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Rural Environmental Registry: An innovative model for land-use and environmental policies

Iris Roitman[a,b,*], Ludgero Cardoso Galli Vieira[a,c], Tamiel Khan Baiocchi Jacobson[a,c], Mercedes Maria da Cunha Bustamante[b,d], Nívea Jorgia Silva Marcondes[a], Kátia Cury[a], Luciana Silva Estevam[a], Rômulo José da Costa Ribeiro[a,c], Vivian Ribeiro[e], Marcelo C.C. Stabile[e], Reinaldo José de Miranda Filho[a,c], Mário Lúcio Avila[a,c]

[a] Projeto Radis, Universidade de Brasília (UnB), Campus de Planaltina, Área Universitária 1, Vila Nossa Senhora de Fátima, CEP 73.340-710 Planaltina, Distrito Federal, Brazil
[b] Brazilian Research Network on Global Climate Change (Rede Clima), Land Use Sub-network, Brazil
[c] Faculdade UnB Planaltina (FUP), Campus de Planaltina, Área Universitária 1, Vila Nossa Senhora de Fátima, CEP 73.340-710 Planaltina, Distrito Federal, Brazil
[d] Universidade de Brasília (UnB), Instituto de Biologia, Campus Darcy Ribeiro, Asa Norte, CEP 70919-970, Brasília, Distrito Federal, Brazil
[e] Instituto de Pesquisa Ambiental da Amazônia (IPAM), Brazil

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ABSTRACT

Large-scale land governance and environmental monitoring are huge challenges for tropical countries with significant forest cover. In this discussion paper, we analyzed the conditions and achievements of the implementation of the Brazilian Rural Environmental Registry (CAR). CAR was an important breakthrough of the Native Vegetation Protection Law for environmental monitoring in Brazil. CAR is the mandatory and self-declaratory registry for rural properties. Owners must provide georeferenced delimitation of their property's boundaries and legally protected areas, such as Areas of Permanent Preservation and Legal Reserves. We used the example of the State of Mato Grosso (transition between the two largest biomes in Brazil – Amazon and Cerrado) to discuss how CAR and its national information system (called SICAR) provide important inputs for land-use, environmental, economic, territorial, and food security policies. Future policies should include increasing investments and coordination between different sectors to integrate CAR and conservation efforts with agricultural production and sustainable management.

1. Introduction

Governance is a key factor in land management and has a central role in mitigation and reduction of greenhouse gas (GHG) emissions from Agriculture, Forestry and Other Land Uses (AFOLU) (IPCC et al., 2014). Globally, deforestation and forest degradation can lead to massive impacts on carbon emissions and biodiversity loss. Carbon stocks in forest biomass decreased by approximately 0.22 Gt per year worldwide in the 2011–2015 period, mainly due to global reduction in forest area (UNFCCC, 2017). Emissions from the AFOLU sector represents 24% of global emissions (IPCC et al., 2014), but the relative contribution is higher in tropical countries. In 2010, the land use, land-use change and forest (LULUCF) sector in Brazil was responsible for 42% of national net carbon emissions (Brazil, 2016a). Recent estimates from the GHG-emission estimates systems (SEEG[1], Portuguese acronym) show that this number increased to 52% in 2016 (SEEG, 2017).

Land-use changes in Brazil have important consequences to global climate change and biodiversity. Brazil is one of the leading producers of agricultural commodities (e.g. soybean and livestock) (FAO, 2017). Brazil's agricultural expansion has driven worldwide concern over emissions associated to land-use changes (Nepstad et al., 2014; Novaes et al., 2017).

Revisions to the Forest Code of 1965 resulted in the controversial Native Vegetation Protection Law (NVPL) (Soares-Filho et al., 2014). Academic community (Silva et al., 2011), social movements and environmental organizations opposed to many environmentally detrimental changes of the law. The NVPL allowed agricultural activities in environmentally sensitive areas previously protected by law.

* Corresponding author at: Projeto Radis, Universidade de Brasília (UnB), Campus de Planaltina, Área Universitária 1, Vila Nossa Senhora de Fátima, CEP 73.340-710 Planaltina, Distrito Federal, Brazil.
E-mail address: iroitman@unb.br (I. Roitman).

[1] SEEG is an initiative from the Climate Observatory with the mandate to produce annual estimates of GHG emissions by sector based on IPCC guidelines.

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Fig. 1. Example of a Rural Environmental Registry (CAR), with the delimitation of the property and respective Area of Permanent Preservation (APP), Legal Reserve (RL), and area deforested prior to July 22, 2008 (consolidated area).

Furthermore, it established different treatments to environmental liabilities of areas deforested prior to July 2008, according to property size. In small properties, farmers were not required to restore areas that had been deforested prior to July 2008 (Soares-Filho et al., 2014; Brancalion et al., 2016).

