 Brazilian Forest Code governs the fate of forests and savannas on Brazil's 394 Mha of privately owned lands. The government claims that a new national land registry (SICAR), introduced under the revised law, could end illegal deforestation by greatly reducing the cost of monitoring, enforcement, and compliance. This study evaluates that potential, using data from state-level land registries (CAR) in Pará and Mato Grosso that were precursors of SICAR. Using geospatial analyses and stakeholder interviews, we quantify the impact of CAR on deforestation and forest restoration, investigating how landowners adjust their behaviors over time. Our results indicate rapid adoption of CAR, with registered properties covering a total of 57 Mha by 2013. This suggests that the financial incentives to join CAR currently exceed the costs. Registered properties initially showed lower deforestation rates than unregistered ones, but these differences varied by property size and diminished over time. Moreover, only 6% of registered producers reported taking steps to restore illegally cleared areas on their properties. Our results suggest that, from the landowner's perspective, full compliance with the Forest Code offers few economic benefits. Achieving zero illegal deforestation in this context would require the private sector to include full compliance as a market criterion, while state and federal governments develop SICAR as a de facto enforcement mechanism. These results are relevant to other tropical countries and underscore the importance of developing a policy mix that creates lasting incentives for sustainable land-use practices.

deforestation | Forest Code | tropical forests | governance | Amazon

Historically, deforestation has accounted for the majority of greenhouse gas (GHG) emissions from developing countries (1, 2). In Brazil, this trend changed dramatically when annual deforestation rates in the Amazon dropped by 76% from 2005 to 2012 (3–5). Avoided deforestation during this period generated emissions reductions on the order of 3.2 Gt CO_2, compared with a historical baseline (5–7). There are several potential explanations for the observed decline in deforestation. These include the establishment of new protected areas (7), restrictions on credit available to illegal deforesters (8, 9), public blacklists of properties and municipalities that deforest illegally (10), moratoria to eliminate deforesters from soy and beef supply chains (5, 11), and command-and-control enforcement actions by state and federal agencies (12–15).

Despite advances, Brazil still faces two key barriers to effective enforcement of deforestation. First, the lack of a comprehensive national database of property boundaries (i.e., a land registry) has made it difficult to link new deforestation to specific land owners. Second, deforestation patches have decreased in size, making them increasingly difficult to detect (16). Both pose substantial challenges for forest monitoring, effective enforcement, and restoration of illegally deforested areas (i.e., forest "deficits") mandated by the Forest Code. This is illustrated by the fact that the majority (~69%) of deforestation from 2002 to 2009 occurred on properties whose boundaries were not publicly registered.

In the face of these difficulties, the Amazon states of Mato Grosso (MT) and Pará (PA) invested in systems to control and monitor deforestation, implementing a land registry known as the Rural Environmental Registry (CAR, Portuguese acronym) in 2008 (MT) and 2009 (PA). To join CAR, landowners must georeference their property boundaries and remaining forests using satellite images (Fig. 1) (17, 18). For the first time, CAR made it possible for government agencies to identify the perpetrators of deforestation and monitor whether individual landowners were complying with the Forest Code. These state land registries served as models for the National Rural Environmental Registry System (SICAR), which today is the main instrument for implementing the new Forest Code. The 2012 Forest Code stipulates that landowners in the Amazon biome should conserve 80% of their property (land area) in native vegetation, whereas those in the Cerrado should conserve 20–35% (19).

SICAR aimed to register roughly 5,000,000 rural properties throughout Brazil by May 2016. This target date was postponed to December 2017 by Law No. 13.295 on June 14, 2016 (20). By August 2016, it had registered 3,700,000 properties spanning 387 Mha (21). The GIS-based environmental registry promises to make landowners accountable for illegal deforestation and restoration requirements, while reducing the cost of monitoring for the government, landowners, and the private sector (22). Commodities buyers currently face high monitoring and transaction costs to ensure deforestation-free supply chains (e.g., the soy moratorium) (23). If the national CAR system were fully implemented—together with complementary public policies—it has the potential to replace these initiatives, reduce deforestation, and lower costs (11, 24).

Although an important first step, registering with CAR does not guarantee that landowners will comply with the law or reduce deforestation. Full compliance involves very high restoration

Significance

Brazil's new Forest Code has the potential to halt illegal deforestation in the country's native forests and savannas through implementation of a federal land registry—along with powerful tools that facilitate enforcement and give landowners a pathway to restoring or compensating their "forest deficits." This study suggests that these tools fall short of their promise. Although landowners in eastern Amazonia have been motivated to join state land registries, many continue to deforest and few have restored their illegally cleared areas. Results indicate that the economic benefits of full compliance with the Forest Code remain scant. To end deforestation, Brazil must realign its financial and policy incentives to encourage this outcome. The fate of the country's forests hangs in the balance.

Author contributions: A.A.A., R.R., M.A.C., M.C.C.S., and A.A. designed research; A.A.A., R.R., M.A.C., and M.C.C.S. performed research; B.S.S.-F. contributed new analytic tools; R.R., A.A., and R.P. collected data in the field; A.A.A., R.R., M.A.C., M.C.C.S., and T.N.P.R. analyzed data; and A.A.A., R.R., M.A.C., M.C.C.S., and M.N.M. wrote the paper.

The authors declare no conflict of interest.

This article is a PNAS Direct Submission.

Freely available online through the PNAS open access option.

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This article contains supporting information online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.1604768114/-/DCSupplemental.

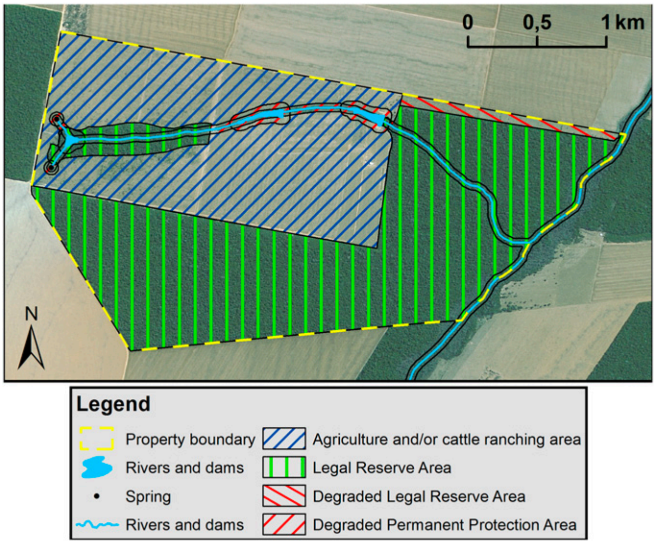


Fig. 1. Example of a CAR (Rural Environmental Registry) property registered according to the national registry standard (SICAR). The property boundary is shown by the dashed yellow line. Legal Reserves are designated by the green hatching, whereas Legal Reserve deficits are marked by red hatching. Buffer zones around rivers and dams (areas of permanent protection) are included in the Legal Reserve area. Blue hatched areas represent agriculture and cattle-ranching areas.

costs, opportunity costs of foregone production, and negligible benefits, given the relatively low risk of receiving fines due to poor enforcement. This also reflects a lack of market demand for legality as a criterion for purchase of commodities (24).

Despite the great potential of public land registries, few studies have quantified their effects on deforestation in the Amazon (but see 17, 25, 26) or their role in ensuring compliance on private properties. Studies of other deforestation-control measures—including payments for environmental services (27, 28) and protected areas (29, 30)— suggest that these programs do not always yield the expected conservation outcomes. The effectiveness of these policies in improving forest governance in the tropics remains an open question, including CAR, which has yet to be fully implemented. To address this gap, we analyzed the recent experiences of Mato Grosso and Pará, with the goal of improving implementation of SICAR in Brazil and similar systems in other countries.

This study addresses three central questions: (*i*) What motivates producers to join CAR? (*ii*) Are registered producers less likely to deforest? (*iii*) Are registered producers more likely to comply with Forest Code restoration requirements? These questions are essential to understanding how individual farmers perceive the incentives at each stage of CAR implementation. To address them, we evaluated costs and benefits of environmental compliance from the producer's point of view. We quantified deforestation in 49,669 rural properties in Mato Grosso and Pará that joined CAR from 2008 to 2013. The control group included properties before CAR registration, whereas the treatment group included properties after registration (31) (*SI Appendix*). To control for exogenous factors (other than CAR) that might influence deforestation, we evaluated a series of models including several potential explanatory variables. Deforestation probability was modeled based on distance to markets, infrastructure, agricultural suitability, and slope (7). Forest patch size represented the supply of forests available for deforestation in a given property. We also assessed the impact of public policies such as the Green Municipalities Program (GMP) in Pará (a federal blacklist restricting credit to municipalities with high rates of illegal deforestation) and the number of fines related to environmental infractions over time.

To estimate the incentives to comply with the Forest Code, we used secondary data and published studies to evaluate the legal status of CAR properties and estimate the economic costs of being compliant (19, 32–34). We also used primary data from questionnaires with farmers and GIS professionals to evaluate costs and benefits at each stage of Forest Code compliance, using a sample of 20 municipalities and 33 in-depth interviews with state officials.

Results and Discussion

Incentives for Joining CAR. By 2013, registered CAR properties covered roughly 32% (23 Mha) of the areas eligible for registration in Mato Grosso and 57% (34 Mha) in Pará. Registered properties were distributed uniformly in both states, suggesting that a broad cross section of producers have joined (Fig. 2). Among the surveyed producers outside CAR, 30% in Pará and 36% in Mato Grosso declared that they would join only if forced to by government or market sanctions.

Both the rapid adoption of CAR and data from our questionnaires suggest that the incentives to join CAR outweighed the costs of remaining outside the system. The most immediate benefit of joining was a lower chance of receiving fines for not complying with state laws in Mato Grosso and Pará, where CAR membership is mandatory for all rural properties. To encourage adherence to the system, state officials reported having ignored legal infractions within CAR properties to avoid "scaring off" new registrants from joining the system.

A second (and likely stronger) incentive to join CAR was access to additional lines of credit for farmers. Resolution No. 3545/2008 of Brazil's Central Bank made it mandatory for producers to present a "license, certificate, or equivalent evidence of environmental compliance" to qualify for public loans (35). Because public loans are Brazil's main instrument for subsidizing the agricultural sector, their interest rates are much lower than those of private banks (28).

