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The Rural Environment Catalog System: A New Sociotechnical Paradigm for Remote Monitoring of Native Forest Protecting and Recovering

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Review Article

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ABSTRACT

Cultural changes are crucial to a deep reform in the public management around the world and technology can leverage these changes in a steady motion. This paper shows an example of important technology-driven social and cultural change in the rural environment management in Brazil with the progressive use of satellite images embedded in geographical information systems (GIS). Important lessons to the rural environment public policies in underdeveloped and developing countries can be drawn from the case of the Rural Environment Catalog System (SICAR) and the most important of them is the power of digital satellite imagery of the Earth to remote monitoring of the rural landscape and forest protection. Other important lesson is that international and multilateral agencies need to be more strategically oriented in the role of structuring funding sources to implement important projects for the rural environment protection.

INTRODUCTION

As such the national experiences of developing Forest and Land-Use Information Systems (FLUIS) reported by Cheung et al. the Federal Government of Brazil has been also investing in capacity building and infrastructure to track Greenhouse Gas (GHG) emissions and land-use change using spatial data and non-spatial data [1]. The case of Project SICAR presented in this paper is the most important currently initiative to monitoring and controlling deforestation in the country and perhaps a new sociotechnical paradigm for Reducing Emissions from Deforestation and Forest Degradation (REDD) in a national scale. In fact, the use of satellite images as an important source of soil information to support activities of forest monitoring by the environment agencies was not a rule in Brazil a decade ago. Only a few federate states of the country could see the power of such a kind of technology to produce updated evidences about the rural landscape and native deforestation until recently, when the Ministry of the Environment (MMA) launched the Rural Environment Catalog System (in Portuguese: Sistema de Cadastro Ambiental Rural SICAR [2]. However, the history of the Project SICAR can be better understood out of the information system discipline, when a convergence of interests between political forces in the Brazilian society aimed to the protection of native forests took place. It was noteworthy the political efforts of the environment community in the National Congress, culminating with the approval of a new Forest Code in May 25th, 2012 (Law n. 12651) after a great (even if temporary) national concertation between environmentalists and farmers representatives. Other important forces that have leveraged the approval of the new Brazilian Forest Code and the development of Geographical Information Systems (GIS) like SICAR are the new generation of technically skilled public servants hired by the federal and state environment agencies in the last decade, the new mind set of the senior management in the Ministry of Environment (MMA), and scientific research and development efforts on satellite imagery technologies carried out in some federal universities and companies in the country. Complexity is the first feature an environment analyst could draw out of the Law n. 12651, the new Brazilian Forest Code containing 86 articles, 184 paragraphs, 227 items, and 52 sub-items, summing up 549 rules to be followed in the rural environment planning, managing, monitoring, and controlling. In short, that forest code is also a huge technical guide on how to deal with many native forests protection and recovery themes in the country, as shown in **(Table 1)**.

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Table 1. Legal rules of the Brazilian forest code.

	Chapter of the Forest Code	Number of Rules		
#	Theme	Articles	Details (*)	Subtotal
I	General Provisions	3	59	62
II	Areas of Permanent Preservation	6	46	52
III	Areas of Restricted Use	2	0	2
III-A	Ecologically Sustained Use of the Apicuns and Salgados	1	19	20
IV	Areas of Legal Reserve	14	50	64
V	Vegetation Suppression for Alternative Use of the Soil	3	6	9
VI	Rural Environment Catalog	2	7	9
VII	Forestal Exploration	4	42	46
VIII	Source Control of Forestal Products	3	11	14
IX	Prohibition of the Use of Fire and Fire Control	3	9	12
X	Program to Support and Incentive the Environment Preservation and Recovery	10	67	77
XI	Control of Deforestation	1	3	4
XII	Family Farming	7	18	25
XIII	Transitional Provisions	10	85	95
XIV	Complementary and Final Provisions	17	41	58
	Total Number of Rules	86	463	549

Note: (*) Written in paragraphs, items, and subitems

In Brazil, the Forest Code ("VI. Rural Environment Catalog" in **Table 1**) and normative decrees that followed it enforce all the private rural properties owners/possessors to include their properties and personal data in a central digital Catalog sponsored by the Federal Government, detailing also a geographical polygon showing the areas of remaining "legal reserve" of native vegetation (if still has some). Concerning the law, the main feature of the Brazilian Forest Code, when compared to other countries norms on environment protection, is that citizens (as individuals) and companies, and not the states, municipalities or public agencies, are the most responsible and accountable entities for the preservation and recovery of native forests. The Forest Code's theme "VI. Rural Environment Catalog" **(Table 1)** set up the legal enforcement for the development of "Project SICAR" sponsored by the Ministry of Environment (MMA) and carried out by the Brazilian Forest Service (SFB), with a technical support of the Federal University of Lavras (UFLA). With the SICAR the SFB (as a MMA' division) intends to support the whole business processes of collecting, storing, computing, and implementing the user access to information of all the (near) five million rural properties in the country (IBGE), and to implement computing algorithms for the environmental compliance analyzes of each rural property registered in the system based on the business rules of the Forest Code [3].