However, there was one potentially promising mechanism of the law: the Rural Environmental Registry (CAR, *Cadastro Ambiental Rural* in Portuguese) (Soares-Filho et al., 2014; Jung et al., 2017). CAR is the mandatory and self-declaratory electronic registry for rural properties. Rural property owners must provide georeferenced data on their property's boundaries, Areas of Permanent Preservation (APPs), Legal Reserve Areas (LRs), Restricted Use Areas (RUs), and areas deforested prior to July 22, 2008 (consolidated areas) (Fig. 1). In LRs, property owners can perform forest management but not clear-cut forests and native vegetation. The size of LRs depends on the biome, vegetation type and deforestation date. RUs consist of environmentally sensitive areas (such as wetlands and hillsides with slope between 25° and 45°), and have a more limited use. APPs have the most restrictive use and comprise riparian vegetation buffers (associated to watercourses and water bodies), and vegetation along hilltops and hillsides with slopes greater than 30 degrees.

In Brazil, 681 million ha (i.e. > 50% of the territory) are registered as rural properties (Brazil, 2016b). The CAR national information system (called SICAR) may provide valuable large-scale data to improve understanding of the different land-uses in the country. SICAR will facilitate compliance with the NVPL and may assist the implementation of the Environmental Regularization Program (PRA, *Programa de Regularização Ambiental* in Portuguese), targeted at resolving environmental liabilities at property level. In this discussion paper, we analyzed the conditions and achievements of CAR implementation. We used the example of the State of Mato Grosso to discuss how CAR and SICAR provide important inputs for land-use, environmental, economic, territorial, and food security policies. The state of Mato Grosso is located in Central Brazil, in a transition area between two biomes, the Amazon forest and the Brazilian Savanna, locally named Cerrado. The state is the main producer and exporter of agricultural commodities, especially soybeans and beef (IBGE, 2017). Despite only having approximately 50% of its territory in the Amazon biome, the cumulative deforestation in that portion of the state amounts to roughly one third of all deforestation registered in the Amazon Biome (INPE, 2017).

2. CAR: from state regulation to federal law and policy

The implementation of CAR and its incorporation into federal law and policy is the result of the country's commitment to building a strong network of tools, programs, and policies to monitor and control deforestation over the past three decades (Fig. 2). International agreements and the support of national and international funding agencies were very important to the success of such initiatives.

In 1988, Brazil and China signed a Cooperation Agreement to launch a complete satellite-monitoring program: the China-Brazil Land Resources Satellite (CBERS) (Furtado and Costa Filho et al., 2003). In the same year, the National Institute of Space Research (INPE) started the Amazon Deforestation Monitoring Program (PRODES), providing high-quality data on Amazon deforestation (Kintisch, 2007). PRODES uses several images (like those produced by LANDSAT and CCD of the CBERS project) to identify clear-cut deforestation in the Amazon at a 30 m resolution. It has assisted command and control actions and influenced environmental policies. INPE later developed important Amazon monitoring systems, such as Real-time Deforestation Detection System (DETER) in 2004, the Forest Degradation Monitoring System (DEGRAD) in 2007, which detects selective logging activities, and the Land-use Changes in Deforested Areas Monitoring System (Terra Class).

In response to increasing Amazon deforestation rates detected by PRODES, in 2004, the Ministry of the Environment (MMA) created the Plan of Action for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAM). PPCDAM aimed to reduce deforestation with integrated actions among federal agencies, state governments, municipalities, civil society entities, and the private sector. The Pilot Program for the Conservation of Brazilian Rainforests (PPG7) was also important. This multilateral initiative started in 1992, with international financial support from Germany, the Netherlands, Italy, France, Japan,