The third incentive to join CAR stemmed from the intervention of public prosecutors. To control growing deforestation rates in Pará, in 2009 public prosecutors pressed the state's large slaughterhouses to stop buying cattle from ranches that did not comply with environmental and labor laws. That same year, Greenpeace proposed an agreement urging the Amazon's four biggest slaughterhouses to boycott cattle from ranches with illegal deforestation after July 2009

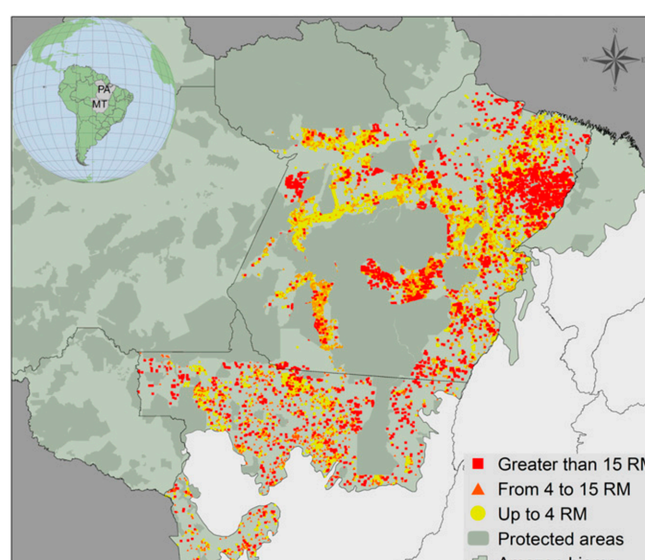


Fig. 2. Spatial distribution of properties enrolled in CAR (Rural Environmental Registry) by 2013, grouped according to their size class. Properties in yellow are small properties of up to four Rural Modules (<4 RM); orange are medium-sized properties (4–15 RM); and red are large properties (> 15 RM).

(36). These initiatives required cattle ranchers in both states to join CAR to sell their product to large slaughterhouses.

Governmental and nongovernmental organizations provided a fourth incentive by subsidizing the GIS surveys needed to register with CAR. Surveys of GIS professionals indicate that the cost of joining CAR averages US $549 for small and US $1686 for large properties in Mato Grosso, compared with US $307 for small and US $845 for large properties in Pará. Estimates are based on the 2013 average exchange rate between the Brazilian Real and US Dollar. These upfront costs represent half the monthly income for some small farmers, making them a significant barrier to entering CAR. NGO programs to cover these costs are an important incentive to join and exist in at least 64 municipalities where such work is undertaken by the following organizations: The Nature Conservancy (TNC), Instituto Socioambiental (ISA), Instituto do Homem e Meio Ambiente da Amazônia (IMAZON), Instituto Centro de Vida (ICV), and Instituto de Pesquisa Ambiental da Amazônia (IPAM).

Since its introduction, CAR has shifted from an instrument focused exclusively on environmental sustainability to one that is vital for the economic sustainability of rural producers. Our results suggest that subsidies to decrease the cost of entering CAR, combined with credit and market restrictions that increase the costs of production outside CAR, have made it relatively costly to remain outside the registry.

Deforestation Within CAR. A key assumption of CAR supporters at the federal level is that registering rural properties in the system will substantially decrease illegal deforestation. This is rooted in the idea that the land registry could radically reduce the cost of property-level monitoring and enforcement. To understand how CAR affected deforestation decisions, we compared annual deforestation rates in registered and unregistered properties, stratifying by property size. To control for other factors that might influence deforestation, we considered a series of models and explanatory variables (*Methods* and *SI Appendix*, Table S5). The final model included deforestation probability (7), remaining forest area, and whether the municipality was part of a federal blacklist to combat high deforestation (37).

Our results indicate that registering with CAR did not necessarily reduce illegal deforestation. Despite controlling for other spatial, economic, and policy factors, we observed substantial variation in the effectiveness of CAR over time and across property sizes (Table 1 and *SI Appendix*, Fig. S1). Small properties (<400 ha) in Mato Grosso and Pará had lower deforestation immediately after entering CAR, but this effect decreased over time and, in the case of Pará, disappeared entirely by 2012. Medium and large properties in both states showed no consistent pattern. For instance, in medium properties (400–1,500 ha) in Mato Grosso, deforestation was higher inside CAR for 2009–2010, but lower for 2011. The inverse was true for large properties (>1500 ha) in Mato Grosso, where deforestation was lower inside CAR in 2009, but higher in 2011 (Table 1 and *SI Appendix*, Fig. S1).

Including the effect of the municipalities blacklist improved our model, but other public policies had no clear effect. Including Pará's green municipalities program (38) and the number of fines at the municipal level issued by IBAMA (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis) (13, 15) did not change the general conclusions described above and, in some cases, reduced the overall predictive power of the models. This suggests that these policies either (*i*) did not reduce deforestation beyond the CAR effect or (*ii*) covaried with CAR at the property level.

Interviews with local farmers in Pará and Mato Grosso confirm the results presented above. Some small farmers reported feeling like they were being watched more closely by the state after joining CAR, supporting the idea that CAR could lower monitoring costs and improve enforcement. However, this initial perception of risk has decreased over time—in some cases to the point where the benefits of increasing deforestation (e.g., increased land value)

Table 1. Average property-level deforestation (ha) within CAR and Control groups

Size Class (RM)	Year	Before CAR (Control)	After CAR	CAR effect (%)	CAR effect (*P* value)
		Mato Grosso			
Up to 4 RM	2009	0.0772	0.0556	−3.25%	0.6513
	2010	0.1293	0.0374	**−7.21%**	**0.0051**
	2011	0.1925	0.0987	−6.12%	0.6445
4–15 RM	2009	0.0949	0.1253	7.41%	0.4346
	2010	0.1204	0.1182	**8.50%**	**0.0737**
	2011	0.2707	0.1323	−4.93%	0.8112
Over 15 RM	2009	0.1780	0.0268	−10.12%	0.2944
	2010	0.2206	0.1609	0.21%	0.9700
	2011	0.1733	0.2294	10.75%	0.6589
		Pará			
Up to 4 RM	2008	0.4430	0.1702	**−27.47%**	**0.0108**
	2009	0.3133	0.0803	**−21.34%**	**0.0000**
	2010	0.3573	0.2653	**−10.89%**	**0.0000**
	2011	0.2596	0.2200	**−5.29%**	**0.0000**
	2012	0.1836	0.1592	−3.19%	0.2785
4–15 RM	2008	0.8486	0.0277	**−34.71%**	**0.0956**
	2009	0.5589	0.4379	**18.54%**	**0.0177**
	2010	0.5400	0.3460	−4.72%	0.1933
	2011	0.3174	0.2612	0.96%	0.7498
	2012	0.3616	0.1728	**−14.61%**	**0.0173**
Over 15 RM	2008	0.9885	0.9923	13.78%	0.5111
	2009	0.5416	0.5416	**21.37%**	**0.0079**
	2010	0.6480	0.4546	**−8.13%**	**0.0416**
	2011	0.4379	0.3288	−2.91%	0.4065
	2012	0.1614	0.2380	14.09%	0.1277

The estimated CAR effect (model 3) is adjusted for forest size, an index of deforestation risk (developed using the Dinamica EGO modeling platform), and presence of the blacklist within the municipality. Bold numbers indicate *P* values that are significant ($P \leq 0.1$).

outweigh the potential costs (e.g., fines). Some farmers confessed to clearing small areas (<10 ha) on their properties, hoping that this small-scale deforestation would escape detection by satellites or be overlooked by state prosecutors. Satellite observations confirmed that a large proportion (63% for PA and 51% for MT) of clearings inside CAR were smaller than 10 ha. Recent studies indicate that this decrease in the size of deforestation patches is widespread (16, 39). Officials from both federal and state agencies confirmed that, in practice, small clearings are systematically ignored due to the logistical difficulty of inspecting deforestation events in situ. Although federal and state environmental agencies have started to use CAR data to issue fines remotely, officials report that this requires substantial labor and that personnel limitations make it impractical to prosecute small deforestation events. This suggests that most landowners deforesting within CAR do so with the expectation of impunity because small deforestation patches are not being detected or prosecuted by the control agencies.

Compliance with Forest Restoration Requirements Within CAR. Attaining zero illegal deforestation within CAR is an important target, but is not enough to guarantee Forest Code compliance. The law requires landowners who have deforested illegally to restore or compensate these clearings to fulfill the minimum Legal Reserve requirement (19). To weigh the costs and benefits of complying, the farmer must consider (*i*) incentives reserved for farmers that are fully compliant, (*ii*) the cost of forest restoration or compensation, (*iii*) the opportunity cost of foregone rents from agricultural production, (*iv*) the potential for future changes in the law, and (*v*) the probability of getting caught and punished for noncompliance. Using our sample and the survey data, we assessed the influence of most of these factors on producer decisions to maintain or restore Legal Reserves and riparian areas on their properties.

Incentives for compliance. At the moment, the economic benefits of full compliance with the Forest Code are scant. Officials from both states report that compliance with these obligations is rarely verified on the ground. Farmers need only present a report stating that they have taken steps to restore their forest debts, but only a fraction of CAR participants provide these reports on a regular basis.

Results from the questionnaires corroborate these findings. Only 6% of landowners with forest debts in Pará and Mato Grosso reported that they were taking the necessary measures to compensate or restore their Legal Reserves, whereas 76% affirmed that they would only compensate or restore if coerced to do so through government fines or market incentives. Even faced with a scenario in which strong restrictions were imposed by private and public actors, 18% said they would never compensate or restore their forest debts. Aside from a lower probability of receiving fines, the only economic incentive currently applicable to forest restoration is a 15% increase in the total amount of subsidized loans available to farmers who can demonstrate a commitment to full compliance with the Forest Code (40). No market initiative targets the forest debts of individual farmers under the Forest Code; they focus instead on eliminating newly deforested areas from commodity supply chains (11, 24). From a market perspective, there is still no difference between a landowner with an 80% Legal Reserve (compliant) and one with only 2% (noncompliant). Nevertheless, compliant and noncompliant landowners will obtain very different economic returns and environmental outcomes from properties of the same size.

Costs of compliance. The economic benefits of fully complying with the Forest Code are very low, whereas the costs are substantial. Illegally deforested areas provide a sizable portion of the income of Amazon farmers. In addition to forgoing this income, farmers are faced with the costs of restoration, which may be high depending on the method used. To estimate the potential costs, we first quantified the environmental deficit in our sampled properties. We found that 2,944 (82.6%) properties in Mato Grosso and 15,170 (76.6%) properties in Pará were not compliant with the Forest Code before joining the CAR system. This represented 841,564 ha and 3,951,664 ha to be restored in Mato Grosso and Pará, respectively (*SI Appendix*, Tables S1 and S2). Considering that restoration costs range from US $536 to 1,327 ha^{-1}, depending on the property's land-use history and adjacent land uses (19, 32), we estimated a total restoration cost from US $0.5 to 1.1 billion in Mato Grosso and from US $2.1 to 5.2 billion in Pará.

There are also substantial opportunity costs associated with (*i*) forgoing production on a given land parcel to begin restoration and (*ii*) maintaining surplus Legal Reserves—i.e., forest assets that could legally be converted for production. Stickler et al. (32) estimated that the first incurred a cost of US $673 ha^{-1}, and the latter incurred a cost of US $500 ha^{-1}. Combining these figures with our sample, we estimate that the total opportunity cost of forgoing production for restoration in 2008 was about US $0.5 billion in Mato Grosso and US $2.6 billion in Pará. The costs of maintaining surplus forests were excluded from our estimate of total compliance costs because they reflected both direct and indirect costs of restoration, as described below.