In practice, it is not a surprise that the CAR has turned out into a federal government program to develop a sophisticated GIS using satellite imagery like SICAR. The original project started in 2014 has been continued until the present day, with more functionalities being added to the original version of the system and new exciting discoveries about the rural properties environment coming to the light each year, with the potential to change dramatically the sociotechnical paradigm of managing public policies on forest monitoring and controlling.

Rural Environment Catalog's Business Processes

The very complex Brazilian Forest Code, as usual in the western administrative systems of the public sector concerning each new regulatory act required a presidential decree and several administrative detailed ordinance to be effective [4]. It is considered the third "forest code" in the history of the country and a very hard lesson with this issue is that the new code, unlike the last one, must be effectively implemented in the nearly five million of rural properties/possessions of the 27 federate states, scattered throughout the 8.5 million km^2 of the national territory.

As a background for the political and administrative debate on the new code, is out of question that a cause of the ineffective implementation of the last codes to protect the native vegetation in the country was the lack of easily access to updated spatial information on the rural environment. In a very large (continental-like) country such as Brazil, the main difficulties to implement environment public policies in the traditional way (to preserve the natural landscape) are the lack of enough monitoring team working in the field, enough (ground) surveillance vehicles and equipment, enough money to support trips costs, and so on. On the first hand, the lessons learned in the past of rural environment management drove the policy makers in the Federal Government bureaucracy to dealt with the challenge of developing an information system to collect, store, compute and make available the data registries concerning every private rural property or possession in the country as required by the Forest Code, a mission delineated in the Presidential Decree n. 7830 signed in October 17, 2012. not educated to use the Internet, or at least electronic computing systems. In fact, the Agricultural Census of 2006 shows that less than 18% of the rural property owners/possessors has at least the college degree a personal According to this normative decree, the Rural Environment Catalog ((named, in Portuguese: "Cadastro Ambiental Rural - CAR) would be an Internet based information system containing data of

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every owner, possessor or person legally accountable for the rural property/possession and its digital georeferenced plant of the rural property/possession polygon detailing areas of social interest, public utility, remaining native vegetation, permanent environment preservation, restricted use, consolidated use, and legal reserve. Despite the legal enforcement of the Forest Code, where each rural property owner/possessor is responsible and accountable for the data of his property/possession in SICAR, another difficulty is that most rural properties owners/possessors are profile that raises several communication barriers to publish and teach how to use SICAR's technologies [5]. Notwithstanding this issue, MMA/SFB' team considered that CAR could only be implemented with the technological support of an information system like SICAR, but with a sociotechnical approach. This solution required a responsibility assignment matrix of the main stakeholders acting in the context of macro business process of the Rural Environment Catalog (CAR) shown in the workflow of **Figure 1**. The process starts with the activity "Elaborate and Update CAR", where each rural property owner/possessor or responsible person must, in a first step, access the website of the CAR through the Internet and download a special standalone GIS application in his/her PC for making the required data registry, and, in a following step, upload the CAR data to the computing servers of the system in the federal environment agency (named, in Portuguese: "Serviço Florestal Brasileiro - SFB") [2]. The CAR website provides technical information to the rural property owner/possessor or responsible person along the interactive activity of making the registry in SICAR. As usual in the country, the implementation of public policies requiring remote and direct interaction of the public sector agencies with individuals using information systems through the Internet is generally mediated by a skilled person who knows how to use a PC and acts properly to aid the benefited person (the word "despachante", in Brazilian Portuguese, stands for a kind of dealer, or a "forward agent", which intermediates the sometimes complex interaction of the State with its citizens).

