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MEASUREMENT OF THE LEGAL RESERVE SURPLUS AREA IN MUNICIPALITIES: AN APPROACH APPLIED TO THE MUNICIPALITY OF RONDONÓPOLIS, MATO GROSSO, BRAZIL

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Abstract

Introduction: The Environmental Reserve Quota (ERQ) is a mechanism that can reduce the cost of environmental regularization of rural properties that have preservation deficit, and mainly, encourage the conservation of natural vegetation in properties that maintain areas in accordance with, or beyond legal requirements, attributing economic value to them.
Objective: To estimate the amount of potential ERQ supply and demand in the municipality of Rondonópolis-MT, in order to identify information about the potential of this market.
Methodology: The land area of properties registered in the Mato Grosso Environmental Registry System (SIMCAR) and vegetation data from the MapBiomas project (forest formation and savanna formation) were used to verify the legal reserve classification of properties based on current legislation. Areas with legal reserve surplus and deficit were identified, based on the sizes of properties and their vegetation.
Results: A total of 1,212 properties registered in the SIMCAR in Rondonópolis-MT were identified, which corresponds to 70% of the total area of the municipality. Rondonópolis-MT has potential supply of 19,561 hectares to be marketed as ERQ, with potential demand of 13,712 hectares, which s represents a spare supply of 5,849 hectares.
Conclusion: There is great potential for the ERQ market; however, the success of this initiative will depend on the inclusion of small properties, mainly of settlements, which will require institutional action to promote land regularization.

Keywords: Environmental Reserve Quota, Environmental Compensation, Legal Reserve, Mato Grosso, Brazil.

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MENSURAÇÃO DO EXCEDENTE DE RESERVA LEGAL EM MUNICÍPIOS: UMA ABORDAGEM APLICADA PARA O MUNICÍPIO DE RONDONÓPOLIS, MATO GROSSO, BRASIL

Resumo

Introdução: A Cota de Reserva Ambiental (CRA) é um mecanismo que poderá reduzir o custo da regularização ambiental das propriedades rurais que apresentam déficit de preservação, e principalmente, incentivar a conservação da vegetação natural nas propriedades que mantiveram áreas de acordo, ou além da exigência legal, atribuindo-lhe valor econômico.
Objetivo: Estimar a quantidade de oferta e demanda potencial de CRA no município de Rondonópolis-MT, com o intuito de identificar informações sobre o potencial desse mercado.
Metodologia: Utilizou-se da malha fundiária dos imóveis cadastrados no Sistema Mato-grossense de Cadastro Ambiental Rural (SIMCAR) e dados de vegetação do projeto MapBiomas (formação florestal e formação savânica), para verificar o enquadramento de reserva legal das propriedades a partir da legislação vigente. Foram identificadas áreas com excedente e déficit de reserva legal, a partir dos tamanhos das propriedades e da fitofisionomia abrangida.
Resultados: Foram identificadas 1.212 propriedades cadastradas pelo SIMCAR no município de Rondonópolis-MT, o que corresponde a 70% da área total municipal. Em um balanço geral, Rondonópolis-MT possui um potencial de oferta de 19.561 hectares para serem comercializados como CRA, enquanto possui potencial demanda de 13.712 hectares. Isso representa uma oferta sobressalente de 5.849 hectares.
Conclusão: Há grande potencial do mercado de CRA, porém o sucesso dessa iniciativa dependerá da inclusão das pequenas propriedades nesse mercado, principalmente de lotes de assentamentos, o que requererá uma ação institucional de fomento à regularização fundiária.

Palavras-chave: Cota de Reserva Ambiental, Compensação Ambiental, Reserva Legal, Mato Grosso, Brasil

MEDICIÓN DEL ÁREA EXCEDENTE DE RESERVA LEGAL EN MUNICIPIOS: UN ENFOQUE APLICADO AL MUNICIPIO DE RONDONÓPOLIS, MATO GROSSO, BRASIL

Resumen

Introducción: La Cuota de Reserva Ambiental (CRA) es un mecanismo que puede reducir el costo de la regularización ambiental de las propiedades rurales que presentan un déficit de conservación y, principalmente, incentivar la conservación de la vegetación natural en las propiedades que mantienen áreas de acuerdo con, o además de, el requerimiento legal, atribuyéndole valor económico.
Objetivo: Estimar la cantidad de oferta y demanda potencial de CRA en la ciudad de Rondonópolis-MT, con el fin de identificar información sobre el potencial de este mercado.
Metodología: Se utilizó la superficie de terreno de los predios inscritos en el Sistema de Registro Ambiental Rural Matogrossense (SIMCAR) y datos de vegetación del proyecto MapBiomas (formación de bosque y formación de sabana) para verificar el marco de reserva legal de los predios con base en la legislación vigente. Se identificaron áreas con excedentes y déficit de reserva legal, con base en el tamaño de las propiedades y la vegetación cubierta.
Resultados: Se identificaron un total de 1.212 inmuebles registrados por SIMCAR en el municipio de Rondonópolis-MT, lo que corresponde al 70% del área total del municipio. Rondonópolis-MT tiene una oferta potencial de 19.561 hectáreas para ser comercializadas como CRA, mientras que tiene una demanda potencial de 13.712 hectáreas.
Conclusión: Existe un gran potencial en el mercado de CRA, pero el éxito de esta iniciativa dependerá de la inclusión de pequeñas propiedades, principalmente de lotes de asentamiento, lo que requerirá una acción institucional para promover la regularización de la tenencia de la tierra.

Palabras clave: Cuota de Reserva Ambiental, Compensación Ambiental, Reserva Legal, Mato Grosso, Brasil.

Introduction

The publication of the New Brazilian Forest Code, through Law 12.661/2012 (BRASIL, 2012), established the Environmental Reserve Quota (ERQ), which came to replace the former Forest Reserve Quota, and dedicated several articles to the regulation of this new instrument that consists of a nominative title representative of area with native vegetation, existing or in the recovery process (Decree 9640/2018).

Legal reserve compensation is a mechanism created by Law 4.771 of 1965, which, in its Article 44, allowed the compensation of reserves in areas equivalent in size and belonging to the same ecosystem and, also, should be from the same hydrographic microbasin (Brasil, 1965). The New Forest Code expanded the compensation of reserves for properties belonging to the same biome, making this market to expand and rural landowners to start considering it an income option (Carneiro, 2019).

There are environmental sectors that criticize this instrument, as if it were a mechanism to make unpunished those who do not preserve the vegetation, which reasoning is influenced by the “polluter-pays” principle, which does not consider the contemporary thinking of the “protector-receiver” principle (Cunha, 2013). However, this view must be relativized, given that the ERQ can play an important role in making environmental preservation compatible, by paying for the conservation of rural properties with legal reserve surplus.

Therefore, ERQ is a mechanism that can reduce the cost of environmental regularization of rural properties that have deforested more than permitted and, mainly, encourage the conservation of areas of natural vegetation on properties that have maintained these areas in accordance with or beyond legal requirements, attributing economic value to them (Bernasconi, 2013). In addition, the ERQ market significantly reduces the cost of regularizing legal reserve deficits, since the costs for the conservation of native vegetation are much lower than those of restoration, at the same time protecting forest surpluses that could be legally deforested (Rajão, 2015).