The combined direct cost of restoration and opportunity cost of forgone production ranges from US $1.0 to 1.6 billion in Mato Grosso (2008) and from US $4.7 to 7.9 billion in Pará (2007), considering a sample area of 57.2% in PA and 31.7% in MT. Considering the total productive area (In our sample, 1.3 Mha in Mato Grosso and 4.3 Mha in Pará are productive lands), we estimate that the average cost of Forest Code compliance ranges from US $768 to 1,270 ha^{-1} in Mato Grosso and from US $1,099 to 1,818 ha^{-1} in Pará. Although the cost of compliance can be reduced significantly through compensation mechanisms such as the Environmental Reserve Quota (CRA), in most cases this remains prohibitively expensive (41). For this reason, the level of Forest Code implementation in Brazil is low (34), and the forest debt in states like Mato Grosso is massive (19, 24).

Changes in the Forest Code. Revisions to the Forest Code have created a substantial disincentive for compliance. The latest of these occurred in 2012, with approval of a new Forest Code that lowered standards for environmental compliance. The 2012 Forest Code not only forgave fines for areas deforested illegally before 2008, but also reduced restoration requirements. The revised law decreased the total area requiring restoration by 41% and 68% in Mato Grosso and Pará, respectively (19). Considering only properties inside CAR, the land area to be restored dropped by 21% in Mato Grosso and 15% in Pará. These reductions affected 55% of the properties in Mato Grosso and 70% in Pará—primarily due to changes in the rules for smallholders. The only prerequisite for this benefit was to join CAR and commit to an official management plan (Portuguese acronym, PRA) to achieve environmental compliance. The new Forest Code thus provided substantial economic payoffs to producers who deforested illegally before 2008, while punishing those that refrained from clearing or invested in forest restoration to comply with the law. The amnesty provided by the new Forest Code increased the perceived risk of compliance by setting a precedent that future changes in the law might benefit farmers who deforest illegally.

Cost–Benefit Analysis of CAR Compliance. The empirical data presented here suggest four stages of compliance (Fig. 3): (*i*) outside CAR (BAU, business as usual), (*ii*) joining CAR (GOV1, governance 1), (*iii*) inside CAR and reducing deforestation (GOV2), and (*iv*) inside CAR and fully compliant with the Forest Code (GOV3). From the farmer's point of view, each stage carries potential costs and benefits that may or may not provide incentives to follow the rules. Our results suggest that there is a clear incentive for landowners to join CAR. This move from business as usual (BAU) to the first stage of governance (GOV1) has a relatively low transaction cost; a minimal increase in the risk of being fined; and substantial financial benefits, such as access to subsidized loans (Fig. 3).

The incentives are less clear when we consider the transition from joining CAR (GOV1) to stopping illegal deforestation (GOV2) and restoring illegally cleared areas (GOV3). Producers who do not deforest earn less by not expanding agriculture, but may benefit from fewer fines and access to green markets (11, 23). Our finding that some CAR properties had lower deforestation than the control group suggests that the perceived financial risks outweighed the benefits of deforesting. On the other hand, the fact that many producers maintained or increased deforestation after joining CAR suggests that the incentives to avoid deforestation vary in space and time (Fig. 3 and Table 1). Finally, our results indicate that landowners in all size classes are unlikely to invest in forest restoration (GOV3) under current conditions. Because most of the benefits can be accrued by joining CAR, achieving full compliance would require additional government or market interventions to realign the incentives for Forest Code compliance.

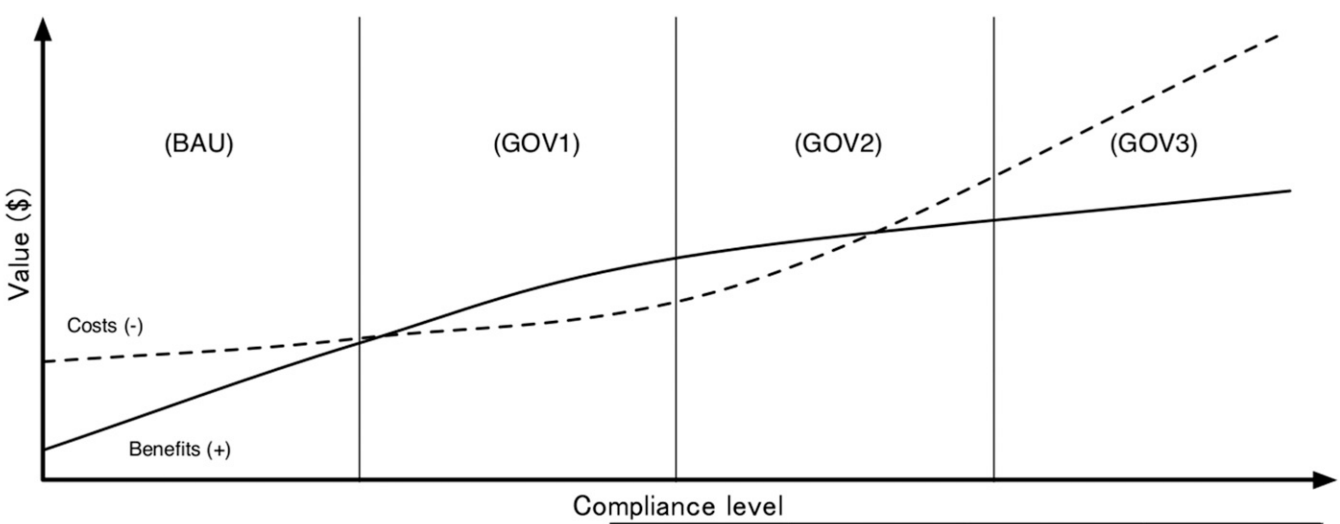
Conclusion and Policy Considerations

The CAR system will play an increasingly central role in the implementation of the Forest Code and climate policy in Brazil (19). This study shows that credit and market restrictions provide strong incentives for producers to join CAR. However, results suggest that its implementation has not contributed significantly to the observed reductions in deforestation from 2008 to 2012. Furthermore, the cost of restoring Legal Reserves and riparian areas remains prohibitively high relative to the benefits of joining CAR.

This study demonstrates that CAR membership does not yet provide the full suite of financial incentives (or command-and-control disincentives) needed to prevent deforestation and ensure full compliance with Forest Code restoration requirements. The existence of incentives like the soy and beef moratoria has helped to inhibit deforestation, but no comparable incentives exist to encourage restoration. Inconsistent monitoring and enforcement and the reluctance of state and municipal managers to punish landowners within CAR act as a safeguard for registered producers who continue deforesting. The resulting perception of impunity severely weakens environmental policies to control deforestation.

CAR's biggest potential stems from the fact that it drastically reduces the cost of monitoring and enforcement, but these savings have yet to materialize in Mato Grosso and Pará. To remedy this, public and private actors will need to shift the costs and benefits related to each of the four stages of compliance outlined above. At a minimum, the government must increase the likelihood of prosecution of illegal deforesters. To accomplish this, the Ministry of Environment could use SICAR to develop mechanisms to automatically detect illegal deforestation, identify the responsible parties, and levy fines. Restoration agreements signed by producers registered with CAR should also be monitored and evaluated using a combination of remote-sensing technologies and field sampling to increase compliance.

On the market side, public and private actors must increase the benefits of complying with the Forest Code beyond reducing the risk of fines. The 2012 Forest Code presents an opportunity to do this by creating new market mechanisms that allow landowners with forest surpluses to trade with farmers that need to compensate their forest debts (41, 42). This offset mechanism can be used to avoid legal deforestation and provide incentives to restore forests in highly degraded areas, particularly if integrated into the Brazilian REDD+ strategy and the Amazon Fund (43). New sustainable supply-chain initiatives (e.g., for beef and soy) should strive to adopt more stringent environmental compliance standards for purchase from industry retailers. Aside from requiring CAR, companies could build a network of suppliers who use Forest Code compliance as a criterion for purchasing products and providing financial incentives (18, 24). This would ultimately increase



		BAU	GOV1	GOV2	GOV3
Costs	Market access restrictions	Yes	No	No	No
	Transaction cost for joining CAR	None	Low	Low	Low
	Opportunity costs	None	None	None or Low	High
	Forest restoration costs	None	None	None	High
Benefits	Subsidized bank loans	No	Yes	Yes	Yes
	Protection from fines for deforestation	Low	Low	None or High	High
	Access to green markets	No	No	Yes	Yes
	Protection from fines for lack of compliance	Low	Low	Low	High

Fig. 3. Theoretical cost–benefit curve of CAR. In the BAU scenario, the costs are higher than the benefits of being outside CAR. The inverse is true in scenarios GOV1 and GOV2. The curves overlap again in GOV3, where the costs are higher than the benefits because of legal reserve restoration costs and possible reductions in productive area.

awareness and trust by buyers throughout the supply chains, reduce the risk of contamination with noncompliant products, and lower the reputational risk for large national and international buyers.

In theory, CAR can increase the government's ability to monitor environmental performance, prosecute illegal deforestation, and distribute the economic benefits of compliance. In practice, this potential has not yet been realized due to incomplete implementation of CAR and supporting public policies. Nevertheless, many commodity companies in the world have pledged zero deforestation (and illegality) within their supply chains by 2020. The experiences of CAR in Pará and Mato Grosso provide valuable lessons that could help federal and state governments make SICAR a more effective instrument for ending illegal deforestation and promoting forest restoration. The lessons learned from this study are relevant to the rest of Brazil and other tropical regions trying to balance food production and forest conservation.

Methods

We used a BACI (Before-After-Control-Impact) design to evaluate whether incentives to obey the law and reduce deforestation outweighed incentives to deforest within CAR. We compared areas that had not yet joined CAR (control) with those that had (treatment) to quantify the influence of the policy intervention (31). We used ordinary least squares regression models to evaluate the differences in deforestation rates between the "CAR" and "control" groups. The dependent variable was the logarithm of the deforestation rate plus one (to account for records with zero deforestation) (*SI Appendix*, *S1. Methods*).

We used different sets of covariates to test the importance of exogenous factors that might influence deforestation and confound our interpretation of CAR's performance, including (*i*) the logarithm of the remaining forest area, because the likelihood of deforestation decreases as forest becomes scarce; (*ii*) a dummy variable to indicate whether the property was enrolled in CAR; (*iii*) an index of deforestation risk (*SI Appendix*) (7); (*iv*) a variable indicating whether the property was in a blacklisted municipality (37); (*v*) the change in the number of fines in a municipality (an indicator of enforcement); and (*vi*) a dummy variable indicating whether the municipality participated in Pará's Green Municipality Program (GMP). We developed a series of models, containing combinations of these covariates, and compared their effectiveness in predicting deforestation at the property level (*SI Appendix*, *S1. Methods* and Tables S5–S14).