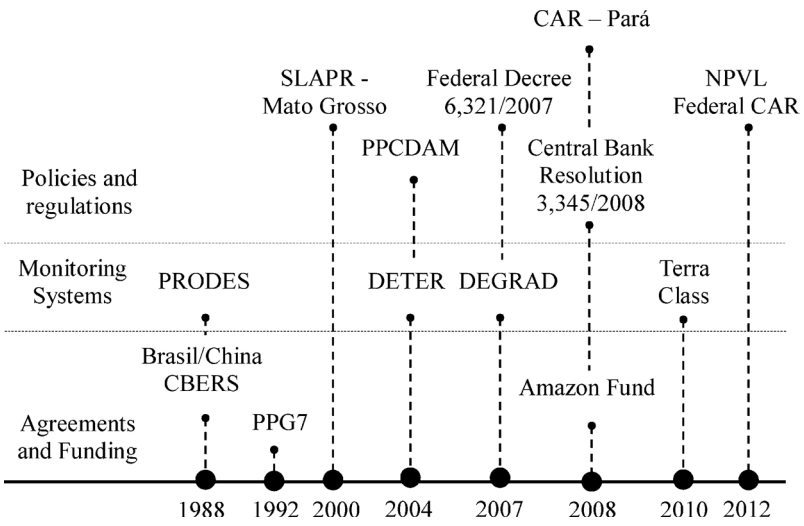

Fig. 2. Outlines of the main agreements, monitoring systems and policies implemented since 1988, which led to the incorporation of the Rural Environmental Registry (CAR) into federal law and policies. CBERS = China-Brazil Land Resources Satellite, PRODES = Amazon Deforestation Monitoring Program, DETER = Real-time Deforestation Detection system, DEGRAD = Forest Degradation Monitoring System, Terra-Class = Land-use Changes in Deforested Areas Monitoring System, PPCDAM = Plan of Action for the Prevention and Control of Deforestation in the Legal Amazon, PPG7 = Pilot Program for the Conservation of Brazilian Rainforests, SLAPR = Environmental Licensing System for Rural Property, and NVPL = Native Vegetation Protection Law.

the United Kingdom, and the European Commission.

In 2000, Mato Grosso (with financial support from PPG7) structured the precursor of CAR: the Environmental Licensing System for Rural Property (SLAPR) (Complementary Law 38/1995). Rural activities needed a state environmental license. It required registration of georeferenced property boundaries and data on the properties' legally protected vegetation into an online system (Pires and Ortega, 2013). Despite the common understanding that SLAPR could help control deforestation, it did not reduce deforestation in the first seven years (Rajão et al., 2012; Azevedo and Saito, 2013). Nonetheless, SLAPR was very effective in establishing a state databases, allowing monitoring at property level. In face of SLAPR's capacity to link illegal deforestation to specific rural properties, the MMA (under the PPG7 program) supported its replication to other Amazon states. In 2004, the State of Pará (the state with the second highest Amazon deforestation rate) incorporated Mato Grosso's system (State Decree 857/2004). In 2008, CAR became mandatory in Pará for all rural properties, regardless of the need for environmental licenses (State Decree 1,148 / 2008) (Pires, 2014).

Funding agencies, particularly the Amazon Fund, have been paramount for the successful implementation of CAR in the Amazon. Created in 2008, the Amazon Fund is managed by the National Bank for Economic and Social Development (BNDES). Most of its money was donated by Norway (US $ 1.1 billion), followed by Germany (US $ 28.3 million) and Brazil's Petrobras (US $ 6.7 million) (Amazon Fund, 2017a). It has supported many highly successful CAR implementation projects, carried out by NGOs such as the Amazon Environmental Research Institute (IPAM), the Amazon Institute for Man and the Environment (IMAZON), The Nature Conservancy (TNC), the Green Gold Institute (IOV) and the Socio-Environmental Institute (ISA).

The Amazon Fund has also supported the implementation of CAR in several state projects not limited to the Amazon biome. This experience represents a valuable example of international cooperation to address some of the mitigation challenges in developing and emergent countries with large extent of forests (Amazon Fund, 2017b; Marcovitch and Pinsky, 2014).

In 2007, Federal Decree 6,321/2007 established that the MMA should publish an annual list of priority Amazon municipalities with critical levels of deforestation, based on INPE's monitoring systems. These municipalities were object of integrated measures to improve federal monitoring and control actions, territorial planning and sustainable economic activities. One of the criteria for leaving the list was that at least 80% of CAR registration of private properties. Joint efforts by funding agencies, NGOs, government (local, state and federal) and communities have increased CAR registration in many municipalities with critical deforestation levels. In 2008, another important measure was the resolution 3,545 from the Central Bank of Brazil (CMN/BACEN, 2008). Producers needed to provide evidence of compliance with environmental legislation to be able to access public agricultural loans. In Mato Grosso and Pará, such evidence was provided by CAR registration (Pires, 2014; Azevedo et al., 2017).

In parliamentary discussions for the NVPL, there was strong opposition from the rural caucus against CAR, as it stood as a threat to public disclosure of environmental liabilities in rural properties (Pires, 2014). However, the strong success story in Amazon states, and the wide support of international funding agencies helped CAR gain momentum and guaranteed its inclusion into the NVPL. After the NVPL, other important funding agencies and programs have been supporting CAR implementation in the Amazon and other biomes, such as the International Climate Fund (ICF), the German Agency for International Cooperation (GIZ) and the Forestry Investment Program (FIP), a partnership between the World Bank, Inter-American Development Bank (BID), and the Climate Investments Fund (CIF).