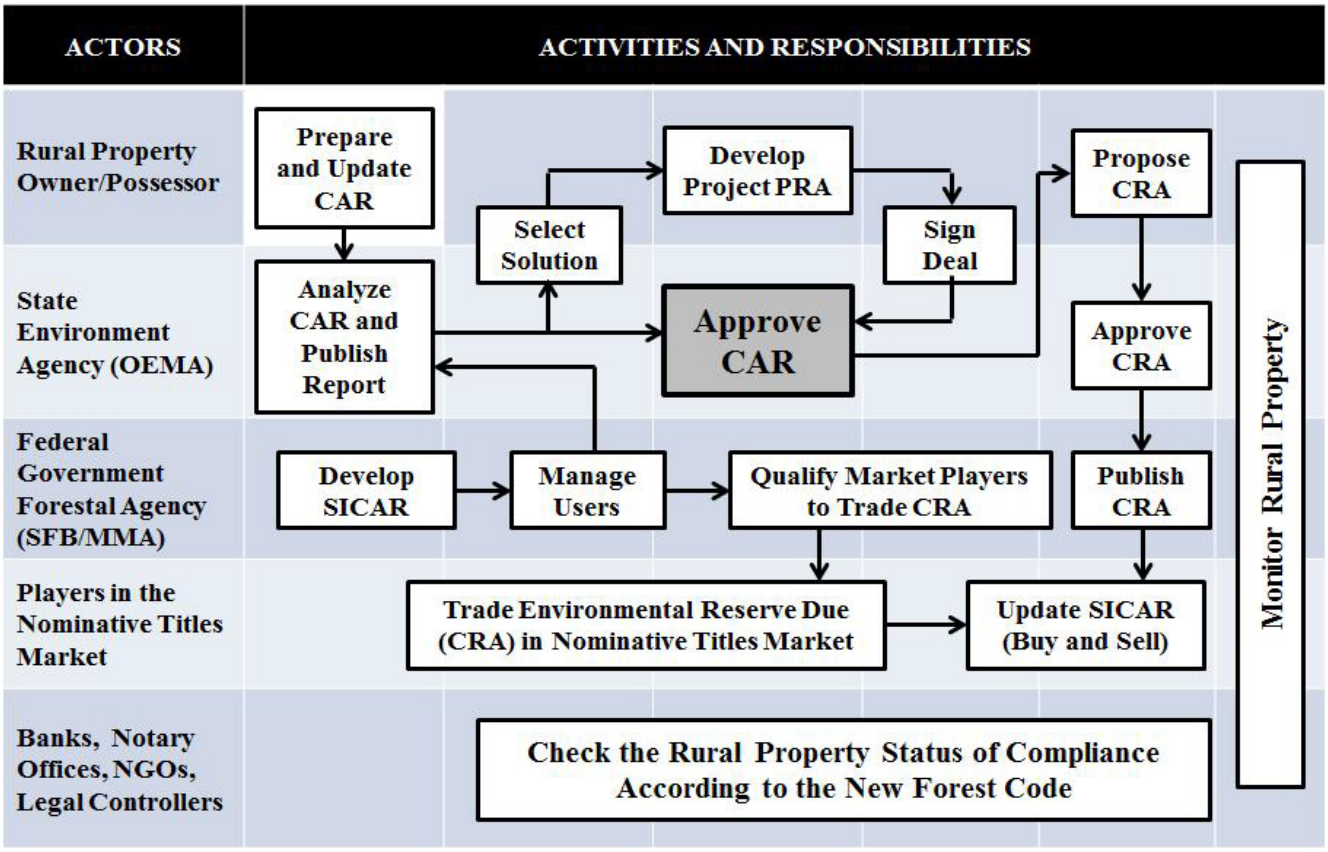

Figure 1. Car business process workflow in SICAR.

Next, the CAR state manager (named, in Portuguese: Órgão Estadual de Meio Ambiente – OEMA) deals with the activity of checking the compliance of the CAR registry with the Forest Code and following regulatory acts. In the agreed division of labor between the Federal Government and the federate states based on the Complimentary Law n. 140 approved in December 8, 2011 (one year before de Forest Code), it is the responsibility and accounting of the states to analyze CAR registries in SICAR central database and take the accordingly legal measures to promote compliance (this compliance will happen in a long term after bringing the owner/possessor to an investment agreement with the aim of recovering native forest in his rural property or, as an option, leasing an area of native forest in another rural land of his property or of another people's property). Considering there are 27 OEMAs in the country and each one implements its own environment management system and some local rural environment rules according to the feature of the native vegetation in its territory (such as the biome "pampa" in the state of Rio Grande do Sul), SICAR has a component to support the activity "Analyze CAR and Publish Report", automating several tasks such as the reports making and publishing. The main pool of complex geo-referencing applications which compose SICAR as a