To estimate the incentives for full Forest Code compliance, we evaluated the legal status of CAR properties (*SI Appendix*, Fig. S2 and Tables S1 and S2) and estimated the economic costs of compliance using secondary data and published studies (19, 32–34). We used qualitative methods to estimate the incentives for the BAU and GOV institutional frameworks, administering questionnaires to 92 farmers and GIS professionals in 20 randomly selected municipalities in Mato Grosso and Pará. We conducted 33 semistructured interviews to comprehend the historical and political context of forest governance in the region. The authors were responsible for discussing and approving the methods for the interviews, as well as for obtaining consent for publishing interview results. Details on the conceptual approach to this analysis are provided in *SI Appendix*.

ACKNOWLEDGMENTS. We thank Paulo Moutinho, Vivian Ribeiro, and two anonymous reviewers for helpful comments on earlier drafts of this paper. We are also grateful to the interview participants for sharing their experiences and key insights that made this work possible. Funding for this work came from the Climate and Land use Alliance, Gordon and Betty Moore Foundation, Norwegian Agency for Development Cooperation (NORAD), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), and Fundação de Amparo à Pesquisa de Minas Gerais (FAPEMIG). Various institutions generously shared data, including Secretaria Estadual de Meio Ambiente (SEMA) in Mato Grosso and Pará.

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Supplemental Information Appendix

S1. Methods

CAR database

The CAR land registry was implemented in the states of Mato Grosso and Pará in 2009 and 2008, respectively. Its goal was to encourage landowner compliance with Brazil's Forest Code and improve the monitoring capacity of each state – one of a suite of land-use policies introduced to reduce illegal deforestation in the Brazilian Amazon. The registry contains spatial data on property boundaries, hydrography, and land use on individual rural properties. Our analysis combines that CAR database with deforestation data from PRODES, a deforestation monitoring system developed by the Brazilian Institute for Space Research (1). The combined dataset summarizes land-use dynamics in 49,669 rural properties enrolled in the CAR program, allowing us to quantify annual deforestation within each property from 2008-2012.

To ensure the robustness of our statistical analyses, we excluded a number of properties from this study. To account for limitations of the PRODES data (which cannot detect clearings under 6.5 ha), we eliminated all properties smaller than 10 ha, as well as those outside the Amazon biome. We excluded properties with cumulative deforestation higher than 95% to eliminate the possibility of deforestation rates being biased by the absence of forest in a specific group of properties. Properties participating in other environmental programs (e.g. land reform) were excluded from the analysis to isolate the impact of CAR on deforestation. More specifically, we excluded rural settlements under the jurisdiction of the National Institute for Agrarian Reform (INCRA), as well as properties certified[1] by INCRA. In the case of Mato Grosso, we also excluded rural properties that had begun the environmental licensing process (LAU) prior to the creation of CAR, since the LAU is more comprehensive and allows licenses for legal deforestation.

To ensure the spatial consistency of the dataset, we excluded any properties with more than 70% of their area overlapping, because it was impossible to determine which boundary was correct. In cases where the overlap was smaller than 70%, we visually inspected each property and excluded the property with the oldest CAR date. We also excluded all properties whose CAR registration lacked a date. Finally, since our goal was to estimate CAR's effect on *illegal* deforestation, we excluded properties that still had surplus forests that could be *legally* deforested. We did not have access to deforestation authorizations and could not evaluate the legality of clearings in these areas. The final filtered database excluded 52.6% of the properties and 29.6% of the area from Pará, leaving 18,738 CAR properties covering 9.4 million ha. In Mato Grosso, 54.8% of the properties and 45.7% of the area were excluded, leaving 3,513 CAR properties spanning 3.0 million ha. Below is a detailed description of the final dataset for each state.

In Pará, there were 13,028 small properties (< 4 rural modules, RM), representing 69.5% of the properties and 13.1% of the land area sampled. Medium properties (4-15 RM) totaled 3,320 (17.7%) and occupied 20.7% of the sample area, whereas large properties (>15 RM) totaled 2,390 (12.8%) and occupied 66.2% of the sample area. Small properties occupied a total of 1.2 million ha, medium properties 1.95 million ha, and large properties 6.2 million ha. In 2008, less than 3% of all properties had enrolled in CAR; by 2012, more than 96.5% of the properties had enrolled. Table S3 illustrates the temporal dynamics of CAR enrollment for properties in Pará. Approximately 84% of the properties had zero deforestation during the period 2008-2012 (a zero-inflated distribution).

[1] This is a requirement for all properties, dictated by INCRA under law #10.267/01. The document is mandatory to sell the property or change its size.

In Mato Grosso the number of small properties (< 4 RM) was 1,909, representing 54.3% of the properties and 9.2% of the land area sampled. Medium properties (4-15 RM) totaled 1,027 (29.2%) and occupied 24.0% of the sample area, whereas large properties (>15 RM) totaled 577 (16.4%) and occupied 66.8% of the sample area. Small properties accounted for 0.3 million ha; medium properties 0.7 million ha; and large properties 2.0 million ha. In 2009, less than 11% of the properties in these size classes had enrolled in CAR. By 2011, more than 97% of the properties had enrolled in CAR. Table S4 illustrates the temporal dynamics of CAR enrollment for properties in Mato Grosso. Approximately 96% of the records had zero deforestation from 2009-2011 (a zero-inflated distribution).

Analysis of deforestation before and after CAR

Finding appropriate "controls" to evaluate the impact of CAR on land-use dynamics presents a challenge. It is not appropriate, for example, to compare the properties inside CAR (which tend to be active/productive farms) with randomly chosen areas outside CAR, which may encompass undesignated public lands or other land uses that have different factors affecting their deforestation probability. To match CAR properties with comparable areas outside CAR, we adopted a BACI (Before-After-Control-Impact) design that involves classifying properties with known boundaries into two groups – registered and unregistered – during each year of the study.

The "CAR group" included properties that were registered in a given year and were therefore considered to be under the influence of the CAR policy. For comparison, we selected properties with known boundaries (the "control group") that were not registered in CAR during that year. The properties classified as part of the CAR group were matched to comparable properties in the control group to evaluate the rate of deforestation before and after CAR in each year. For example, a property registered with CAR in 2010 was considered part of CAR in subsequent years, but belonged to the control group prior to 2010. By comparing these two groups, we quantified the effect of CAR on deforestation from 2008 to 2012. Due to the restricted number of CAR properties in Mato Grosso at the beginning and end of the study period (2008 and 2012), we restricted our analysis to the period from 2009 to 2011.

To control for the effect of property size on deforestation rates, we divided the dataset into three size classes defined by the number of rural modules (RM) – a legal designation whose absolute area varies by municipality. The Forest Code uses the number of RMs as a criterion to define the legal rights and obligations of a given property. The first group consists of small properties with less than 4 RM (under 400 ha in most Amazon municipalities); the second includes medium properties ranging from 4 to 15 RM; and the third consists of large properties with more than 15 RM (usually larger than 6,000 ha).

We used standard ordinary least squares (OLS) regression models to estimate average deforestation rates, adjusted for property size, the remaining forest area, CAR group, and year effects. A detailed mathematical description of these analyses is provided below (see "Statistical Methods"). To evaluate the effect of exogenous factors (i.e. factors other than CAR) on deforestation, we quantified exogenous deforestation risk using the Dinâmica EGO modeling platform (SimAmazon model), described in Soares-Filho et. al. (2). This spatially explicit model uses a "weights of evidence" approach to estimate the overall probability of deforestation for each property. This Bayesian method accounts for the individual and combined effects of different drivers of deforestation. Our analysis considered the following exogenous drivers of Amazon deforestation: 1) distance to rivers; 2) distance to major roads; 3) maximum net present value of soy and cattle rents; 4) edaphic suitability for mechanized crops; 5) elevation; 6) slope; and 7) distance to urban centers. Based on these factors, we calculated an index of deforestation probability (EGO index), which was included as a covariate in the regression models.

Following Cisneros et al. (3), we included the *blacklist* covariate, B_{it}, which indicates whether property i belongs to a municipality blacklisted at time t. We also evaluated the *change in the number of fines* (i.e. for environmental infractions) as a covariate, C_{it}, which serves as a proxy for the strength of enforcement in a given municipality. We also used data on the Green Municipality Program (GMP)— available for 2011 and 2012 in the state of Pará only— to create a dummy variable considered as a potential covariate. We then developed several regression models, comprised of different subsets of these covariates (Table S5) and evaluated their effectiveness in predicting deforestation rates at the property level, within different size classes (see also "Statistical methods").

Statistical methods

Below is a brief mathematical description of the statistical model. To account for covariates, let Y_{it} be a continuous random variable representing the deforested area (ha), of property i at time t. F_{it} represents the area of forest (ha) remaining in property i at time t. Each property can be classified into one of three groups, related to size. Let $j_{[i]}$, $j_{[i]} \in \{1, 2, 3\}$, be the index related to each size group, or simply j. For properties up to 4 RM, then $j = 1$; for properties between 4 and 15 RM, then $j = 2$; and for properties greater than 15 RM, then $j = 3$. Furthermore, each property i can be classified through time t into the CAR or Control groups. Thus, let $k_{[i,t]}$ be the index representing the CAR ($k = 1$) or Control ($k = 2$) groups of property i at time t.

The response variable Y_{it} has a zero-inflated distribution. As previously described, 84% of the records for Pará state and 95.6% of those for Mato Grosso state had zero deforestation ($Y_{it} = 0$). In 2009, for example, 540 (93.6%) of the 577 properties in Mato Grosso larger than 15 RM had zero deforestation. Observing 32 properties with non-zero deforestation would thus require 500 properties, on average. Non-zero deforestation data ($Y_{it} > 0$) occurred in small subsets of properties and were highly asymmetric, with extreme values. To account for this empirical distribution of the response variable, we wrote the base OLS statistical model (hereafter named model 1) as follows:

$$\log(Y_{it} + 1) = \mu_{jt} + \alpha_{jt} logF_{it} + \beta_{jt} x_{it} + \epsilon_{it}$$

where the dependent variable is the logarithm of the deforestation rate plus one (to account for records with zero deforestation). The logarithm function also reduces the effect of highly asymmetric deforestation values on the dependent variable. The logarithm of the remaining forest area was included in the model as a covariate, $logF_{it}$, following a standard form used in epidemiological statistical regression models (4). The dummy variable, x_{it}, indicates whether property i at time t is enrolled in CAR ($x_{it} = 1$) and ϵ_{it} is a random variable representing the error.

We evaluated seven different OLS models, considering different subsets of covariates as described below.