The effective development of the ERQ market depends on some definitions through regulation at federal and state level. For this, it is essential to know the potential ERQ supply and demand in each region to identify the potential benefits of this regulation. Essential for this purpose, the GIS (Geographic Information System) is an efficient tool for such a survey, as it is a system made up of a set of computer programs, which integrates data, equipment and people with the aim of collecting, storing, retrieving, manipulating, visualizing and analyzing data spatially referenced to a known coordinate system (Fitz, 2018).

Thus, the aim of this study is to estimate the potential of the ERQ market in the municipality of Rondonópolis - MT, which is characterized as a case study of relevance to the national agricultural reality. The expansive cycle of agricultural commodities poses increasing

challenges for identifying the economic opportunity of using less appropriate areas, for reasons of soil fertility and topography, for environmental compensation. In this context, Rondonópolis stands out as a dynamic agribusiness pole in the Midwestern region of Brazil, with important logistical relevance to the State of Mato Grosso. This contribution, within this analytical scope, comprises, in addition to the introduction, a section that analyses the institutional matrix of the environmental legislation, with a view to characterizing ERQ, followed by a brief identification of the evolution of deforestation in the State of Mato Grosso, the identification of methodological procedures and results of the empirical evaluation and, finally, the conclusive comments.

Literature Review

Economic approach to the "polluter-pays" principle

In the context of the Brazilian Legal Amazon, changes in land use and the promotion of conversion of pristine savanna areas and forests for agricultural production, in addition to limits imposed by forestry legislation, are the result of economic incentives involved with the expansion of agribusiness (Pivetta, 2022). In this context, the "polluter-pays" legal principle permeates environmental legislation, as it aims to induce the internalization of agents that generate environmental damage (Freitas, 2021).

It should be highlighted that throughout the evolution of economic thought, two theoretical approaches to the discussion of this problem have been developed. In the Arthur C. Pigou's approach, it is up to the government to internalize to the economic agent the social cost produced by its decision to inefficiently allocate resources, through the imposition of taxation or other penalties. Alternatively, according to the Ronald Coase's perspective, the way to value the harmful effects occurs through the adoption of market mechanisms that price the polluting source (Salles & Matias, 2022).

Market prices, however, are not always able to correctly measure the social costs of the capitalist production process. Negative externalities, therefore, are side effects that are not directly priced in microeconomic decisions, but which collectively incur losses to society. The case of pollution is emblematic of this situation, as it is not directly measured as a productive cost by economic agents, despite its incurrence as a social cost, due to the divergence between the private *versus* social marginal product (Grossman, 2006).

The solution by using market arrangements to resolve the polluter-pays principle stems from the inference that transaction costs may be higher than externalities arising from the inefficient allocation of natural resources. It should be noted that transaction costs are related to the informational and governance processes of ordering economic transactions. In this

context, the transfer of rights to generate negative externalities can be a socially efficient arrangement. That is, the effectiveness of preventing environmental damage must also be measured, considering the costs involved with preservation (Daly & Farley, 2011).

Therefore, according to the Ronald Coase's social cost theorem, state regulations tend to present informational and bureaucratic inefficiencies greater than those involved with direct negotiation between economic agents. Consequently, the free commercialization of polluting rights, when adequately priced, can be informational incentives with lower transactional costs than the imposition of state regulation measures (Cánepa, 2003).

In this perspective, the normative arrangements of payments for environmental services (PES) aim at the development of environmental markets that trade pollution rights and that, at the same time, reduce the opportunity costs for economic agents. Despite the various possible conceptualizations, the most followed semantics for the meaning of these arrangements can be summarized as "[...] benefits arising from anthropic initiatives in favor of ecological systems" (Brito & Marques, 2017, 360).

Therefore, environmental services are the efforts that economic agents make in maintaining the support capacity of ecosystems. On the other hand, more generally, ecosystem services are the direct and indirect benefits arising from the operation of environmental systems. Thus, payments to environmental services are reimbursements for expenditures allocated to preventing the occurrence of damage to environmental functions (Nusdeo, 2006).

In this comprehensive theoretical context, ERQ can be characterized as a compensation mechanism for environmental services established by the Brazilian forest legislation in 2012, with broad effectiveness potential. As an example, in the national territory, rural properties with legal reserve deficit have an estimated area of demand for compensation, between 15.33 million hectares (Young et al., 2017) and 13.1 million hectares (Freitas et al, 2016).

However, the constitution of liquid markets requires, at federal level, in addition to the definition of jurisprudence on the transfer rights of legal reserve surpluses, that operational procedures be institutionalized by federative units that, up to the present moment, require implementation, as will be reported in the following section.

Legal framework and environmental legislation

The New Brazilian Forest Code, as it is known and Law 12.651 of May 25, 2012 (Brasil, 2012), disciplined, from articles 44 to 50, the Environmental Reserve Quota - ERQ, a nominative title representing an area with native vegetation, existing or in the recovery process. Article 44 of the aforementioned law provides that ERQ represent areas of native vegetation,

existing or in the recovery process, under environmental easement regime, or that correspond to the Legal Reserve surplus, or that is protected in the form of a Private Natural Heritage Reserve (RPPN), or that exist on properties within Conservation Units in the public domain that have not yet been expropriated. Paragraph 4 of the same article provides that the ERQ of native vegetation that integrates the Legal Reserve of properties classified as small property, with its main characteristic as being smaller than four tax modules, may be instituted.

Each ERQ unit corresponds to one hectare of preserved or regenerating native vegetation, and will allow landowners to negotiate, within the same biome, surplus reserves with each other. In this way, it would be an economically less costly alternative for those who have forest reserve deficit, as well as a financial incentive for those who have surpluses to continue preserving native vegetation. ERQ is also an alternative to offset legal reserve deficits due to deforestation carried out before July 22, 2008, as described in Article 66 of the Forest Code.

Landowners interested in the commercialization of ERQ must meet the requirements described in Article 45 of the Forest Code, that is, to have the property duly included in the Rural Environmental Registry (CAR), in order to validate the amount of existing vegetation on the property. In addition, they must have the property registration duly registered in the registry service and have no debts in the Rural Territorial Property Tax – ITR system. Small properties face a challenge in this matter, as many landowners, especially in settlements, only have land use rights and do not have the property registration duly registered with the land registration notary.

In the state of Mato Grosso, Complementary Law No. 592, of May 26, 2017 (Mato Grosso, 2017) was instituted, which concerns the Environmental Regularization Program and the Mato Grosso System of Environmental Registration - SIMCAR, which is regulated by State Decree 1.031 of 2017 (Mato Grosso, 2017). This legislation provides in its articles 40 and 41 the percentage of reserve established for cases considered as exception in article 68 of the forest code. In addition, Article 42 provides that rural properties located in areas with forest vegetation, which converted their areas by May 26, 2000 and maintained Legal Reserve percentage above 50%, will have the right to offer compensation to third parties, the excess percentage of legal reserve, through easement or Environmental Reserve Quota – ERQ.