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sophisticated information system is implemented to support this activity, automatically performing several hundreds of "business rules" required by the Forest Code and the followed administrative manuals and guides. The business intelligence (BI) of the analysis module of SICAR is the most valuable "gem" of the system, implementing the field monitoring experience and best efforts of the specialists in the technical team of MMA/SFB, some of those acquired in another important federal environment agency: Brazilian Institute of Environment and Renewable Natural Resources. This system intelligence is aimed to support the decision to be made by the OEMA in this activity, which could be split, in the next step, in two alternate paths of activities: "Approve CAR" if a rural property is considered compliant with the rules, and "Select Solution" if the CAR registry shows that a rural property is not compliant with the environment protection rules. The activity "Select Solution" means that some environmental solution must be offered by the property owner/possessor to restore the native vegetation using any of the several possibilities approved by the Forest Code (for example, planting native trees intercalated with exotic trees). In the next step, the activity "Develop Project PRA" means the solution offered by the rural property owner/possessor to the state agency (OEMA) must be presented as a project to be implemented in an approved schedule (where PRA stands for, in Portuguese, something like "Environment Recovery Project") and signed by the parts like a contract (in the activity "Sign Deal"). There is also a rule allowing the rural property owners/possessors to make money trading nominative titles based on their native vegetation exceeding the minimum area required by the Forest Code, which is called CRA" (Environmental Reserve Quote). These forest titles may be traded with other rural property owners/possessors to equalize their lack of minimum area of required native forest, making this way an entire biome even with the Forest Code – in short, the lack of native forest in a rural property may be compensated by an acquisition of nominative titles of exceeding native forest in another rural property. Other alternate solution to a rural property owner/possessor to compensate the lack of enough native forest in one rural property of him is annotate in SICAR that he has another rural property with the same area of exceeding native forest.

However, the Forest Code legislator conditioned this forest trade right to the registration of the exceedingly area of native forest in an "unique control system", which in practice is the SICAR, but keeping the tasks of emission, cancelling and transferring the CRA under the responsibility of the environment agencies of each one of the federate states State Environmental Agency - OEMA (OEMA). According to the CAR workflow designed in **Figure 1**, a rural property compliant to the Forest Code whose owner/possessor is interested in trading its exceeding native vegetation has to ask the OEMA an emission of the respective nominative title (activity "Propose CRA"), where the OEMA, in its turn, has to approve or not the proposition (activity "Approve CRA"). Once a CRA is approved by the OEMA (activity "Approve CRA"), the next step in the CAR workflow is to publish the title in the SICAR (activity "Publish CRA") and wait for the launching of the title in the market by the players qualified by the federal agency (SFB). It is responsibility of Brazilian Forest Service (a public sector organization similar in its duties to the US Forest Service) to continually develop the SICAR and manage the users of the system (activities "Develop SICAR" and "Manage Users"). The economic, social and political benefits of a forest Catalog of the rural properties updated in a central database like SICAR are:

1. To provide a standard and secure business process and information system to efficiently implement the rules of the Forest Code in all the federate states, assuring the local features and avoiding duplication of investments and administrative efforts between the states and federal agencies.

2. To easy the control of cataloging the rural properties throughout the country by the Federal Government, allowing this way a consolidated vision on the implementation of the national Forest Code.

3. To keep all the players in the environmental public policies looking at the same set of native forest data on rural properties, implementing the informational concept of "Single Source of Truth - SSOT").

4. To allow active transparency on the implementation of the Forest Code, helping this way the environment lobbies to press the states and federal government to effectively implement the code (in Brazil, there is a popular saying that governments, like roosters, cook only under pressure); by accessing SICAR a citizen or a public/private organization may get data on any rural property in the country concerning compliance to the Forest Code, multiplying the enforcement of the social control.

5. To automate the workflow in order to manage the cycle of the CAR with process efficiency and data security, making the cost of implementing the Forest Code more predictable and stable.

6. To allow a further data quality improvement on the registries of the rural properties owners/possessor in the remote areas of the country, where there are still frequent conflicts over land tenure.

Several federate states have their own information systems on rural properties, some of them implemented before the SICAR, but covering just their territories. As usual in the Brazilian political system, the Project SICAR was born after several agreements between federate states and the Federal Government based on the federal Complimentary Law n. 140, approved by the National Congress in December 8, 2011, where the central information system of CAR registries would be stored in a central database accessible by all the forest agencies in the country. Other complimentary projects have been implemented in alignment with SICAR, such as a distance learning platform to educate people living in any place in the country on how to deal with the Rural Environment Catalog (CAR).