Articulation between public sector, non-governmental organizations (NGO's), research and financial institutions was essential to integrate landscape planning in agricultural properties, monitoring, and restoration efforts toward sustainable agricultural production. This was especially important for small landholders and rural settlements because state governments are required to assist in CAR registration in small properties. Different funding agencies have invested in programs helping CAR registration for smallholder farmers. Such programs may improve farmers' livelihoods by providing knowledge and information (human capital) on how to comply with the NVPL and how to prepare for market demands for sustainably produced goods (Jung et al., 2017).

The implementation of CAR in a large and diverse (ecologically and socially) country as Brazil is a challenge that involves coordination of different stakeholders and government levels, capacity building of farmers and public agents, technological tools for the use of remote sensing and spatial information, and adequate funding for these activities. In spite of its massive acceptance and implementation, there are still political controversies regarding the public access to CAR data. The Brazilian Confederation of Agriculture and Livestock (CNA) is against publication of CAR data that identifies property owners with environmental liabilities (CNA, 2016). The Federal Prosecutor's Office (MPF) defends public disclosure of such data (MPF, 2016).

3. CAR and SICAR systems

To register a property in the SICAR system, the user/landowner can either upload georeferenced data or draw polygons to delineate the

different uses and protected areas, over a high-resolution imagery supplied by the government. It is important to note the key role of these high-resolution images (5 m RapidEye images), which have been acquired by the government annually since 2012. They are composed of a mosaic of images from different dates, covering the whole country, and serve as reference for a specific year. Without them, it would not be possible to check the information input by the user in the system, nor would it be possible to implement CAR effectively.

The previous law (the Brazilian Forest Code of 1965) required the LRs' registration in a real estate notary office. This proved to be a bureaucratic and expensive process because it demanded a Technical Responsibility Term, signed by a registered professional and prior approval of the environmental agency. The NVPL replaced this obligation for a simple on-line, self-declaratory delimitation, followed by approval by the state environmental agency. Some authors argue that exemption from technical responsibility simplifies registration but can lead to less accurate data (Araújo and Juras, 2012; Laudares et al., 2014; D'Avila, 2015). Notary office registration may assure greater legal security and accuracy, but compliance was extremely low and few landowners registered their LRs.

A fundamental motivation for CAR subscription is that this registration and compliance to the PRA are mandatory for landowners to access official lines of credit for agricultural activities (Azevedo et al., 2017). In fact, most of rural properties in Brazil have already been registered in SICAR (Brazil, 2017). According to the recent survey from the Brazilian National Institute for Colonization and Agrarian Reform (Incra), rural properties in Brazil comprise a total of 5,776,542 private properties (521,837,119 ha) and 9322 public properties (160,062,971.85 ha) (Brazil, 2016b). By October 2017, a total of 3.8 million properties (65%) had already been registered in SICAR, covering 434,379,375 ha (64%) of rural properties area (Brazil, 2017).

The next challenges for the CAR consolidation are including future investments for nationwide CAR analysis and validation and for structuring the PRA. Partnerships among interested stakeholders can strengthen this process. Each state is responsible for independently analyzing and validating the information declared by the users. Should the information provided be insufficient or incorrect, the owner must rectify it for further analysis and validation. Analysis can be a time-consuming process due to the large number of registrations and small number of assigned personnel for this process in some states. The Brazilian Forest Service operates SICAR at federal level and offers capacity building workshops to states' environmental agencies. Each state has its own regulation and administrative autonomy.

3.1. SICAR and environmental policies

SICAR will improve environmental monitoring in Brazil and may support national strategies for reducing carbon emissions and conserving biodiversity and other ecosystem services. The system helps identify who is in breach of the environmental legislation. As such, SICAR also serves as a law-enforcement tool, as recently evidenced by the Remote Control Operation, in which the MMA used SICAR to identity and send fines remotely to landowners who carried out illegal deforestation (IBAMA, 2017).

Constant and large-scale integration of APPs and LRs' data can optimize strategies for the maintenance and restoration of vegetation in such areas (Silva et al., 2011). Soares-Filho et al. (2014) estimated 21 million ha of deforested areas in APPs and RLs. Nationwide analysis of SICAR data, along with other monitoring tools such as PRODES, will provide better estimates of this area. Once consolidated, SICAR will allow mapping vegetation remnants and ecological corridors, and assessing landscape fragmentation levels. It will also help determine the degree of threat to fauna species that need large contiguous areas, and identify strategic areas for conservation and restoration (Laudares et al., 2014; Savian et al., 2014; Bleich, 2016).