Since the implementation of the Environmental Reserve Quota, several works have been published addressing the importance and effectiveness of using this legislation. Scoton (2016) reports that for the ERQ to fulfill its preservation objective, it is necessary to guarantee that the income earned in its commercialization is actually destined to the maintenance and conservation of the compensable area. According to Porto and Santos (2017), the motivation or incentive for maximum effort within the scope of ERQ should be leveraged from the moment the instrument is fully operational, so that the activity of negotiations between CRA applicants

and providers should occur on a voluntary basis.

According to Silva and Ranieri (2014), ERQ is able to promote environmental conservation by effectively maintaining remnants of native vegetation in rural areas with lower opportunity and implementation costs. Gasparinetti and Vilela (2018) reported that ERQ, in principle, does not have the long-term objective of reducing deforestation, but of maintaining the balance of deforested and compensated areas. According to Ferreira et al. (2021), this equity criterion should be the main motivator for the full functioning of the environmental compensation mechanism, since the forests used for compensation should come from regions where the pressure for land use conservation is lower in relation to regions of higher opportunity cost. In this way, combined with other public policies, ERQ will serve as a tool to regularize the legal reserve situation of properties, and will function as a financial incentive for the preservation of the existing native vegetation on properties, thus helping to reduce deforestation.

Deforestation advancement in Mato Grosso

The Cerrado Biome has the richest flora among savanna biomes in the world, with 6,429 cataloged species (Scariot et al., 2005), therefore, it has recognized magnitude in terms of biodiversity and endemic species (Alves et al., 2020). According to Alves et al, (2020 and 2022), this hotspot has accumulated constant environmental changes, with the main threat being the expansion of agriculture and livestock, which together with the disorderly growth of urban areas, has generated intense transformations and environmental problems.

According to Merten and Minella (2002, 33):

> "The large-scale expansion of agricultural areas has shaped Brazilian landscapes in recent decades and the environmental consequences of these transformations are still not properly evaluated". However, it is possible to state that "the replacement of forested areas for agricultural purposes is associated with decrease in water quality and changes in the biological, physical and chemical processes of natural systems."

Illegal deforestation has been one of the major environmental problems in Brazil (Jordani, 2013; Ministério do Meio Ambiente, 2010), with the Cerrado biome being the most affected, with the most intense deforestation occurring in the region known as the "Arc of deforestation", which is located on the agricultural frontier from the Midwestern region to the Northern region of the country (Ministério do Meio Ambiente, 2010; Bonini, 2019). Deforestation rates in the Cerrado biome are higher than in the Amazon rainforest, while efforts to conserve this biome are much lower than in the Amazon (Klink & Machado, 2005). According to Biudes et al., (2015), the ecosystems of the state of Mato Grosso have suffered significant

deforestation over the last few decades, in addition, the state has one of the highest deforestation rates in Brazil. In this sense, Angelini et al., (2017) reported that deforestation in the state of Mato Grosso has increased every year, along with agricultural production.

From the 1960s to the 1980s, the Superintendence for the Development of the Midwestern region – SUDECO, was responsible for implementing the infrastructure for the colonization of the Cerrado biome, which included the municipality of Rondonópolis, and in parallel it also planned the development of agriculture, leaving in charge of the Brazilian Agricultural Research Corporation (EMBRAPA) research for the cultivation of land that was previously considered useless for any type of culture (Alves, 2003). Penha and Francisco (2017) found that since the 1970s, with the introduction of new techniques and technologies in the agricultural space, driven by the expansion of the agricultural activity, the deforestation process intensified. Spera et al. (2014) observed that in the state of Mato Grosso, most areas most suitable for agricultural production had already been occupied in early 2000s, which includes the region of Rondonópolis, and that from that date onwards, the search for less suitable regions with strong conversion from native vegetation to livestock increased.

In a compilation of studies carried out by Assis (2020), it was found that the factors responsible for the rapid agricultural expansion in the Cerrado biome include: 1) investments in technology and scientific research for the correction of highly leached and acidic soils and for the development of cultivars more adapted to the environmental conditions of the Cerrado; 2) the occurrence of six months of rainy season, favorable to the installation of rainfed agriculture, and mainly of flat relief in some specific regions, favorable to intensive mechanization; 3) the relatively high technological and economic level of rural producers who migrated from the Southern and Southeastern regions of Brazil to the Cerrado; and 4) the establishment of large multinational grain storage and processing companies.

Agricultural development and deforestation in the state of Mato Grosso have been linked to increased exports of soy and beef to China, the European Union and the Middle East. Increased soy expansion, deforestation and exports were observed in periods in the early 2000s when the Brazilian currency, the Real, lost value compared to the US dollar and when world prices for agricultural commodities were on the rise (Richards et al, 2012).

According to Picoli et al. (2020), due to the implementation of policies, such as the soy moratorium and the cattle moratorium, which make it difficult to trade these commodities originating from areas of illegal deforestation, and also the new forest code, between 2010 and 2017, there was a decrease in the rate of expansion of crops and pastures over new areas, prevailing the conversion of areas already deforested for crops of greater interest to the market. In addition, tools to combat deforestation with the use of remote sensing and geoprocessing techniques for environmental surveillance, allowed for faster identification of irregularly deforested areas, delimitation and monitoring of embargoes, and facilitated access to

information by companies, who are now able to more easily track the environmental situation of properties where commodities are produced.

Methodological Procedures

Delimitation of Rural Properties participating in the research

In 2017, the government of the State of Mato Grosso instituted the Rural Environmental Registration of Mato Grosso System (SIMCAR), which is a statewide electronic system for the registration, consultation, monitoring and management of the environmental situation of rural properties. This system was instituted based on Complementary Law of the State of Mato Grosso No. 592, of May 26, 2017 (Mato Grosso, 2017), and one of its aims, as described in article 5 of that law, is to monitor the maintenance, recomposition, regeneration, compensation and suppression of native vegetation and vegetation cover in areas of permanent preservation, of restricted use and legal reserve, within rural properties.

The Environment Department of the State of Mato Grosso (SEMA-MT) uses as a basis the perimeters of properties declared in SIMCAR, which are duly proven through documents, in order to comply with the current legislation that establishes minimum amount of legal reserve in agreement with the phytophysiognomy (ies) existing in rural properties and the percentages and criteria established in Federal Law No. 12.651, of May 25, 2012 (Brasil, 2012).

A rural property registered with SIMCAR may contain one or more registration, or any other document that proves ownership of the property, provided that these areas are contiguous and belong to the same owner. In this system, properties receive a registration code and their perimeter is publicly available. Thus, it was decided to use this database to carry out this work, since this analysis is consistent with the one that will be carried out by the agency responsible for environmental regularization.

It should be highlighted that the choice of reference time periods aims to analyze the evolution of native vegetation cover, within the legally required criteria (2000 and 2008), in contrast to that found on the base date when the research was carried out (2020). Properties were selected according to the municipality declared in the SIMCAR register, which is consistent with the notary registration, which is due to the fact that several properties are found between municipal limits. In addition, registrations in situation of being canceled or suspended were removed, as well as those that overlapped with Conservation Units, Indigenous Lands, and Urban Areas, since this overlapping could compromise the property ownership legality.