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SICAR: A Project Without A Budget

CAR is a successful environmental monitoring program nowadays, but its early days as a project were plenty of all kind of difficulties, mainly concerning the lack of a strong political sponsorship inside and outside the federal and state governments, computing infrastructure (datacenter, network, support team) for the system development, skilled system development team, and money (approved budget). According to a former conclusion of Wellving on Forest and Land-Use Information Systems (FLUIS) project funding in developing countries, there was an enormous amount of money allocated by international environment funding agencies for the traditional field work of collecting CAR registries of the rural properties owners/possessors in all the municipalities, in a census approach, but nor a cent for the development of SICAR (the small budget to develop SICAR in the early days was afforded only by the MMA and was not enough to purchase an adequate Information and Communication Technology ICT infrastructure [6].

International agencies funding environment projects

International funding agencies operating in the environmental projects arena like (KfW), Ministry for the Foreign Affairs of Norway (MFA), and Department for Environment, Food and Foreign Affairs of the United Kingdom (DEFRA/UK) altogether have donated a ten digit amount of money to implement environment projects in Brazil since 2009. However, the donators agencies did not required a strategic vision to prioritize projects in the funding process, allocating almost all the money to the biome Amazon and transferring the executive responsibility of money allocation along some lines of investment to the Amazon Fund created with the Decree nº 6527, of August 1st, 2008. As political drivers, the Amazon Fund has the general goals of non-refundable investments in actions aimed at prevention, monitoring and fighting against deforestation, and promoting conservation and sustainable use of the biome Amazon. The money donated until 2016 is presented in **Table 2** showing the Ministry for the Foreign Affairs of Norway as the entity with by far the major amount of donations (96.9%).

Table 2. International donations to the amazon fund [8].

Funding Source	Budget (USD)	%
Ministry for the Foreign Affairs (Norway)	1,100,276,320.84	96.9
Kreditanstalt für Wiederaufbau (Germany)	32,533,562.40	2.9
Petróleo Brasileiro (Brazil)	2,577,797.85	0.2
Total	1,135,387,681.09	100.0

The respective banking transactions, in a by-project approach, was assigned to the "Banco National de Desenvolvimento Econômico e Social" (BNDES) of Brazil, leaving to the Ministry of Environment (MMA) just the responsibility of delimiting the amount of donations to be accepted and to play a role in Amazon Fund governance committees. While acknowledging the gigantism of BNDES on its traditional mission of funding big budget private development projects submitted by companies, an advantage recognized by the former MMA's management team, in fact other very big financial organizations in the Federal Government with much more experience in dealing with public entities at subnational levels could also have been raised to the level of Amazon Fund management, such as Caixa Econômica Federal (Federal Savings Bank–CEF) with its almost two thousand engineers spread all over the country. These decisions has been taken under incentives of international environmental entities concerning the problem of deforestation in the Amazon biome (4,196,943 km^2) and at the best environment and social interests, but also at the price of pushing to the second level of prioritization all other Brazilian biomes with native deforestation like "Cerrado" (2,036,448 km^2), "Mata Atlântica" (1,110,182 km^2), "Caatinga" (844,453 km^2), "Pampa" (176,496 km^2), and "Pantanal" (150,355 km^2) [5].

Amazon fund biases

The international donations, because a lack of strategic driver oriented to goals and estimated outcomes and impacts, funded a lot of small projects in benefit of federate states and native communities in the biome Amazon supported by non-governmental organizations (NGOs), but were ineffective to implement the Forest Code in a national scale until the present day. The Amazon Fund, despite its relevance in funding environment projects concerning REDD, has been also controversial in some extent, criticized in the starting by a MMA minister because the excessive slowness of BNDES in its bureaucratic process of analyzing environment projects (O GLOBO) and nowadays is under pressure of some parliamentary representatives in the National Congress asking for an auditing action by the Accounting Court of the Union [7]. Candotti, for instance (as the Director of the Amazon Museum in the early years of 2012), declared that any project with focus in the environmental preservation may get funding into BNDES, but the bureaucracy of the bank in the last three years has transformed the application of the money an epopee [8].This complaint is also present in the KfW' report and it is not difficult to conclude that such a bureaucratic bias comes after the long experience of BNDES in funding "big business" companies which have armies of accountants, lawyers and engineers to fill in very long project application papers [9]. By the experience of environment agencies in the country, the timeline to get an environment project approved by BNDES was between one year and one year and a half long and Candotti summed up this unwilling situation