Model	Description
1	$\log(Y_{it} + 1) = \mu_{jt} + \alpha_{jt} logF_{it} + \beta_{jt} x_{it} + \epsilon_{it}$
2	$\log(Y_{it} + 1) = \mu_{jt} + \alpha_{jt} logF_{it} + \gamma_{jt} E_{it} + \beta_{jt} x_{it} + \epsilon_{it}$
3	$\log(Y_{it} + 1) = \mu_{jt} + \alpha_{jt} logF_{it} + \gamma_{jt} E_{it} + \delta_{jt} B_{it} + \beta_{jt} x_{it} + \epsilon_{it}$
4	$\log(Y_{it} + 1) = \mu_{jt} + \alpha_{jt} logF_{it} + \gamma_{jt} E_{it} + \lambda_{jt} C_{it} + \beta_{jt} x_{it} + \epsilon_{it}$
5	$\log(Y_{it} + 1) = \mu_{jt} + \alpha_{jt} logF_{it} + \gamma_{jt} E_{it} + \eta_{jt} P_{it} + \beta_{jt} x_{it} + \epsilon_{it}$
6	$\log(Y_{it} + 1) = \mu_{jt} + \alpha_{jt} logF_{it} + \gamma_{jt} E_{it} + \delta_{jt} B_{it} + \eta_{jt} P_{it} + \beta_{jt} x_{it} + \epsilon_{it}$
7	$\log(Y_{it} + 1) = \mu_{jt} + \alpha_{jt} logF_{it} + \gamma_{jt} E_{it} + \delta_{jt} C_{it} + \eta_{jt} P_{it} + \beta_{jt} x_{it} + \epsilon_{it}$

The variable B_{it} indicates whether property i belongs to a blacklisted municipality at time i, described in Cisneros et al (3); E_{it} is the deforestation index (EGO), described earlier; C_{it} is the change in the number of fines over time; and P_{it} is a dummy variable indicating the presence of the Green Municipality Program (GMP) ($P_{it} = 1$). Tables S5-S14 summarize the model results. The variables included in each model are in Table S5. A comparison of the adjusted R^2 for each model is presented in Table S6. The CAR effect of each model is presented in Table S7, while the coefficients and model estimates from models 1-7 are presented in Tables S8-S14. The "best" model was selected by maximizing the adjusted R-squared ($R^2_{adj.}$), which includes a penalty for additional variables (see Table S6). This model selection was corroborated by the Akaike Information Criteria (AIC) metric, which yielded the same results.

Overall, Model 3 (Table S10) did the best job of predicting deforestation at the property level across both states (see also Table S6). Predictors included in that model were: the (log) area of remaining forest, risk of deforestation as indicated by the EGO index, participation in the blacklist, and membership in CAR. Although the other two variables (GMP and Fines) had an effect on deforestation in some models (and also independently), they likely covaried with membership in CAR and did not add sufficient explanatory power to warrant inclusion in the final model (see Table S7 for a comparison of the CAR effect in each model). Although the municipal blacklist had an effect in Model 3, its coefficient suggests that being blacklisted did not necessarily reduce deforestation in CAR properties (Table S10). This may be because the federal policy of blacklisting occurs in municipalities with high deforestation rates. Municipal and state governments have responded to these federal blacklists by creating programs such as Pará's Green Municipalities Program, but there is likely a time lag between being blacklisted and any observed effect on deforestation.

Incentives for institutional change

Our analysis of farmers' behavior and preferences relied on an analytical framework derived from institutional theory (5-7). We evaluated farmer incentives for institutional change (IC) as follows:

$$IC = IN - (OC + TC + RB)$$

Where **IN** is the net income (considering production costs and revenue); **OC** is the opportunity cost due to institutional restrictions on resource use, **TC** is the transaction cost related to monitoring and enforcement and **RB** is the risk of breaking the rules by deforesting illegally. These consequences include the payment of fines, legal fees, losses from market restrictions, and other issues perceived by the farmer (8). Together, these elements represent **IC,** the incentive associated with a given institutional framework. Using this framework, we evaluated the likelihood that an economic agent (producer) would adhere to a given set of rules by considering the tradeoffs among costs and benefits for any given scenario. Results of these qualitative analyses are summarized in Figure 3.

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S2. SI Figures

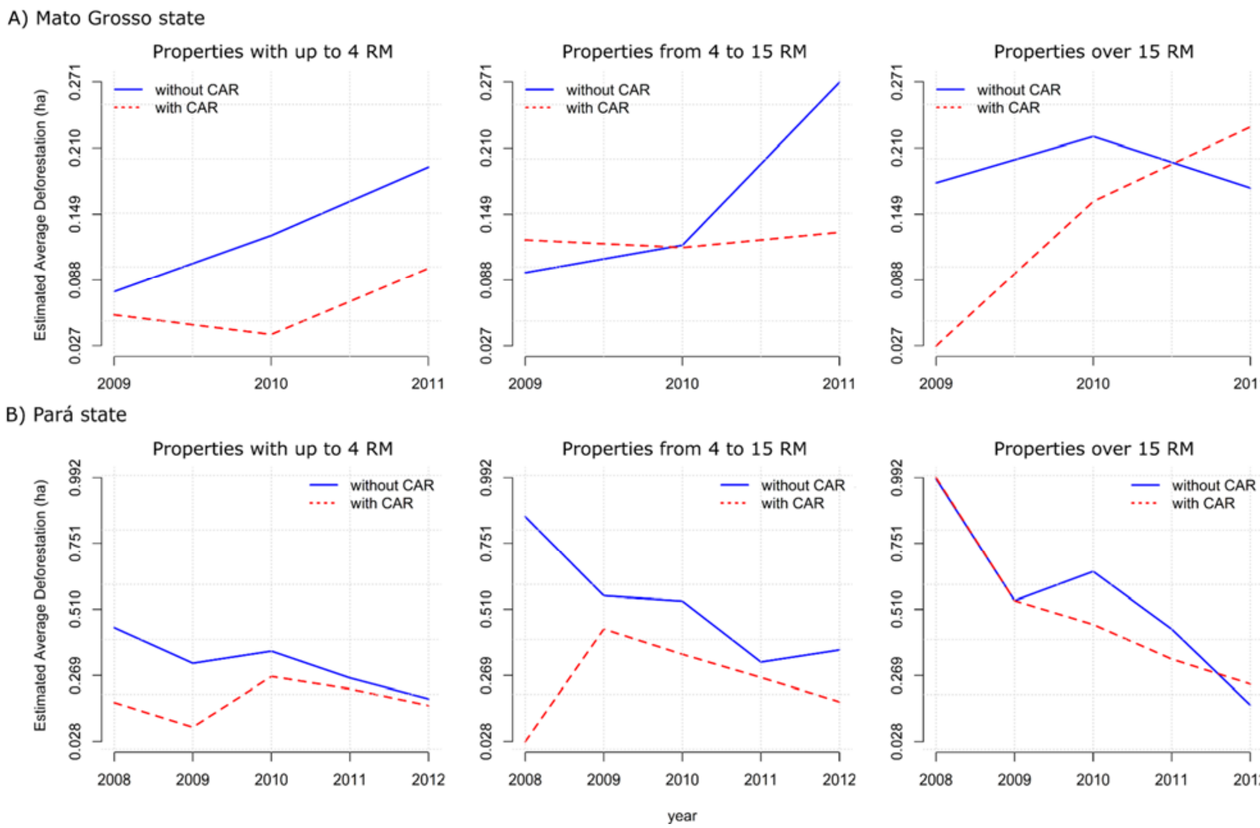

Figure S1. Annual deforestation rates (per property) within the CAR and Control groups in Mato Grosso (MT) and Pará (PA). The groups were divided into (a) small properties (< 4 RM); (b) medium-sized properties (4-15 RM); and (c) large properties (> 15 RM). Blue lines represent deforestation in the Control group. Dashed red lines represent deforestation in the CAR group.

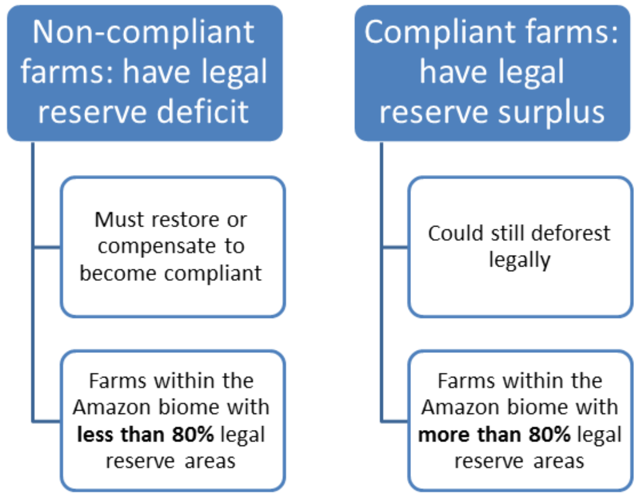

Figure S2: Farm-scale requirements to achieve environmental compliance under Brazil's Forest Code (FC). To determine whether a property had Legal Reserve deficits or surpluses, we conducted a spatial-temporal analysis using CAR property boundaries and annual deforestation data from PRODES/INPE. The analysis accounted for remaining forestland within properties in 2007 (Pará) and 2008 (Mato Grosso). Properties with over 80% forest cover were considered to have a surplus – meaning they exceeded FC conservation requirements. Those with le

S3. SI Tables

Table S1. Area of original and remaining forestland (including forest deficits and surpluses) in rural properties of Pará state (2007), grouped according to size classes.

State of Para (2007)						
Properties with forest deficit (Legal Reserve deficit)						
Property size classes	No. of properties	Original forest area (ha)	Remaining forest area (ha)	Remaining forestland (%)	Forest deficit (below 80%)	Forest deficit (ha)
under 4 RM	10,999	1,027,431	404,818	39.40%	- 40.60%	417,127
4 to 15 RM	2,581	1,468,735	584,059	39.77%	- 40.23%	590,929
over 15 RM	1,590	5,803,471	1,699,169	29.28%	- 50.72%	2,943,608
Total	15,170	8,299,637	2,688,046	32.39%	- 47.61%	3,951,664
Properties with forest asset (Legal Reserve surplus)						
Property size classes	No. of properties	Original forest area (ha)	Remaining forest area (ha)	Remaining forestland (%)	Forest surplus (above 80%)	Forest surplus (ha)
under 4 RM	2,787	262,986	243,445	92.57%	12.57%	33,056
4 to 15 RM	903	582,851	548,855	94.17%	14.17%	82,574
over 15 RM	945	2,023,231	1,919,872	94.89%	14.89%	301,287
Total	4,635	2,869,068	2,712,172	94.53%	14.53%	416,918
Total sample: 19,805 properties						
Property size classes	No. of properties	Original forest area (ha)	Remaining forest area (ha)	Remaining forestland (%)		
under 4 RM	13,786	1,290,417	648,263	50.24%		
4 to 15 RM	3,484	2.051.586	1,132,914	55.22%		
over 15 RM	2,535	7,826,702	3,619,041	46.24%		
Total	19,805	11,168.705	5,400,218	48.35%		

Table S2. Area of original and remaining forestland (including forest deficits and surpluses) in rural properties of Mato Grosso state (2008), grouped according to sizes classes.