Credit area validation criteria or legal reserve deficit

The Legal Amazon corresponds to the area of operation of the Superintendence for the Development of the Amazon - SUDAM delimited in line with article 2 of Complementary Law

n. 124, of January 3, 2007 (Brasil, 2007). It has an approximate surface area of 5,015,067.75 km², corresponding to approximately 58.9% of the Brazilian territory. The region is made up of 772 municipalities in several states, of which all 141 of Mato Grosso are included[4].

Federal Law No. 12.651, of May 25, 2012 (Brasil, 2012), establishes in its article 12 the percentage of legal reserve required in properties located in the Legal Amazon, being 80% (eighty percent) in properties located in forest areas and 35% (thirty-five percent) in properties located in Cerrado areas, except for cases provided for in art. 68 of the same Law. Properties classified as exception have their reserve percentage established in accordance with criteria described in the state decree of Mato Grosso No. 1.031 of June 2, 2017, and article 40 describes that properties with less than four tax modules (MF) must maintain the existing reserve percentage established on July 22, 2008, while larger properties fall under article 41, as described in Table 01.

Table 1

Legal reserve requirement rules for rural properties above four tax modules in Mato Grosso.

Item	Phytophysiognomy	Situation on May 26, 2000	Legal Reserve Requirement
I	Forest	Conversion of 50%	50%
II	Cerrado	Conversion of 80%	20%
III	Forest	Conversion less than 20%	Maintain what existed in 2000
IV	Cerrado	Conversion less than 80%	Maintain what existed in 2000

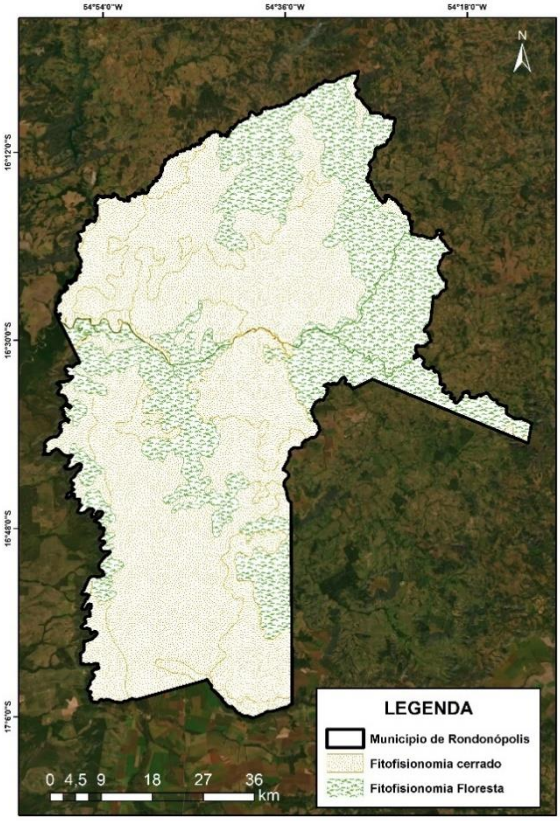
Source: Article 41 of State Decree 1031 of June 2, 2017.

For the delimitation of native vegetation in the years 2000, 2008 and 2020, data from collection 6 of the MapBiomas project for the respective years were used (PROJETO MAPBIOMAS, 2021). The project uses mosaics from the Landsat satellite to carry out coverage and land use classifications and makes data available free of charge on its online platform. Data are available in the raster format and divided into different use classes. This information was first converted to the shapefile format, and then all native vegetation classes[5] were grouped into a single one, and then classified according to phytophysiognomy, cerrado or forest, based on limits of the RADAM Brasil[63] project (Figure 1), which does not discriminate vegetation using the same characteristics as MapBiomas.

[4] Access through: https://monitoramento.sema.mt.gov.br/simcar/tecnico.app/autenticar.
[5] The vegetation classes considered for the municipality of Rondonópolis as non-anthropized according to MapBiomas Collection 6 are: forest formation, savanna formation, flooded field and swampy area, and grassland formation.
[6] The delimitation of the Radam Brasil Project is available at: http://www.sema.mt.gov.br/transparencia/index.php/sistemas/simgeo.

Figure 1

Delimitation of the vegetation phytophysiognomy in the municipality of Rondonópolis according to the RADAM Brasil project (Brasil, 1982)



Source: Produced by the authors.

The government of the State of Mato Grosso, defined through Decree No. 1025 of July 29, 2021 (Mato Grosso, 2021), that the classification of vegetation phytophysiognomy for the definition of legal reserve in rural properties in the state must be carried out on the basis of the State Socioeconomic-Ecological Zoning or on the RADAM Brasil Project. Thus, due to the non-existence of the aforementioned zoning, this study used the delimitation of the RADAM Brasil Project and, with that, it was possible to intersect this information with the boundaries of properties to determine the amount of native vegetation, and consequent remaining legal reserve for each year and property.

The RADAM Project (Radar da Amazônia) was a survey carried out by the Brazilian government in the 1970s for the research of natural resources in the Amazon, and which was later expanded to the entire national territory, starting to be called RADAM Brasil Project. One of the products of this project was the classification of vegetation into phytophysiognomies, from which, for the state of Mato Grosso, it is possible to find Cerrado and forest classes.

Data extraction

Rural properties were first divided according to: 1) Size, as areas smaller than 04 tax modules, 240 hectares for the municipality of Rondonópolis, have different requirements; 2) Vegetation phytophysiognomy, Cerrado and Forest; and 3) Quantitative vegetation in the years 2000, 2008 and 2020, for the application of legal reserve requirement rules. The combination of these situations and rules made it possible to identify areas with potential ERQ offers and demands, as described in Table 02.

Table 2

Criteria used to classify rural properties with potential ERQ supply or demand.

Property size	Phytophysiognomy	Potential ERQ offer	Potential ERQ demand
Up to 04 tax modules	Cerrado	Current vegetation remnant	None
	Forest	Current vegetation remnant	None
Above 04 tax modules	Cerrado	Current vegetation exceeding 35%	Deforestation after 2000 exceeding 65%, or before exceeding 80%
	Forest	If deforestation occurred before 2000: Current remnant exceeding 50%; If after, current remnant exceeding 80%	If deforestation occurred up to 2000: Current remnant less than 50%; If after, current remnant less than 80%