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saying that: It is much easier to get credit for cattle breeding or soybean cultivation instead of investing in capaíba oil, for example [8].The performance evaluation of the BNDES in managing Amazon Fund was highlighted later in the KfW's report (in litteris). BNDES had no experience in selecting grant-financed projects in forest protection. Through the FA, the BNDES is starting to fulfil its potential as a lever and ambassador for environmental policy in Brazil ("put the environmental cause on a different level"). In 2016 the KfW's report recognized the need to change some strategic drivers of the Amazon Fund, considering, for instance, the composition of the fund's portfolio as a sensible indication. Concerning the need for funding projects on monitoring and controlling systems in the rural landscape is also present in that KfW' report, finally discovering the CAR program (litteris). Support for monitoring and control, which in the past have proven to be the key to success in preventing deforestation and which need to be maintained if past achievements are not to be jeopardized, in increasingly being enhanced by projects for land use planning and sustainable production. All representatives of implementing institutions interviewed during the mission were either working on the introduction of the rural land register CAR, from registration through to monitoring and sustainable production in the areas and within the limits prescribed by the CAR, or on supporting the management of indigenous territories. Up to now, the decision to approve applications and allocate the FA funds to projects, municipalities and federal states is not systematically (co-) determined by such aspects as the applicant's or beneficiaries' need for support, successful impact of applicant's activities in the past or own efforts on the part of applicants to reduce deforestation and implement forest protection policies. A corresponding adjustment of the selection criteria most likely has the potential to significantly increase the allocation efficiency [9].

Rural Environment Information and Knowledge

A rural land environment database would get only half its potential utility if it is not implemented with a strategic purpose. In the world of Information and Communication Technology (ICT), the kind of strategic software applications used to implement different visions of data (such as statistics) stored in databases sources anywhere is called Business Intelligence (BI) systems. SICAR stores enough data to show users in strategic level (such as rural environment policy makers) a set of information on rural land use that may be very useful to BI and knowledge discovery. The SICAR's database model has tables concerning all the subjects and stakeholders present in the Forest Code and much more: people (rural properties owners/possessors), public entities (like federal states and municipalities), environmental agencies in the states, legal enforcement public institutions (prosecutors, internal controllers, accounting offices and police departments), other public agencies (in agricultural and water branches, for example), and also a lot of rural properties data such the geographical position of the polygon vertices, total area of the property, Legal Reserve (RL) area to native vegetation, area of vegetation near the water sources (called "Permanent Preservation Area – APP" in the Forest Code), Mountain Slope Area, and other areas of interest to native forest preservation or recovery. Although each owner/possessor updates the areas of its property in SICAR, the system also (automatically) calculates these areas with a GIS application. Then, comparing the informed and the calculated rural property areas is important to know if an old rural property titling map is accurate or not (sometimes, big differences in total areas of rural properties are discovered with this comparison by SICAR, revealing mistakes never observed before on old deeds of ownerships). Considering SICAR is a GIS and its data model has satellite image (spatial) data with resolution of five meters on rural properties and also alphanumerical (non-spatial) data of its owners/possessors, potential applications in the government are as following.

Benefits of Satellite Images

Cheung et al. related important lessons to be learned with such a kind of initiative in developing countries with a broader view, some of them confirmed in the SICAR project [1]. The environmental benefits of SICAR are mainly the availability of satellite digital information to remote monitoring the anthropogenic use of the soil in rural properties for checking up its compliance with the Forest Code and to remote monitoring the execution of investment projects on preservation and/or recovering the native vegetation. In a very large country like Brazil, environment agencies in national and sub-national levels of government have a lot of difficulties to carry on forest monitoring activities in the traditional way (without satellite images), failing in the accomplishment of their core mission: to preserve the nature. An important lesson comes after the experience of using multispectral satellite images technology in SICAR, demonstrated that MMA's strategical decision to purchase this kind of technology for the project was right. As Arnett points out, fundamental to the identification of land cover change is the detection of abrupt disturbance events, and in a forestry context it is important to identify disturbances in a timely manner in order to inform management decisions [10]. Thus, the idea of "one-type-of-satellite-image-fits-all-needs" is a common mistake made by government purchasers aiming to support any FLUIS project in public sector organizations, revealing a lack of knowledge of satellite imagery technology. As recommended by Arnett multispectral wavelength data accurately detects stand replacing and non-stand replacing disturbances in the Earth's surface, showing that this technology is capable to assess forest disturbances with an emphasis on the spatial detail and temporal availability [10]. Consequently, this kind of satellite technology also used in SICAR will be able to detect differences in the land cover caused by the evolution of grain crops culture each year, showing the stages of cultivation, a benefit searched by all the agriculture stakeholders (farmers, funding banks, agribusiness suppliers, government agencies, and so on).