Brazil's National Plan for Native Vegetation Recovery aims to expand and strengthen public policies, financial incentives and other measures for recovering at least 12.5 million ha of native vegetation in APPs, LRs and degraded areas with low productivity. SICAR data will be extremely useful to meet these objectives. Constant monitoring provided by SICAR may also assist the consolidation the National Policy for Payment of Environmental Services. SICAR can also provide valuable inputs to help Brazil meet United Nation Framework Convention of Climate Change (UNFCC) goals, including Brazilian Nationally Determined Contribution (NDC), which aims at eliminating illegal deforestation in the Amazon and restoring 12 million ha of native vegetation up to 2030. It may also support biodiversity conservation efforts toward meeting Aichi targets of the Convention on Biological Diversity (e.g. halving the rate of natural habitats loss and ensuring biodiversity conservation through sustainable management by 2020) (Martinelli et al., 2010; Savian et al., 2014; Goulart et al., 2016a, 2016b).

A recent study investigating smallholders' expected deforestation behavior following CAR registration, in the states of Piauí and Bahia (Cerrado biome), showed that smallholders with less native vegetation than the legal limit are less inclined to deforest. On the other hand, many smallholders that had more native vegetation (intact or regenerating) than required by law (surplus native vegetation) are likely to clear the vegetation up to the legal limit. Thus, CAR registration may even incentivize deforestation (Rasmussen et al., 2017). Yet, if a property has surplus native vegetation, this area can be used as a tradable legal title called Environmental Reserve Quota (CRA, Portuguese acronym). When the LR of a property is partially or completely deforested, the landowner must either restore the area (which can be costly) or buy CRA quotas from a property within the same biome. The system is subject to state legislation. In Mato Grosso, for instance, CRA quotas can only bought within the state. However, the CRA trading system is yet to be regulated. This trading market could motivate conservation in properties with surplus native vegetation and facilitate compliance to the NVPL. SICAR could assist the market for CRAs by identifying and monitoring deforested LRs and surplus native vegetation (Soares-Filho et al., 2014). Technically, the system will only be able to operate once CARs have been widely validated.

Earlier estimates indicate that property registration in Mato Grosso had no positive impact on avoided deforestation between 2000 and 2007 (Rajão et al., 2012; Azevedo and Saito, 2013). A recent study (between 2005 and 2014), showed that deforestation in Mato Grosso and Pará reduced by 10% following property registration. CAR effectiveness varied over time, possibly due to different policies and increasing pressure of the private and public sector to both reduce deforestation and register in the CAR (Alix-Garcia et al., 2017).

3.2. CAR and other land-use policies

Although CAR was designed to meet environmental policy demands, it also works as a powerful tool for other land-use policies and agricultural and forestry sectors. CAR is the first step toward the environmental regularization of the rural properties (i.e. compliance to PRA), thus warranting legal security to production and trade of agricultural goods and access to official lines of credit (Moretti and Zumbach, 2015). Effective CAR registration does not substitute the legal steps toward land tenure regularization. However, in many cases it is a prerequisite for such. In Agrarian Reform settlements, CAR registration precedes the land regularization process. The Terra Legal Program, aimed at the regularization of illegally occupied public lands in the Amazon, also requires CAR registration.

One of the most innovative aspects of SICAR is that most of its information is public. The CAR public consultation module, launched at the end of 2016, allows the public to download CAR information by municipality and georeferenced data in shapefile format (http://www.car.gov.br/publico/imoveis/index). It provides a map of Brazil with time analysis and thematic filters such as: amount of properties and registered areas, analyzed registries, embargoed areas, areas

overlapping with indigenous lands, conservation units, and environmental liability areas in APP's and RL's. This represents an advance in transparency and allows checking compliance to the NPVL. It is a powerful tool for environmental monitoring and the assessment of control and inspection bodies' performance.

3.3. Transparency for supply-chain governance

While commodity agriculture is a strong driver of deforestation, pressure from government, public opinion, and NGOs campaigns has compelled retailers and commodity traders to commit to more sustainable and deforestation free production (Nepstad et al., 2014; Azevedo et al., 2015). An important example is the zero-deforestation agreement, signed by Brazil's four largest meatpacking companies in Pará with Greenpeace in 2009. This agreement also required CAR registration from suppliers. After the agreement, supplying properties significantly reduced deforestation rates and CAR registration increased rapidly (Gibbs et al., 2016). However, a later study showed that deforestation leakage (deforestation in non-supplying properties) and cattle laundering (moving fattened cattle from properties with embargoes or deforestation to a deforestation-free property only for the purpose of sale) undermined the impacts of the agreement (Alix-Garcia and Gibbs, 2017). Agreements could become more effective by including the entire supply chain and tracking all movements of cattle sold to participating slaughterhouses to prevent leakage and cattle laundering (Alix-Garcia and Gibbs, 2017).