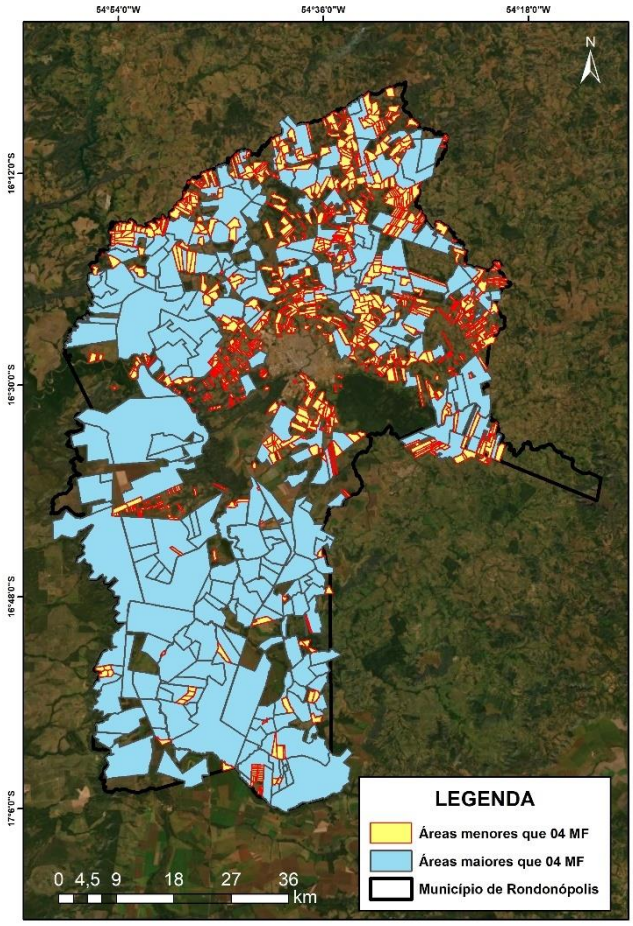
Source: Adapted from Bernasconi, 2013.

Results and Discussions

Overall, 1,212 properties registered in SIMCAR in the municipality of Rondonópolis were identified, which together, compose an area of 342,550 (three hundred and forty-two thousand, five hundred and fifty) hectares, which corresponds to 71% of the total area of the municipality, which is 482,402 (four hundred and eighty-two thousand, four hundred and two) hectares (IBGE, 2021) (Figure 2). Using the RADAM Brasil project delimitation, it was found that of these, 405 properties have exclusively vegetation phytophysiognomy classified as Forest, while 563 have Cerrado vegetation, and 244 have both phytophysiognomies.

Figure 2

Properties selected for the elaboration of this study

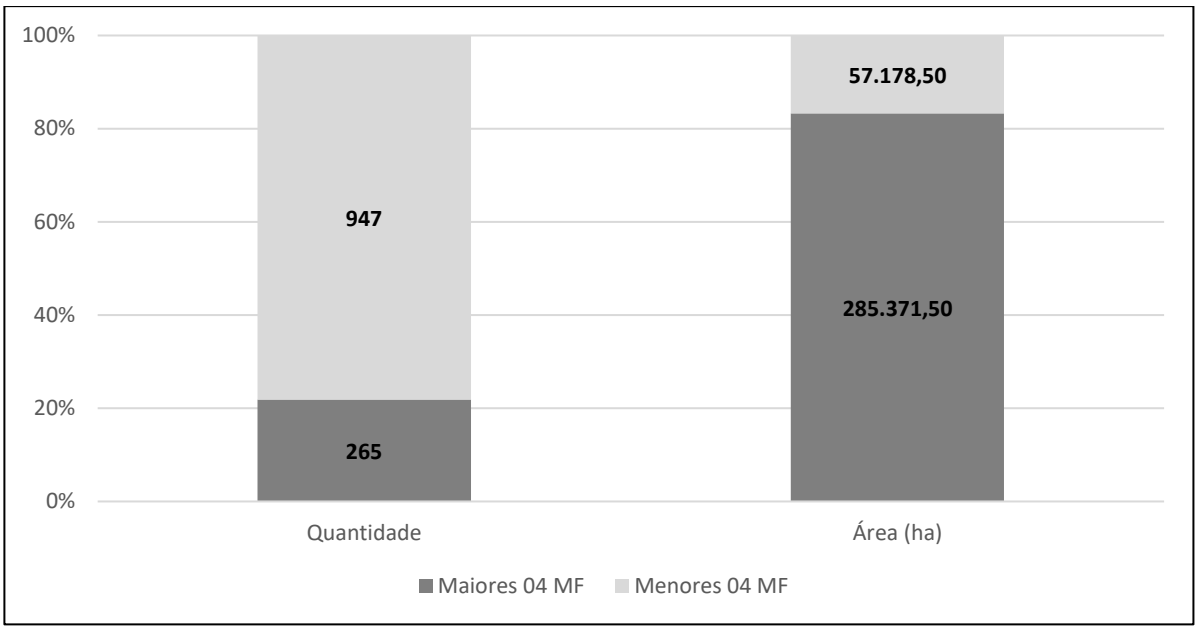


Source: Produced by the authors.

Of the total of 1,212 properties, 947 (78%) are smaller than 04 tax modules, totaling an area of 57,178.5 ha (17%). On the other hand, 265 (22%) are larger than 04 tax modules, totaling an area of 285,371.5 ha (83%) (Figure 3).

Figure 3

Number and area of properties larger and smaller than 04 tax modules in the municipality of Rondonópolis

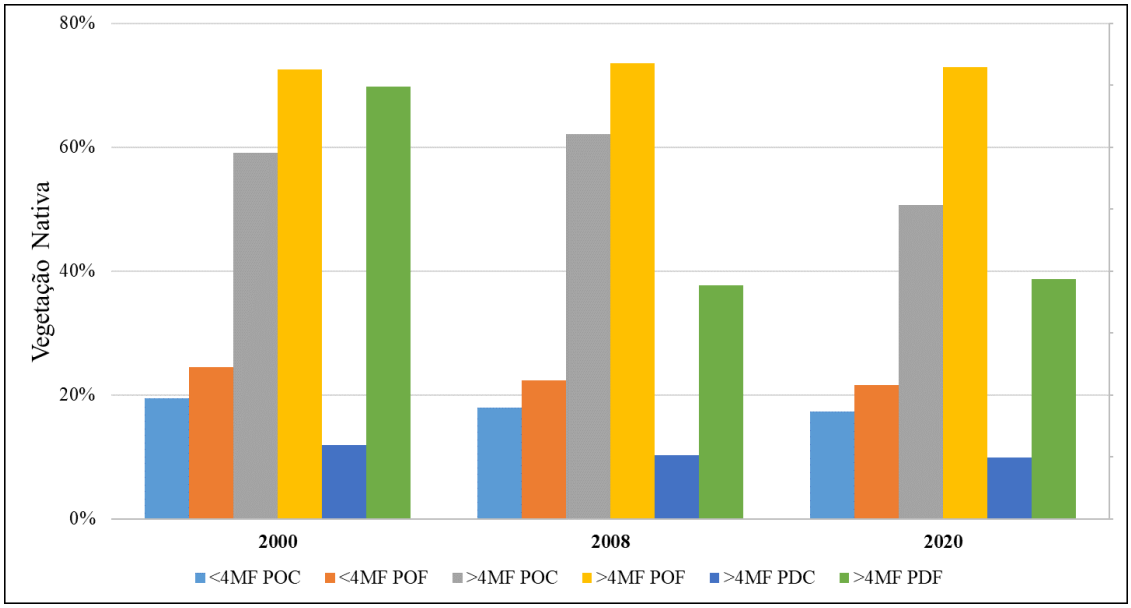


Source: Produced by the authors.