Environmental benefits

Other important application of SICAR's satellite images is to provide useful information to diagnosing the level of forest preservation and/or recovering in any scale of area: a rural property, an ecological corridor, microbasin, basin, biome, municipality, federal state, geopolitical region in the country, and the country as a whole. In the same way, the SICAR's information could be

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useful to planning investments on recovering the native vegetation in these tiles of the soil and on discovering and monitoring water sources for urban and rural communities. GIS information like those provided by SICAR may be useful also to identifying and monitoring environment risk areas of soil like hillsides without vegetation near urban concentrations and roadways. SICAR's images benefits are also linked to the planning and monitoring of Forest Code implementation in higher strategic level: to identify forest areas with potential to have native trees with seeds and to measure, with enough precision, the carbon equivalent weight sequestered before and after the recovery of degraded areas of soil with new vegetation. Ironically, SICAR can be the most important tool to the monitoring of environmental outcomes and impacts of investments supported by the Amazon Fund.

Rural land policies benefits

Of recent settlement, some rural areas of Amazonia are still to be pacified in terms of land titling and SICAR's satellite images may be useful to support the mapping of rural properties and to identify its owners/possessors. In fact, it is very easy to identify land conflicts in SICAR just by querying all the people who required the ownership of a same rural property.

Agribusiness benefits

The planning of agricultural production may also be benefit from SICAR's GIS applications with satellite images, that can identify and calculate rural areas in compliance with the Forest Code and available to plantation in any scale of size. In the same way, agricultural crops and livestock production can be estimated and economically evaluated in advance with SICAR's information on plantation and pasture areas, which could be of much interest for banking and insurance industries. Besides risk management in funding the agribusiness, the security industry may be benefit from SICAR by allowing the analysis of damaged areas of plantation with support of satellite images and correlated alphanumerical data. The forecast of harvests can also be improved with the using of SICAR's satellite images, allowing stock exchange dealers, farmers and other players in the agribusiness to forecast crop prices more accurately and fairly. Forest management with agribusiness economic scale can also be estimated with SICAR's information, allowing the sizing of this kind of production in a sustainable way. Capacity of production in the fishing industry may also be estimated with SICAR's information on artificial pools in any area of the country, together with information on the kind of species cultivated on each pool (this information is stored in the IBAMA's databases and may be accessed by any citizen in the country). Another social benefit of SICAR's satellite images is that of localizing rural possessions historically belonging to traditional communities first settled inlands such as Indians, Quilombolas, and Caiçaras, and their land boundaries.

Alphanumerical data

Even without satellite images the rural properties information of SICAR may be of much interest to the government. The personal data of the properties owners/possessors, for example, in practice perform a set of census data useful to one calculate an index of rural properties concentration, such as a Gini Index using the area of the properties as the matter of concentration. The SICAR's data could be used in compliment to the census data collected by IBGE, improving the information sources about people and their rural properties/possessions [3].

Data about land owners/possessors can be useful also to checking up data stored in other important information systems such as the land tax system belonging to the Federal Government in Brazil. For instance, both systems could benefit from exchanging its data to check up if the same person had declared the same amount of area and revenue of the same rural property, which would result in the same amount of land tax to be collected by the revenue agency.

Evolution of data registration

Why may SICAR be considered a successful information system project for the native forest protection and recovery in Brazil? As shown in **Table 3**, it seems the information already published by the Brazilian Forest Service of the Ministry of the Environment (extracted from the SICAR database), tell by itself on the evolution of data registration since 2014 [11].

Table 3. Evolution of rural properties registration in SICAR.

Region of the Country	Number of CAR egistries	Areas of Rural Properties (ha)		% (B/A)
		Estimated (A)	Registered (B)	
North	642,087	93,717,515	132,875,281	141.8
Northeast	1,343,907	76,074,156	66,338,560	87.2
Midwest	396,762	129,889,570	125,318,115	96.5
Southeast	1,101,792	56,374,996	64,300,626	114.1
South	1,250,895	41,780,627	42,787,389	102.4
Conservation Units (*)	19,326	25,716,745	25,716,745	100.0
Total	4,754,769	423,553,609	457,336,716	108.0