State of Mato Grosso (2008)						
Properties with forest deficit (Legal Reserve deficit)						
Property size classes	No. of properties	Original forest area (ha)	Remaining forest area (ha)	Remaining forestland (%)	Forest deficit (below 80%)	Forest deficit (ha)
under 4 RM	1,762	255,316	78,666	30.81%	- 49.19%	125,587
4 to 15 RM	812	570,924	209,347	36.67%	- 43.33%	247,392
over 15 RM	370	1,340,641	603,928	45.05%	- 34.95%	468,585
Total	2,944	2,166,881	891,941	41.16%	- 38.84%	841,564
Properties with forest asset (Legal Reserve surplus)						
Property size classes	No. of properties	Original forest area (ha)	Remaining forest area (ha)	Remaining forestland (%)	Forest surplus (above 80%)	Forest surplus (ha)
under 4 RM	164	27,156	25,623	94.35%	14.35%	3,898
4 to 15 RM	231	169,855	161,118	94.86%	14.86%	25,234
over 15 RM	225	768,938	728,439	94.73%	14.73%	113,289
Total	620	965,949	915,180	94.74%	14.74%	142,421
Total sample: 3,564 properties						
Property sizes groups	No. of properties	Original forest area (ha)	Remaining forest area (ha)	Remaining forestland (%)		
under 4 RM	1,926	282,472	104,289	36.92%		
4 to 15 RM	1,043	740,779	370,465	50.01%		
over 15 RM	595	2,109,579	1,332,367	63.16%		
Total	3,564	3,132,830	1,807,121	57.68%		

Table S3. Enrollment of properties in CAR in Pará state (2008-2012).

Property size class	Property type	2008	2009	2010	2011	2012
under 4 RM	Control	99.40%	96.80%	75.44%	45.1%	3.48%
	CAR	0.60%	3.20%	24.56%	54.9%	96.52%
4 a 15 RM	Control	99.25%	90.90%	59.58%	34.65%	3.49%
	CAR	0.75%	9.10%	40.42%	65.35%	96.51%
over 15 RM	Control	97.66%	87.57%	52.13%	31.55%	2.55%
	CAR	2.34%	12.43%	47.87%	68.45%	97.45%

Table S4. Enrollment of properties in CAR in Mato Grosso state (2009- 2011).

Property size class	Property type	2009	2010	2011
under 4 RM	Control	97.27%	41.03%	1.10%
	CAR	2.73%	58.97%	98.90%
4 a 15 RM	Control	90.36%	35.74%	1.66%
	CAR	9.64%	64.26%	98.34%
over 15 RM	Control	89.60%	40.21%	2.08%
	CAR	10.40%	59.79%	97.92%

Table S5. Variables included in each of the tested ordinary least squares regression models.

OLS regression models	Included variables					
	logForest	CAR	EGO	Blacklist	Fines	GMP
1	X	X				
2	X	X	X			
3	X	X	X	X		
4	X	X	X		X	
5	X	X	X			X
6	X	X	X	X		X
7	X	X	X		X	X

Table S6. Adjusted coefficient of determination (R^2_{adj}) for each of the OLS models. Bold text indicates the best value; bold red text indicates the average of the best model.

Property size class (Rural Module, RM)	Year	Model 1	2	3	4	5	6	7
Mato Grosso (2009-2011)								
under 4 RM	2009	1.19%	1.21%	**1.31%**	1.30%	-	-	-
	2010	1.54%	1.53%	**1.81%**	1.58%	-	-	-
	2011	1.21%	1.35%	**1.68%**	1.28%	-	-	-
4 to 15 RM	2009	1.19%	1.21%	**1.31%**	1.30%	-	-	-
	2010	1.54%	1.53%	**1.81%**	1.58%	-	-	-
	2011	1.21%	1.35%	**1.68%**	1.28%	-	-	-
over 15 RM	2009	1.19%	1.21%	**1.31%**	1.30%	-	-	-
	2010	1.54%	1.53%	**1.81%**	1.58%	-	-	-
	2011	1.21%	1.35%	**1.68%**	1.28%	-	-	-
	Mean value	1.31%	1.37%	**1.60%**	1.38%	-	-	-
Pará (2008-2012)								
under 4 RM	2008	7.36%	8.76%	**9.41%**	8.83%	8.76%	**9.41%**	8.83%
	2009	5.52%	5.84%	**7.70%**	5.95%	5.84%	**7.70%**	5.95%
	2010	3.56%	3.72%	**4.21%**	4.05%	3.72%	**4.21%**	4.05%
	2011	2.29%	2.62%	2.87%	2.63%	2.62%	**2.88%**	2.63%
	2012	1.78%	2.02%	2.13%	2.14%	2.02%	2.11%	**2.15%**
4 to 15 RM	2008	7.36%	8.76%	**9.41%**	8.83%	8.76%	**9.41%**	8.83%
	2009	5.52%	5.84%	7.70%	5.95%	5.84%	7.70%	5.95%
	2010	3.56%	3.72%	4.21%	4.05%	3.72%	4.21%	4.05%
	2011	2.29%	2.62%	2.87%	2.63%	2.62%	2.88%	2.63%
	2012	1.78%	2.02%	2.13%	2.14%	2.02%	2.11%	**2.15%**
over 15 RM	2008	7.36%	8.76%	**9.41%**	8.83%	8.76%	**9.41%**	8.83%
	2009	5.52%	5.84%	**7.70%**	5.95%	5.84%	**7.70%**	5.95%
	2010	3.56%	3.72%	**4.21%**	4.05%	3.72%	**4.21%**	4.05%
	2011	2.29%	2.62%	2.87%	2.63%	2.62%	**2.88%**	2.63%
	2012	1.78%	2.02%	2.13%	2.14%	2.02%	2.11%	**2.15%**
	Mean value	4.10%	4.59%	**5.26%**	4.72%	4.59%	**5.26%**	4.72%

Table S7. Estimated CAR effect for each of the proposed OLS models. Statistically significant results are shown in bold red text (α = 0.10).

Property size class (Rural Module, RM)	Year	Model							**Mean value**
		1	2	3	4	5	6	7	
Mato Grosso (2009-2011)									
under 4 RM	2009	-3.77%	-3.54%	-3.25%	-3.47%	-	-	-	-3.50%
	2010	**-7.38%**	**-7.23%**	**-7.21%**	**-7.27%**	-	-	-	-7.27%
	2011	-5.87%	-5.89%	-6.12%	-5.89%	-	-	-	-5.94%
4 to 15 RM	2009	8.87%	8.62%	7.41%	8.85%	-	-	-	8.44%
	2010	**8.37%**	**8.33%**	**8.50%**	**8.40%**	-	-	-	8.40%
	2011	-5.70%	-5.12%	-4.93%	-5.02%	-	-	-	-5.19%
over 15 RM	2009	-9.54%	-9.70%	-10.12%	-10.89%	-	-	-	-10.06%
	2010	1.81%	2.31%	0.21%	1.69%	-	-	-	1.50%
	2011	11.56%	13.84%	10.75%	14.11%	-	-	-	12.56%
	Mean value	-0.18%	0.18%	**-0.53%**	0.06%	-	-	-	-0.12%
Pará (2008-2012)									
under 4 RM	2008	**-31.03%**	**-31.35%**	**-27.47%**	**-31.36%**	**-31.35%**	**-27.47%**	**-31.36%**	-30.20%
	2009	**-25.55%**	**-26.11%**	**-21.34%**	**-25.93%**	**-26.11%**	**-21.34%**	**-25.93%**	-24.62%
	2010	**-11.49%**	**-11.45%**	**-10.89%**	**-11.11%**	**-11.45%**	**-10.89%**	**-11.11%**	-11.20%
	2011	**-5.24%**	**-5.41%**	**-5.29%**	**-5.40%**	**-5.42%**	**-5.23%**	**-5.40%**	-5.34%
	2012	-3.00%	-3.01%	-3.19%	-3.09%	-3.18%	-3.27%	-3.28%	-3.15%
4 to 15 RM	2008	-30.24%	-33.81%	**-34.71%**	-33.86%	-33.81%	**-34.71%**	-33.86%	-33.57%
	2009	**26.87%**	**25.56%**	**18.54%**	**24.58%**	**25.56%**	**18.54%**	**24.58%**	23.46%
	2010	-5.04%	-5.18%	-4.72%	**-5.99%**	-5.18%	-4.72%	**-5.99%**	-5.26%
	2011	0.72%	0.96%	0.96%	0.87%	1.21%	1.28%	1.14%	1.02%
	2012	**-14.62%**	**-14.48%**	**-14.61%**	-14.37%	**-14.61%**	**-14.66%**	**-14.47%**	-14.54%
over 15 RM	2008	32.05%	16.98%	13.78%	15.95%	16.98%	13.78%	15.95%	17.92%
	2009	**31.71%**	**27.56%**	**21.37%**	**26.43%**	**27.56%**	**21.37%**	**26.43%**	26.06%
	2010	-6.76%	**-6.75%**	**-8.13%**	-6.20%	**-6.75%**	**-8.13%**	-6.20%	-6.99%
	2011	-5.24%	-3.40%	-2.91%	-3.53%	-3.40%	-2.93%	-3.56%	-3.56%
	2012	12.48%	13.48%	14.09%	12.56%	13.50%	14.19%	12.77%	13.30%
	Mean value	-2.29%	-3.76%	**-4.30%**	-4.03%	-3.76%	-4.28%	-4.02%	-3.78%

Table S8. Estimated coefficients and statistical inference results for model 1. Bold text indicates statistical significance; bold red text indicates significant CAR effect.

Property size class (Rural Module, RM)	Year	logForest		CAR			R^2adj
		estimate	Pr(>|t|)	CAR effect	CAR effect(%)	Pr(>|t|)	
Mato Grosso (2009-2011)							
under 4 RM	2009	1.0469	0.0000	0.9623	-3.77%	0.5984	1.19%
	2010	1.0469	0.0000	**0.9262**	**-7.38%**	**0.0040**	1.54%
	2011	1.0646	0.0000	0.9413	-5.87%	0.6594	1.21%
4 to 15 RM	2009	1.0458	0.0078	1.0887	8.87%	0.3526	1.19%
	2010	1.0595	0.0016	**1.0837**	**8.37%**	**0.0776**	1.54%
	2011	1.0381	0.0703	0.9430	-5.70%	0.7818	1.21%
over 15 RM	2009	1.0424	0.0679	0.9046	-9.54%	0.3244	1.19%
	2010	1.0452	0.0743	1.0181	1.81%	0.7443	1.54%
	2011	0.9730	0.3262	1.1156	11.56%	0.6366	1.21%
Pará (2008-2012)							
under 4 RM	2008	1.2420	0.0000	**0.6897**	**-31.03%**	**0.0035**	7.36%
	2009	1.1923	0.0000	**0.7445**	**-25.55%**	**0.0000**	5.52%
	2010	1.1571	0.0000	**0.8851**	**-11.49%**	**0.0000**	3.56%
	2011	1.1114	0.0000	**0.9476**	**-5.24%**	**0.0000**	2.29%
	2012	1.0803	0.0000	0.9700	-3.00%	0.3094	1.78%
4 to 15 RM	2008	1.2378	0.0000	0.6976	-30.24%	0.1634	7.36%
	2009	1.2070	0.0000	**1.2687**	**26.87%**	**0.0010**	5.52%
	2010	1.0824	0.0000	0.9496	-5.04%	0.1637	3.56%
	2011	1.0494	0.0001	1.0072	0.72%	0.8119	2.29%
	2012	1.0274	0.0085	**0.8538**	**-14.62%**	**0.0173**	1.78%
over 15 RM	2008	1.2352	0.0000	1.3205	32.05%	0.1604	7.36%
	2009	1.1923	0.0000	**1.3171**	**31.71%**	**0.0002**	5.52%
	2010	1.1149	0.0000	0.9324	-6.76%	0.0905	3.56%
	2011	1.0837	0.0000	0.9476	-5.24%	0.1276	2.29%
	2012	1.0909	0.0000	1.1248	12.48%	0.1746	1.78%

Table S9. Estimated coefficients and statistical inference results for model 2. Bold text indicates statistical significance; bold red text indicates significant CAR effect.