Using native vegetation values found for each situation defined in Table 2, the existing percentage for each phytophysiognomy in the years 2000, 2008 and 2020 was compared. It was observed that there was little change in percentages during the period, with the exception of areas larger than 04 MF, which have potential ERQ demand in forest phytophysiognomy. In 2000, these properties had about 70% of their vegetation preserved; however, in 2008, they had only 38%, which in absolute numbers represents a decrease of 706 ha. In areas larger than 04 MF with potential ERQ supply in Cerrado, there was a decrease of 3,704 ha between 2008 and 2020, which represented a decrease of 11 percentage points, indicating unfavorable evolution in terms of preservation (Figure 4).

Figure 4

Temporal evolution of the percentage of vegetation in the analyzed properties



Source: Produced by the authors.
Legend: <4MF: Areas smaller than 04 tax modules; >4MF: Areas larger than 04 tax modules; POC: potential ERQ offer in cerrado; POF: potential ERQ offer in forest; PDC: potential ERQ demand in cerrado; PDF: potential ERQ demand in forest.

Small properties, including settlement areas and other properties with up to four tax modules, are highly representative in the ERQ supply, as there are 585 properties in the Cerrado phytophysiognomy with potential offer of 5,347 ha, and in the Forest phytophysiognomy, there are 510 with potential to 5,675 ha. It is worth mentioning that the same property can be included in both phytophysiognomies (Table 3).

Table 3

ERQ offer by property size and phytophysiognomy

Property size	Phytophysiognomy	Potential ERQ offer			
		No. of properties	Phytophysiognomy area	Vegetation in 2020	ERQ
Less than 4 MF	Cerrado	585	30.800	5.347	5.347
Less than 4 MF	Forest	510	26.301	5.675	5.675
More than 4 MF	Cerrado	31	32.120	16.262	5.020
More than 4 MF	Forest	29	15.324	11.180	3.518
Total Cerrado		616	62.920	21.609	10.367
Total Forest		539	41.625	16.855	9.193
General Total		1.155	104.545	38.464	19.561

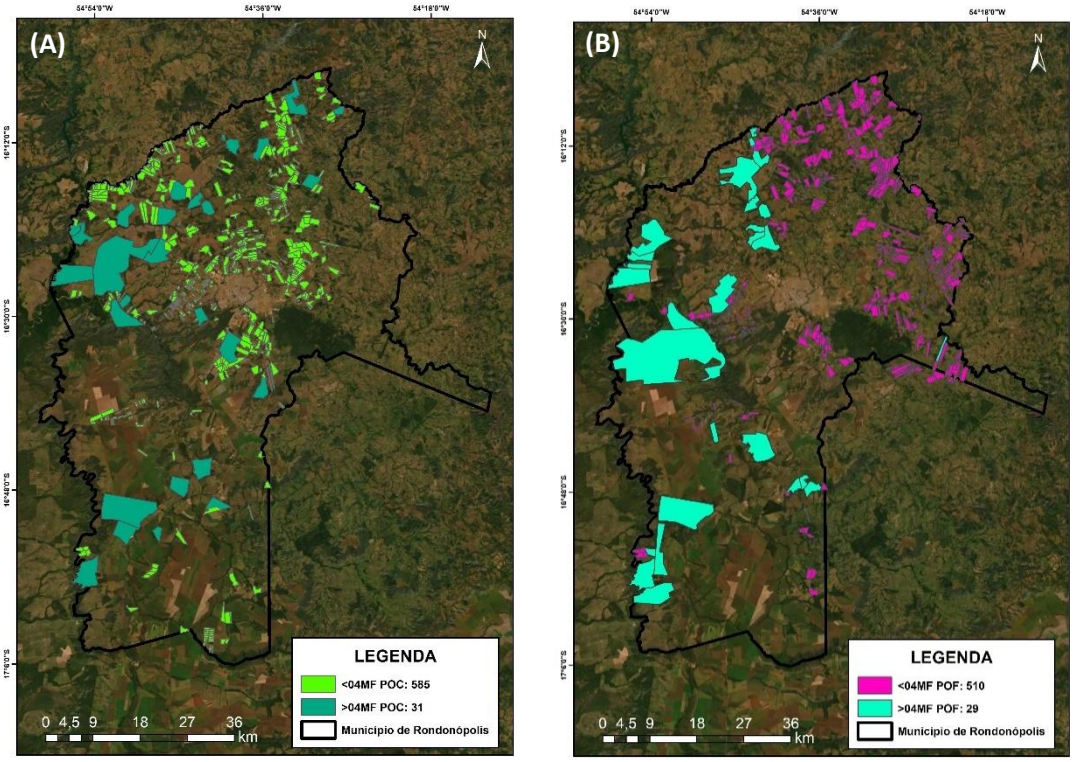
Source: Produced by the authors.

Small properties have an average of 60 ha, but total 11,022 ha, 56% of the total for the municipality, which can be converted into ERQ, demonstrating the key role they play in this market (Figure 5). It should be highlighted that economic incentives and the free negotiation of rights over environmental reserve surpluses can be an efficient alternative for reducing the opportunity cost of environmental preservation.

Data indicate the potential of ERQ offer in properties with up to 04 tax modules, which can be traded for the benefit of compensation in larger rural properties aimed at intensive agricultural production. However, there is a challenge in the implementation of this compensation system in these areas, as many do not have their land situation completely regular, in which the landowner often maintains it only as possession title.

Figure 5

Location of properties with potential ERQ offer in the Cerrado (A) and Forest (B) phytophysiognomies



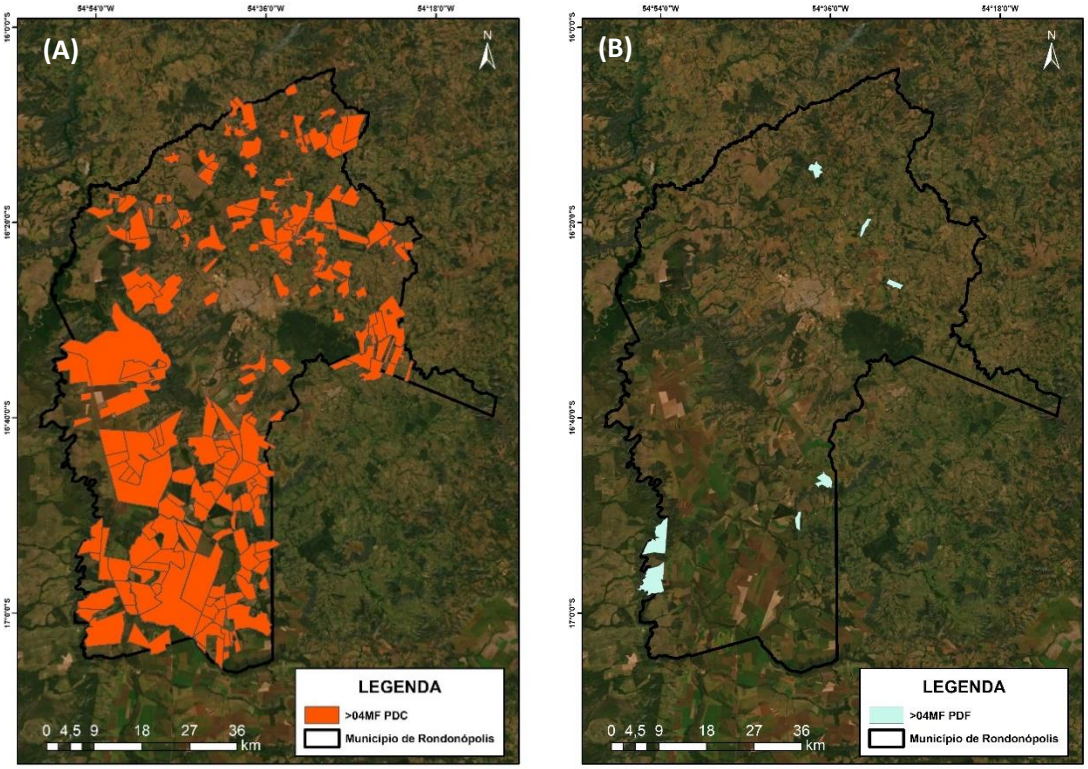
Source: Produced by the authors.
Legend: <4MF: Areas smaller than 04 tax modules; >4MF: Areas larger than 04 tax modules; POC: potential ERQ offer in cerrado; POF: potential ERQ offer in forest; PDC: potential ERQ demand in cerrado; PDF: potential ERQ demand in forest.