Another important supply-chain agreement was the soy moratorium, signed in 2006, in which major soybean traders agreed not to buy soy grown from Amazon lands deforested after July 2006. In 2014, this date moved to July 2008 to be consistent with the amnesty cut-off date given by the NVPL (July 2008). This agreement had much greater effect in reducing directly soy-related Amazon deforestation than the CAR registration and federal enforcement mechanisms (Gibbs et al., 2015). In this context, SICAR will allow industries and retailers of agricultural goods to monitor the environmental situation of its suppliers more effectively. Investors and funding agencies can also monitor the environmental impacts of agricultural and forestry activities they support.

A recent study that evaluated compliance to the soy moratorium in Mato Grosso showed that 85% of the sampled properties followed the agreement (i.e. no deforestation after July 2008). However, 65% of these properties did not comply with the NVPL requirement regarding the LRs (Azevedo et al., 2015).These authors recognize the importance of supply-chain governance and suggest that consumer-demand driven initiatives should also require CAR registration and compliance to the NVPL.

4. Mato Grosso SICAR data

The state of Mato Grosso occupies 90.2 million ha and contains three large hydrographic basins (Alto Paraguai, Araguaia-Tocantins and Amazonas). Located in the south border of the Amazon, it stands as an extensive rainforest-savanna ecotone. The state harbors 13.2 million ha of Indigenous Lands and 5.6 million ha of Conservation Units (Federal, State and Municipal) of all categories, including private ones (Natural Heritage Private Reserve). With a population of approximately 3 million people, its demographic density is very low (3.36×10^{-4} inhabitants/ha).

Mato Grosso is one of the largest agricultural and livestock producers in the. In the 2015–2016 harvest season, it was the leading producer of cattle, soybean, corn and cotton (Table 1) and projections suggest it will continue to do so in the next decade (IBGE, 2017). On the other hand, in 2016 and 2017, Mato Grosso had the second highest deforestation rate in the Legal Amazon (1489 km^2 y^{-1} and 1341 km^2 y^{-1}, respectively) (INPE, 2017). In 2013, most of Mato Grosso's deforested area (85%) was concentrated in southern Amazon and due to livestock expansion areas (Egler et al., 2013).

Table 1
Mato Grosso's production of main agricultural and livestock products in Brazil in the 2015-216 harvest season.
Source: IBGE, 2017.

Product	Mato Grosso's Production (million)	Percent production in Brazil (%)	Position in production rank in Brazil
cattle (heads)	4.54	14.8	1
soybean (tons)	26.06	27.2	1
corn (tons)	19.01	24.5	1
cotton (tons)	0.94	63	1
rice (tons)	0.51	4.5	4
bean (tons)	0.43	12.9	3

Table 2
SICAR public information on the state of Mato Grosso available in 30/10/2017. CAR = Rural Environmental Registry, SICAR = National CAR Information System, LR's = Legal Reserves, APP's = Permanent Protection Areas, PRA = Environmental Regularization Program, RUs = Restricted-Use Areas.
Source: Brazil (2017).

SICAR data type	Number of rural properties	Rural properties area (million ha)
Properties with CAR registration	114,174	74.76
Properties with CAR analyzed	2,073	8.54
Properties in adhesion to the PRA	71,806	50.28
LR's to be regularized	107,953	31.27
APP's to be restored	52,542	0.70
RUs to be regularized	904	0.21
Overlaps with Indigenous Territories	1,149	3.93
Overlaps with Conservation Units	43	0.11
Overlaps with embargoed areas	7,048	11.77

In the state of Mato Grosso, more than 100,000 properties have already been registered in SICAR, but only 1.6% of the them have been validated (10% of the area) (Table 2) (Brazil, 2017). According to Federal Decree 7,830/12, which establishes the complementary norms and regulations for the PRA, the delay in the state department's official response leads to temporary validity of the registrations. Thus, until environmental agencies respond, registrations with erroneous data or environmental liabilities will be valid for the purposes of the law, including for access to public credit (Laudares et al., 2014; D'Avila, 2015).

In Mato Grosso, although validation is still incipient (1.8% of CAR registered properties), SICAR data from September 2017 showed that 94% of CAR registered properties have to regularize their LRs, and 46% of them must restore their APPs (Table 2). More than seven thousand registered properties overlapped with embargoed areas (areas of prohibited use due to previous environmental liabilities), which represents 6% of registered properties and 16% of total registered the area. Identification of such areas is valuable for law enforcement actions. SICAR data revealed more than one thousand properties and 3.9 million ha of overlaps with Indigenous Land (Brazil, 2017). This spatialized data can support the Brazilian territorial management plan and the National Policy of Environmental Management and Indigenous Land.