Note: (*) Conservation units are forest reserves under public domain

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Table 3 shows the amount of data registered in SICAR by regions of the country, summing up more than 4.7 million CAR registered in the SICAR's database, with a total area of more than 457.3 million hectare (ha). The region of the country where the CAR registration pace has been the slowest is the Northeast, where "only" 87.2% of the estimated area of private rural properties are registered in the system. As estimated in the project starting, the Northeast Region is the latest in the registration pace mainly because of budget and human resources shortage at the environmental agencies, but (surprisingly) the state with the worst performance in the CAR registration process is Espírito Santo, where only 48.5% of the private rural properties were already registered in the system until December 2017. Land registry has been always a complex issue in Brazil and the last visible outcome of this historical question is an economic and social phenomenon that is becoming clear in SICAR's database: the registered area is larger than the estimated area of private rural properties in the country, summing up 108.0% of the national territory registered in SICAR. It is expected that in the next step of the CAR management cycle, when each CAR registered in the system will be carefully analyzed by the environmental agencies in the states, the total area of land registries will be closer to the total area of CAR registries. Besides the publication of statistical data, SICAR's database is also an object of open data, from where a citizen with access to the Internet with a browser can get the registered raw data of the private rural properties registered in a municipality. These data are just the public one, such as the areas and shapefiles of a rural property, but not the personal data, such as the name, address, telephone and email of its owner/possessor. The SICAR's data collection to be published is growing faster and will be much more interesting in the following years to the extent the states evolve in their analysis of the CAR registered in the database [12].

CONCLUSION

The last three decades of experience with on-site inspection to enforce the application of native forest protection law in Brazil have demonstrated that this traditional way of rural environment monitoring is ineffective. Contracting an army of field inspectors without appropriate GIS and accurate data on the rural landscape would be a very expensive and unwise way to (try to) solve this complex problem in a large developing country. Brazilian Forest Service of the Ministry of Environment (MMA/SBA), despite of its budget shortage, has shown an answer to this monumental environmental management challenge with the project SICAR, a GIS with detailed data and satellite images covering each private and public rural property/ownership in the country. In its fifth year of the development schedule, in practice the project has turned out a program and has proved that with some political support, forest engineering's intelligence and satellite technology is possible to effectively monitoring the use of the soil by farmers and checking out their compliance with the Forest Code. Other important lessons learned with project SICAR are in the following "decalogue":

- A strong political leadership to sponsor the project and a skilled team composed of forest engineers and professionals alike with knowledge of GIS solutions and its benefits are sine qua non conditions to support such a kind of initiative.

- Satellite images are required data which must be purchased by specific application needs and not aiming to solve all FLUIS needs of all the government agencies.

- An error threshold in measuring rural properties' polygons with satellite images may be accepted for the monitoring and controlling purposes (thus, satellite imagery with high resolution is not required unless there is also a land regulatory purpose in the policy).

- The environment public policies do not have to be mixed with rural land regulation policies because this latter is by far more complex (specially more time consuming) than the former (in Brazil, for instance, land issues take decades to be solved in the courts of justice, representing an inacceptable high risk to any project schedule aimed to the forest protection and recovery).

- Collecting rural landscape data must be a challenging task and should have its own budget and an adequate long term strategy (in the case of project SICAR, the MMA/SFB's strategy of collecting data by individual declaration of the owners/possessors of rural properties in the system itself through the Internet, with appropriate positive and negative incentives, proved to be correct, achieving almost 100% of the estimated outcomes of this step of the project in only four years).

- Building effective communication channels with the rural land owners/possessors, with appropriate language and media, is a key success factor, but frequently neglected by FLUIS project managers, a common mistake that may cause serious risks to the political sustainability of the project and compromises the productivity of the team.

- Skilled information security professionals are required to support the public managers on selecting rural land data that may be published (in countries with an Information Access Law like Brazil this issue may be raised to the courts and cause severe impact to the project performance if not well managed in the environment agencies.

- Small environment projects aimed to collecting data in a local scale run much better under NGOs management than in environment agencies (because of their inherent bureaucracy and higher costs, government agencies must be preserved to deal only with big budget and more complex projects).

- Polytechnic universities can be very useful in supporting government agencies at science and technology issues and decisions in a daily basis (excepting, of course, the naïve idea of using Open Source software for all needs).

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• Considering that culture is the eye of the needle through which change must pass young and enthusiastic public servants staffing environment agencies must be recruited to the project team, mixing their natural energy and political activism pro the environment cause with the experience of their older colleagues, all together to support cultural changes in native forest preservation policies.

In the case of CAR, the program will require a budget of eleven digits in the following years to make the Forest Code really effective in Brazil. A new generation of innovative projects to recovering native vegetation in large areas of private rural properties has still to be elaborated and appropriately funded, where a new environment-driven market place to investments can find its way and thus overcome prejudices that separate environmentalists and capitalists.

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