Properties larger than four MF with potential ERQ offer appear in smaller number, when compared to small ones; however, areas with native vegetation surplus are very representative. For the Cerrado, 31 properties with average size of 1,240 ha with 5,020 ha exceeding the minimum of 35% of legal reserve were identified. For the Forest phytophysiognomy, there are 29 properties with average size of 1,800 ha that together, have 3,518 ha that exceed 50% of the legal reserve (Table 1).

Properties smaller than four MF do not have potential ERQ demand, given that they must maintain the amount of native vegetation existing on the property in 2008 and any deforestation occurring after that date must be regenerated on site, as described in the State Decree 1.031 of June 12, 2017. On the other hand, the large number of properties larger than four MF with ERQ demand in the Cerrado phytophysiognomy, 13,464 ha, stands out. This number results from the presence of native vegetation in only 10% of the total area of this phytophysiognomy, while at least 20% should be present (Figure 6). For the Forest phytophysiognomy, there is a demand for only 248 ha in 07 properties (Table 4).

Figure 6

Location of properties with potential ERQ demand in the Cerrado (A) and Forest (B) phytophysiognomies



Source: Produced by the authors.
Legend: <4MF: Areas smaller than 04 tax modules; >4MF: Areas larger than 04 tax modules; POC: potential ERQ offer in Cerrado; POF: potential ERQ offer in forest; PDC: potential ERQ demand in Cerrado; PDF: potential ERQ demand in forest.

Table 4

ERQ demand by property size and phytophysiognomy.

Property size	Phytophysiognomy	Potential ERQ demand			
		No. of properties	Phytophysiognomy area	Vegetation 2020	ERQ
Smaller than 4 MF	Cerrado	-	-	-	-
Smaller than 4 MF	Forest	-	-	-	-
Larger than 4 MF	Cerrado	185	132.868	13.109	-13.464
Larger than 4 MF	Forest	7	2.204	854	-248
General Total		192	135.072	13.963	-13.712

Source: Produced by the authors.

In a general balance, the municipality of Rondonópolis has potential offer of 19,561 ha to be marketed as ERQ, while it has potential demand of 13,712 ha, which represents a spare offer of 5,849 ha. This empirical evidence indicates the potential for additional income through environmental preservation in smaller rural properties. However, it will depend on the inclusion of small properties in this market, mainly on settlement areas, which will require government action to encourage land regularization.

ERQ potential in settlements

In the municipality of Rondonópolis, a total of 10 settlements are registered with INCRA – "Instituto Nacional de Colonização e Reforma Agrária" (Table 5). However, there are 02 others registered as belonging to "Poxoréu" and "Pedra Preta", which are partially inserted in the municipality of this study and will be considered in this analysis (Figure 7).

Table 5

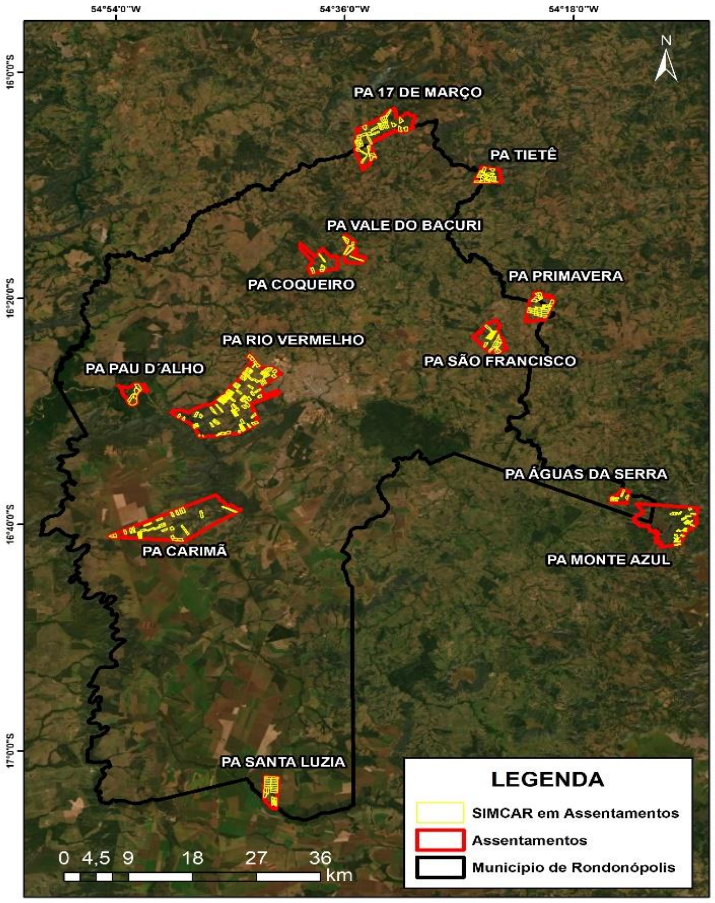
Settlements in Rondonópolis and their characteristics

Settlement name	Municipality	Capacity	Number of families	Total Area (ha)	Vegetation Area (ha)
PA 17 De março	Rondonópolis	99	96	3104,01	1223,54
PA Águas Da Serra	Rondonópolis	18	18	386,58	58,45
PA Carimã	Rondonópolis	194	175	5972,22	1813,41
PA Coqueiro	Rondonópolis	40	39	1224,83	273,43
PA Monte Azul	Pedra preta	120	89	4009,78	2652,73
PA Pau D´Alho	Rondonópolis	25	22	637,70	284,17
PA Primavera	Rondonópolis	50	45	1258,82	176,08
PA Rio Vermelho	Rondonópolis	320	244	7719,53	2292,07
PA Santa Luzia	Rondonópolis	27	27	855,93	127,74
PA São Francisco	Rondonópolis	50	50	1373,84	255,18
PA Tietê	Poxoréo	37	24	714,30	382,64
PA Vale Do Bacuri	Rondonópolis	30	24	617,71	120,93
Total	**-**	**1010**	**853**	**27875,2**	**9660,4**

Source: Produced by the authors.