In Mato Grosso, a percentage of overlap in CAR between private properties is acceptable (and not accounted for), depending on the size of the property and municipal land units, called fiscal modules (FMs), which varies from 60 to 100 ha: 10% (size ≤ 4 FMs), 4% (4 FMs < size < 15 FMs) 3% (large). In properties with overlaps above these limits, CAR registration is classified as pending, and the property

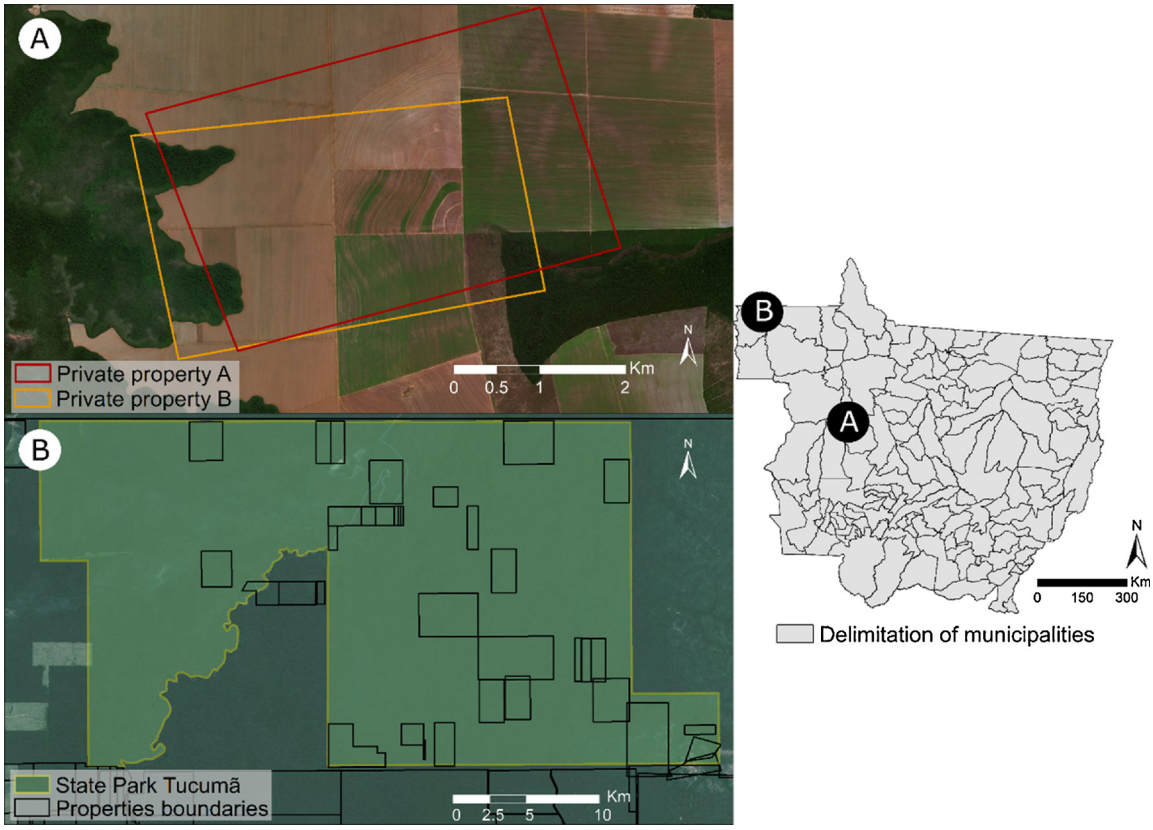

Fig. 3. Examples of overlapping rural properties registered in the SICAR database in the state of Mato Grosso. A. Overlaps between two private properties. B. Overlaps between private rural properties and the Tucumã State Park.

owners must offer proof of ownership in order to proceed to CAR validation (Normative Instruction number 11 of 09/29/2015 of Mato Grosso's Environmental Secretary).

Our spatial analysis of CAR data provided by Mato Grosso's State Secretariat (methods described in S11) revealed overlaps between private properties' delimitations (Figs. 3A and 4). In September 2016, SICAR database had 109,225 polygons in Mato Grosso, totaling 67,738,929.24 ha. There were 10.2% of overlapping areas with private properties. Some of the overlaps may due to different precision levels, but some may indicate disputes in land delimitation and tenure. It also revealed that 50 rural private properties (370,365.96 ha) were registered inside Conservation Units and/or Indigenous Lands. In the Tucumã State Park, for example, there are many private-property CAR overlaps (Fig. 3B).