Property size class	Year	logForest		EGO		CAR			R^2adj
(Rural Module, RM)		estimate	Pr(>|t|)	estimate	Pr(>|t|)	CAR effect	CAR effect(%)	Pr(>|t|)	
Mato Grosso (2009-2011)									
under 4 RM	2009	1.1966	0.0000	**1.0010**	**0.0020**	0.9646	-3.54%	0.6215	5.84%
	2010	1.1567	0.0000	0.9999	0.8162	**0.9277**	**-7.23%**	**0.0050**	3.72%
	2011	1.1140	0.0000	**1.0009**	**0.0003**	0.9411	-5.89%	0.6578	2.62%
4 to 15 RM	2009	1.2430	0.0000	**1.0027**	**0.0000**	1.0862	8.62%	0.3655	5.84%
	2010	1.0862	0.0000	1.0003	0.6033	**1.0833**	**8.33%**	**0.0797**	3.72%
	2011	1.0527	0.0001	1.0004	0.4944	0.9488	-5.12%	0.8040	2.62%
over 15 RM	2009	1.2352	0.0000	**1.0039**	**0.0000**	0.9030	-9.70%	0.3161	5.84%
	2010	1.1502	0.0000	**1.0035**	**0.0000**	1.0231	2.31%	0.6804	3.72%
	2011	1.1195	0.0000	**1.0037**	**0.0000**	1.1384	13.84%	0.5757	2.62%
Pará (2008-2012)									
under 4 RM	2008	1.2458	0.0000	**1.0009**	**0.0221**	**0.6865**	**-31.35%**	**0.0029**	8.76%
	2009	1.1966	0.0000	**1.0010**	**0.0020**	**0.7389**	**-26.11%**	**0.0000**	5.84%
	2010	1.1567	0.0000	0.9999	0.8162	**0.8855**	**-11.45%**	**0.0000**	3.72%
	2011	1.1140	0.0000	**1.0009**	**0.0003**	**0.9459**	**-5.41%**	**0.0000**	2.62%
	2012	1.0802	0.0000	1.0000	0.8758	0.9699	-3.01%	0.3065	2.02%
4 to 15 RM	2008	1.3290	0.0000	**1.0065**	**0.0000**	0.6619	-33.81%	0.1078	8.76%
	2009	1.2430	0.0000	**1.0027**	**0.0000**	**1.2556**	**25.56%**	**0.0016**	5.84%
	2010	1.0862	0.0000	1.0003	0.6033	0.9482	-5.18%	0.1524	3.72%
	2011	1.0527	0.0001	1.0004	0.4944	1.0096	0.96%	0.7513	2.62%
	2012	1.0305	0.0066	1.0003	0.4620	**0.8552**	**-14.48%**	**0.0184**	2.02%
over 15 RM	2008	1.3630	0.0000	**1.0110**	**0.0000**	1.1698	16.98%	0.4253	8.76%
	2009	1.2352	0.0000	**1.0039**	**0.0000**	**1.2756**	**27.56%**	**0.0009**	5.84%
	2010	1.1502	0.0000	**1.0035**	**0.0000**	**0.9325**	**-6.75%**	**0.0910**	3.72%
	2011	1.1195	0.0000	**1.0037**	**0.0000**	0.9660	-3.40%	0.3281	2.62%
	2012	1.1199	0.0000	**1.0030**	**0.0000**	1.1348	13.48%	0.1437	2.02%

Table S10. Estimated coefficients and statistical inference results for model 3. Bold text indicates statistical significance; bold red text indicates significant CAR effect.

Property size class (Rural Module, RM)	Year	logForest estimate	logForest Pr(>|t|)	EGO estimate	EGO Pr(>|t|)	Blacklist estimate	Blacklist Pr(>|t|)	CAR effect	CAR effect(%)	CAR Pr(>|t|)	R^2adj
Mato Grosso (2009-2011)											
under 4 RM	2009	1.0451	0.0000	0.9988	0.1858	1.0302	0.2439	0.9675	-3.25%	0.6513	1.31%
	2010	1.0460	0.0000	0.9994	0.5561	1.0179	0.5239	**0.9279**	**-7.21%**	**0.0051**	1.81%
	2011	1.0653	0.0000	1.0001	0.9207	1.0306	0.3458	0.9388	-6.12%	0.6445	1.68%
4 to 15 RM	2009	1.0400	0.0250	1.0002	0.8332	**1.0770**	**0.0343**	1.0741	7.41%	0.4346	1.31%
	2010	1.0523	0.0072	0.9990	0.4031	1.0304	0.4272	**1.0850**	**8.50%**	**0.0737**	1.81%
	2011	1.0315	0.1482	0.9985	0.2864	1.0019	0.9647	0.9507	-4.93%	0.8112	1.68%
over than 15 RM	2009	1.0391	0.1139	0.9986	0.2528	0.9631	0.4272	0.8988	-10.12%	0.2944	1.31%
	2010	1.0748	0.0067	1.0003	0.8061	**0.8367**	**0.0006**	1.0021	0.21%	0.9700	1.81%
	2011	1.0197	0.5139	**1.0026**	**0.0786**	**0.8062**	**0.0002**	1.1075	10.75%	0.6589	1.68%
Pará (2008-2012)											
under 4 RM	2008	1.2289	0.0000	1.0002	0.5439	**1.5264**	**0.0000**	**0.7253**	**-27.47%**	**0.0108**	9.41%
	2009	1.1781	0.0000	1.0000	0.8923	**1.3173**	**0.0000**	**0.7866**	**-21.34%**	**0.0000**	7.70%
	2010	1.1496	0.0000	**0.9992**	**0.0107**	**1.1654**	**0.0000**	**0.8911**	**-10.89%**	**0.0000**	4.21%
	2011	1.1116	0.0000	**1.0006**	**0.0227**	**1.0998**	**0.0000**	**0.9471**	**-5.29%**	**0.0000**	2.87%
	2012	1.0797	0.0000	0.9998	0.3968	**1.0386**	**0.0010**	0.9681	-3.19%	0.2785	2.13%
4 to 15 RM	2008	1.2856	0.0000	**1.0055**	**0.0000**	**1.6903**	**0.0000**	**0.6529**	**-34.71%**	**0.0956**	9.41%
	2009	1.1818	0.0000	1.0009	0.1569	**1.5226**	**0.0000**	**1.1854**	**18.54%**	**0.0177**	7.70%
	2010	1.0711	0.0001	0.9996	0.5749	**1.1378**	**0.0001**	0.9528	-4.72%	0.1933	4.21%
	2011	1.0499	0.0003	1.0002	0.6748	1.0310	0.2548	1.0096	0.96%	0.7498	2.87%
	2012	1.0259	0.0228	1.0001	0.7969	**1.0472**	**0.0404**	**0.8539**	**-14.61%**	**0.0173**	2.13%
over than 15 RM	2008	1.3485	0.0000	**1.0106**	**0.0000**	1.2404	0.0226	1.1378	13.78%	0.5111	9.41%
	2009	1.2165	0.0000	**1.0032**	**0.0000**	**1.1726**	**0.0001**	**1.2137**	**21.37%**	**0.0079**	7.70%
	2010	1.1566	0.0000	**1.0038**	**0.0000**	0.9395	0.1104	**0.9187**	**-8.13%**	**0.0416**	4.21%
	2011	1.1143	0.0000	**1.0035**	**0.0000**	1.0560	0.0903	0.9709	-2.91%	0.4065	2.87%
	2012	1.1110	0.0000	**1.0026**	**0.0000**	1.0842	0.0028	1.1409	14.09%	0.1277	2.13%

Table S11. Estimated coefficients and statistical inference results for model 4. Bold text indicates statistical significance; bold red text indicates significant CAR effect.

Property size class		logForest		EGO		Delta-Fines		CAR			
(Rural Module, RM)	Year	estimate	Pr(>|t|)	estimate	Pr(>|t|)	estimate	Pr(>|t|)	CAR effect	CAR effect(%)	Pr(>|t|)	R^2adj
Mato Grosso (2009-2011)											
under 4 RM	2009	1.0439	0.0000	0.9985	0.1017	0.9990	0.8232	0.9653	-3.47%	0.6283	1.30%
	2010	1.0456	0.0000	0.9992	0.4088	0.9941	0.6396	**0.9273**	**-7.27%**	**0.0048**	1.58%
	2011	1.0644	0.0000	0.9999	0.9115	0.9999	0.9896	0.9411	-5.89%	0.6581	1.28%
4 to 15 RM	2009	1.0411	0.0209	0.9997	0.7858	**1.0114**	**0.0718**	1.0885	8.85%	0.3539	1.30%
	2010	1.0537	0.0059	0.9987	0.2593	0.9969	0.7891	**1.0840**	**8.40%**	**0.0771**	1.58%
	2011	1.0324	0.1373	0.9986	0.2790	0.9968	0.6651	0.9498	-5.02%	0.8078	1.28%
over 15 RM	2009	1.0341	0.1597	0.9989	0.3474	**1.0130**	**0.0914**	0.8911	-10.89%	0.2585	1.30%
	2010	1.0536	0.0445	1.0015	0.2596	**1.0356**	**0.0390**	1.0169	1.69%	0.7621	1.58%
	2011	0.9958	0.8861	1.0038	0.0094	0.9967	0.7685	1.1411	14.11%	0.5690	1.28%
Pará (2008-2012)											
under 4 RM	2008	1.2460	0.0000	1.0009	0.0221	0.9995	0.8854	**0.6864**	**-31.36%**	**0.0029**	8.83%
	2009	1.1960	0.0000	1.0008	0.0069	1.0121	0.0272	**0.7407**	**-25.93%**	**0.0000**	5.95%
	2010	1.1572	0.0000	1.0000	0.8991	1.0231	0.0028	**0.8889**	**-11.11%**	**0.0000**	4.05%
	2011	1.1140	0.0000	1.0009	0.0004	1.0003	0.8893	**0.9460**	**-5.40%**	**0.0000**	2.63%
	2012	1.0806	0.0000	1.0000	0.9728	0.9968	0.2476	0.9691	-3.09%	0.2947	2.14%
4 to 15 RM	2008	1.3320	0.0000	1.0065	0.0000	0.9958	0.5516	0.6614	-33.86%	0.1069	8.83%
	2009	1.2421	0.0000	1.0030	0.0000	0.9669	0.0019	**1.2458**	**24.58%**	**0.0023**	5.95%
	2010	1.0918	0.0000	1.0002	0.7972	1.0820	0.0000	**0.9401**	**-5.99%**	**0.0964**	4.05%
	2011	1.0518	0.0001	1.0003	0.5600	1.0057	0.2159	1.0087	0.87%	0.7746	2.63%
	2012	1.0305	0.0065	1.0003	0.4450	0.9977	0.6374	0.8563	-14.37%	0.0193	2.14%
over 15 RM	2008	1.3725	0.0000	1.0107	0.0000	0.9565	0.0000	1.1595	15.95%	0.4517	8.83%
	2009	1.2345	0.0000	1.0040	0.0000	0.9591	0.0009	**1.2643**	**26.43%**	**0.0014**	5.95%
	2010	1.1505	0.0000	1.0035	0.0000	1.0988	0.0000	0.9380	-6.20%	0.1217	4.05%
	2011	1.1173	0.0000	1.0037	0.0000	1.0078	0.0948	0.9647	-3.53%	0.3093	2.63%
	2012	1.1168	0.0000	1.0029	0.0000	1.0372	0.0000	1.1256	12.56%	0.1713	2.14%