This information can support policies and actions to solve conflicts related to land tenure, territorial planning and regularization, and indigenous rights. Currently, SICAR has automatic filters that identify the existence of overlaps with Conservation Units, Indigenous Land, and embargoed areas (areas object of administrative sanctions due environmental crimes or infractions). When overlaps with these areas exceed tolerance levels (10% in small properties and 3% in large ones), the CAR is classified as pending and must be rectified to complete registration. In one hand, the owner is obliged to proceed to rectification. On the other, conflict areas are more easily identified, and displayed to the government agencies and society.

5. Conclusion

CAR is an innovative tool for land-governance and environmental policies in Brazil. The widespread of CAR registration in the Amazon resulted from an efficient monitoring system to determine critical deforestation areas, integrated government and NGO's efforts, and heavy investments from national and international funding agencies. The success of its initial implementation phase in Brazil lies on the fact that a) it offers a user-friendly online platform for registration, b) it uses high-resolution wall-to-wall imagery to provide a constant monitoring system, and iii) it is mandatory for environmental regularization and access to official lines of credit.

The most innovative aspect of SICAR is its transparency. It provides public information on rural land-use cover and compliance to environmental regulation nation-wide. Furthermore, it allows for more transparency within different supply chains, assisting different actors to monitor environmental impacts from the agricultural and forestry activities they support. Revealing a clear and constant picture of the environmental liabilities and production areas may help integrate agricultural and environmental agendas. However, this is limited by the slow implementation of the NPVL and other conservation policies. Analysis and validation of CAR nationwide is an essential step to ensure the functionality of the tool and full compliance with environmental legislation. Partnerships among interested stakeholders can strengthen this process, helping Brazil became a leading tropical country in environmental monitoring.

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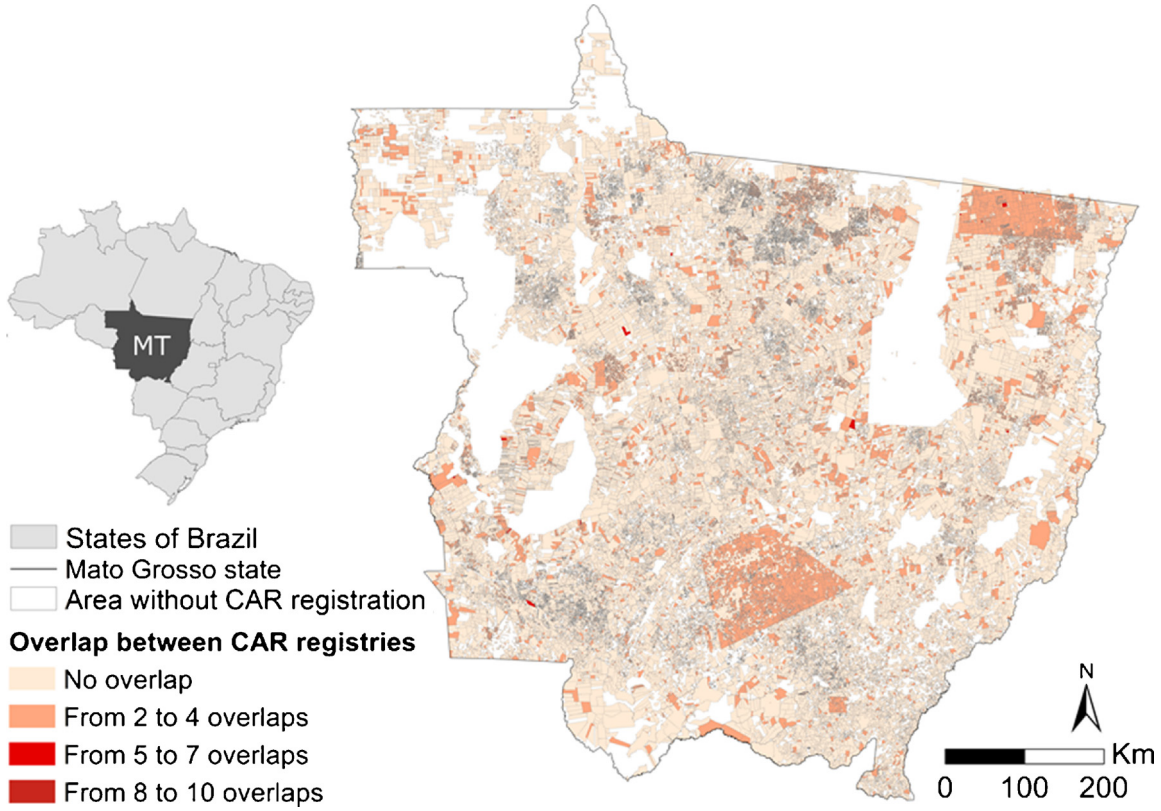

Fig. 4. Density of overlaps between private rural properties registered in SICAR database in the state of Mato Grosso.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.landusepol.2018.04.037.

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