Table S12. Estimated coefficients and statistical inference results for model 5. Bold text indicates statistical significance; bold red text indicates significant CAR effect.

Property size class				logForest		EGO		GMP		CAR			
(Rural Module, RM)	Year	Estimate	Pr(>|t|)	estimate	Pr(>|t|)	estimate	Pr(>|t|)	estimate	Pr(>|t|)	CAR effect	CAR effect(%)	Pr(>|t|)	R^2adj
Pará (2008-2012)													
under 4 RM	2008	0.6977	0.0000	1.2458	0.0000	**1.0009**	**0.0221**	NA	NA	**0.6865**	**-31.35%**	**0.0029**	8.76%
	2009	0.7059	0.0000	1.1966	0.0000	**1.0010**	**0.0020**	NA	NA	**0.7389**	**-26.11%**	**0.0000**	5.84%
	2010	0.8985	0.0030	1.1567	0.0000	0.9999	0.8162	NA	NA	**0.8855**	**-11.45%**	**0.0000**	3.72%
	2011	0.8653	0.0002	1.1139	0.0000	**1.0009**	**0.0003**	1.0028	0.9291	**0.9458**	**-5.42%**	**0.0000**	2.62%
	2012	0.9238	0.0652	1.0792	0.0000	1.0000	0.8909	1.0311	0.2429	0.9682	-3.18%	0.2819	2.02%
4 to 15 RM	2008	0.4580	0.0000	1.3290	0.0000	**1.0065**	**0.0000**	NA	NA	0.6619	-33.81%	0.1078	8.76%
	2009	0.6397	0.0003	1.2430	0.0000	**1.0027**	**0.0000**	NA	NA	**1.2556**	**25.56%**	**0.0016**	5.84%
	2010	1.1961	0.1441	1.0862	0.0000	1.0003	0.6033	NA	NA	0.9482	-5.18%	0.1524	3.72%
	2011	1.2033	0.0755	1.0581	0.0000	1.0005	0.3473	0.9316	0.1399	1.0121	1.21%	0.6907	2.62%
	2012	1.2729	0.0238	1.0271	0.0192	1.0002	0.5977	1.0495	0.2315	**0.8539**	**-14.61%**	**0.0174**	2.02%
over 15 RM	2008	0.2342	0.0000	1.3630	0.0000	**1.0110**	**0.0000**	NA	NA	1.1698	16.98%	0.4253	8.76%
	2009	0.4645	0.0000	1.2352	0.0000	**1.0039**	**0.0000**	NA	NA	**1.2756**	**27.56%**	**0.0009**	5.84%
	2010	0.6650	0.0039	1.1502	0.0000	**1.0035**	**0.0000**	NA	NA	**0.9325**	**-6.75%**	**0.0910**	3.72%
	2011	0.6482	0.0004	1.1202	0.0000	**1.0038**	**0.0000**	0.9899	0.8446	0.9660	-3.40%	0.3274	2.62%
	2012	0.4747	0.0000	1.1173	0.0000	**1.0029**	**0.0000**	1.0404	0.3624	1.1350	13.50%	0.1437	2.02%

Table S13. Estimated coefficients and statistical inference results for model 6. Bold text indicates statistical significance; bold red text indicates significant CAR effect.

Property size class (Rural Module, RM)	Year	logForest estimate	logForest Pr(>|t|)	EGO estimate	EGO Pr(>|t|)	Blacklist estimate	Blacklist Pr(>|t|)	GMP estimate	GMP Pr(>|t|)	CAR effect	CAR effect(%)	CAR Pr(>|t|)	R^2adj
Pará (2008-2012)													
under 4 RM	2008	1.2289	0.0000	1.0002	0.5439	**1.5264**	**0.0000**	NA	NA	**0.7253**	**-27.47%**	**0.0108**	9.41%
	2009	1.1781	0.0000	1.0000	0.8923	**1.3173**	**0.0000**	NA	NA	**0.7866**	**-21.34%**	**0.0000**	7.70%
	2010	1.1496	0.0000	**0.9992**	**0.0107**	**1.1654**	**0.0000**	NA	NA	**0.8911**	**-10.89%**	**0.0000**	4.21%
	2011	1.1127	0.0000	**1.0005**	**0.0257**	**1.1027**	**0.0000**	0.9660	0.2734	**0.9477**	**-5.23%**	**0.0000**	2.88%
	2012	1.0792	0.0000	0.9998	0.4155	**1.0374**	**0.0017**	1.0152	0.5704	0.9673	-3.27%	0.2680	2.11%
4 to 15 RM	2008	1.2856	0.0000	**1.0055**	**0.0000**	**1.6903**	**0.0000**	NA	NA	**0.6529**	**-34.71%**	**0.0956**	9.41%
	2009	1.1818	0.0000	1.0009	0.1569	**1.5226**	**0.0000**	NA	NA	**1.1854**	**18.54%**	**0.0177**	7.70%
	2010	1.0711	0.0001	0.9996	0.5749	**1.1378**	**0.0001**	NA	NA	0.9528	-4.72%	0.1933	4.21%
	2011	1.0556	0.0001	1.0003	0.5180	1.0463	0.1044	**0.9103**	**0.0605**	1.0128	1.28%	0.6743	2.88%
	2012	1.0245	0.0351	1.0001	0.8481	**1.0427**	**0.0753**	1.0270	0.5283	**0.8534**	**-14.66%**	**0.0169**	2.11%
over 15 RM	2008	1.3485	0.0000	**1.0106**	**0.0000**	**1.2404**	**0.0226**	NA	NA	1.1378	13.78%	0.5111	9.41%
	2009	1.2165	0.0000	**1.0032**	**0.0000**	**1.1726**	**0.0001**	NA	NA	**1.2137**	**21.37%**	**0.0079**	7.70%
	2010	1.1566	0.0000	**1.0038**	**0.0000**	0.9395	0.1104	NA	NA	**0.9187**	**-8.13%**	**0.0416**	4.21%
	2011	1.1163	0.0000	**1.0036**	**0.0000**	**1.0646**	**0.0646**	0.9592	0.4447	0.9707	-2.93%	0.4024	2.88%
	2012	1.1112	0.0000	**1.0026**	**0.0000**	**1.0849**	**0.0044**	0.9968	0.9445	1.1419	14.19%	0.1252	2.11%

Table S14. Estimated coefficients and statistical inference results for model 7. Bold text indicates statistical significance; bold red text indicates significant CAR effect.

Property size class (RM)	Year	logForest		EGO		Delta_Fines		PMV		CAR			R^2adj
		estimate	Pr(>|t|)	estimate	Pr(>|t|)	estimate	Pr(>|t|)	estimate	Pr(>|t|)	CAR effect	CAR effect(%)	Pr(>|t|)	
Pará (2008-2012)													
under 4 RM	2008	1.2460	0.0000	**1.0009**	**0.0221**	0.9995	0.8854	NA	NA	**0.6864**	**-31.36%**	**0.0029**	8.83%
	2009	1.1960	0.0000	**1.0008**	**0.0069**	**1.0121**	**0.0272**	NA	NA	**0.7407**	**-25.93%**	**0.0000**	5.95%
	2010	1.1572	0.0000	1.0000	0.8991	**1.0231**	**0.0028**	NA	NA	**0.8889**	**-11.11%**	**0.0000**	4.05%
	2011	1.1139	0.0000	**1.0009**	**0.0004**	1.0002	0.8960	1.0024	0.9402	**0.9460**	**-5.40%**	**0.0000**	2.63%
	2012	1.0795	0.0000	1.0000	0.9357	0.9964	0.1928	1.0353	0.1892	0.9672	-3.28%	0.2662	2.15%
4 to 15 RM	2008	1.3320	0.0000	**1.0065**	**0.0000**	0.9958	0.5516	NA	NA	0.6614	-33.86%	0.1069	8.83%
	2009	1.2421	0.0000	**1.0030**	**0.0000**	**0.9669**	**0.0019**	NA	NA	**1.2458**	**24.58%**	**0.0023**	5.95%
	2010	1.0918	0.0000	1.0002	0.7972	**1.0820**	**0.0000**	NA	NA	**0.9401**	**-5.99%**	**0.0964**	4.05%
	2011	1.0576	0.0000	1.0005	0.3914	1.0066	0.1544	0.9239	0.1019	1.0114	1.14%	0.7096	2.63%
	2012	1.0268	0.0204	1.0002	0.5813	0.9967	0.5029	1.0540	0.1976	**0.8553**	**-14.47%**	**0.0185**	2.15%
over 15 RM	2008	1.3725	0.0000	**1.0107**	**0.0000**	**0.9565**	**0.0000**	NA	NA	1.1595	15.95%	0.4517	8.83%
	2009	1.2345	0.0000	**1.0040**	**0.0000**	**0.9591**	**0.0009**	NA	NA	**1.2643**	**26.43%**	**0.0014**	5.95%
	2010	1.1505	0.0000	**1.0035**	**0.0000**	**1.0988**	**0.0000**	NA	NA	0.9380	-6.20%	0.1217	4.05%
	2011	1.1185	0.0000	**1.0037**	**0.0000**	**1.0080**	**0.0884**	0.9799	0.6978	0.9644	-3.56%	0.3066	2.63%
	2012	1.1166	0.0000	**1.0029**	**0.0000**	**1.0371**	**0.0000**	1.0038	0.9321	1.1277	12.77%	0.1649	2.15%