Figure 7

Rondonopolis settlements and properties with SIMCAR



Source: Produced by the authors.

Settlements located in Rondonópolis have the capacity to establish up to 1,010 families, with 853 of them registered, considering that each family occupies an area, which would be the total number of properties that should be registered in SIMCAR. In all settlements, the number of registered families (853) is greater than the number registered in SIMCAR (268).

The total area of all settlements is 27,875.24 hectares, but only 5,559.24 hectares, about 20%, are registered in SIMCAR. It is thus verified that there is great need to register these properties with SEMA, as this portion without registration represents an amount of 18,214.87 hectares, with 8,568.57 hectares of native vegetation with potential to be used as ERQ offer (Table 6).

Table 6

Total area and native vegetation in the settlements of Rondonópolis

Settlement name	Number of families	SIMCAR Number	Area with SIMCAR (ha)	Area without SIMCAR (ha)	Vegetation with SIMCAR (ha)	Vegetation without SIMCAR (ha)
PA 17 De Março	96	29	775.93	1880,47	276.33	947.21
PA Águas Da Serra	18	5	103.65	328.12	16.32	42.13
PA Carimã	175	28	637.07	4158,80	58.50	1754,91
PA Coqueiro	39	3	74.97	951.40	2.10	271.33
PA Monte Azul	89	24	224.23	1357,06	66.15	2586,58
PA Pau D´Alho	22	5	268.03	353.53	82.96	201.21
PA Primavera	45	16	420.93	1082,74	62.56	113.52
PA Rio Vermelho	244	94	1589.80	5427,46	238.99	2053,08
PA Santa Luzia	27	21	563.68	728.19	7.58	120.16
PA São Francisco	50	12	264.22	1118,66	46.54	208.64
PA Tietê	24	25	507.64	331.66	206.40	176.24
PA Vale Do Bacuri	24	6	129.10	496.78	27.37	93.56
Total	**853**	**268**	**5559,24**	**18214,87**	**1091,80**	**8568,57**

Source: Produced by the authors.

It was not found in the cartographic bases of INCRA, the certification of areas of any settlement. No area in SIMCAR was found in the “Validated” situation, a fact that can be considered as an indication that families occupying these areas do not have the possession documentation, since, in order to validate the property registration in SIMCAR, it is necessary to present valid documentation of possession or ownership.

This absence of land regularization allows and generates divergences regarding the limits and registration of properties, and makes it difficult for environmental agencies to control devices to prevent deforestation, fires and other types of environmental violations. In an attempt to reverse this situation, Federal Law No. 11.952 in 2009 (BRASIL, 2009) simplified the procedures of processes to guarantee property rights to occupants of remaining federal public lands in the Legal Amazon. This law created the “Federal Terra Legal” Program, which would be the main public policy instrument for land titling for settlers and occupants. Such competence, formerly exercised by the “Instituto Nacional De Colonização e Reforma Agrária”

(INCRA), was delegated to the then Ministry of Agrarian Development (MDA).

It is noteworthy that this law was amended through Provisional Measure No. 759/2016, which was converted into Law No. 13.465, of July 11, 2017 (BRASIL, 2017), which changed concepts, requirements, pricing policy and resolution clauses. Thus, the federal government created the "Titula Brasil" Program through Ordinance No. 01, of December 2, 2020 (Secretaria Especial de Assuntos Fundiários, 2020), which aims to increase the operational capacity of procedures for titling and land regularization of rural areas under the control of the Union or the "Instituto Nacional De Colonização e Reforma Agrária". The rules for this process are in Normative Instruction 105[74], published in January 2021, by INCRA, which has exclusivity in issuing title documents and also in defining areas subject to regularization, but transfers to municipalities the management of applications, declarations and documents related to land regularization procedures, as well as inspections and georeferencing (Zeneratti, 2021).

It is important to point out that there are Bills being processed in the National Congress, such as: PL No. 2633/2020 and PL No. 510/2021, among others, dealing mainly with the time frame and the quantitative area subject to land regularization. Thus, the established bureaucracy is evident for those who own real estate in settlements to receive their title, which is the legitimate document as proof of ownership for their registration in SIMCAR, as described in art. 26 item V of Decree 1031 of June 2, 2017 (Mato Grosso, 2017), and consequently the use of the remaining vegetation as ERQ.

The Environmental Reserve Quota was instituted by art. 44 of Law No. 12.651, of May 25, 2012 (Brasil, 2012), but only regulated by Decree No. 9.640, of December 27, 2018 (Brasil, 2018), which defines that the issuance of quotas requires approval the location of the legal reserve in SIMCAR and, among other documents, the registration of the property issued by the competent land registry agency. On the other hand, the evaluation of ERQ implementation in other units of the federation, although outside the scope of the present work, constitutes an opportunity to validate the present methodology in regulatory and operational contexts different from that of Mato Grosso.

As an example of the potential for generating income for small rural producers, the BVRio[85] Institute platform provides a table with the current ERQ values by biome and by Brazilian State, and for the Cerrado biome of Mato Grosso, it was found, in April 2022, average ERQ value of R$ 155,00 per hectare per year. Considering the 9,660 ha of native vegetation with potential to be marketed as ERQ in the settlements of Rondonópolis, there would be an amount of R$ 1.500.298,00 per year, which could be converted into income for settlers, encouraging the preservation of vegetation in properties within these areas, attributing them economic value.

[7] Available at https://www.in.gov.br/en/web/dou/-/instrucao-normativa-n-105-de-29-de-janeiro-de-2021-301562186
[8] Available at: https://www.bvrio.org/florestal/cra/plataforma/prepara.do

Conclusion

In the analyzed case study, it could be concluded that the potential ERQ market estimated for the municipality of Rondonópolis presents supply greater than demand. This allows rural property owners to regularize their liabilities related to the legal reserve of the property, at the same time promoting the maintenance of existing vegetation within the municipality itself through the payment of environmental services via ERQ. On the other hand, large part of this offer comes from properties smaller than four tax modules, which need to regularize their land situation.

Rural settlements have 49.4% of the potential ERQ supply in the municipality of Rondonópolis; however, many of these properties do not even have the initial registration in SIMCAR, and none of them have this registration already approved by the competent body (SEMA). This evidence demonstrates the need for public policies for the environmental and land regularization of these properties, in order to make this potential market for environmental services viable.

The results indicate the potential for generating income for small rural landowners through payments for environmental services for the preservation of legal reserve surpluses. As pointed out by the economic literature, through the perspective of Ronald Coase, preservation can be achieved with lower opportunity costs in rural properties aimed at intensive agricultural production through the acquisition of rights over legal reserves arising from properties of up to four tax modules.

The methodology used proved to be effective in estimating the legal reserve requirements of properties and, consequently, identifying the potential for ERQ transactions. As points to be prioritized for the implementation of this market, the following aspects can be listed:

(i) Adoption of automated artificial intelligence systems for validation of ERQ and PRA of rural properties, and validation by digital means of areas of environmental reserves, in accordance with legal guidelines;

(ii) Prioritization of the ownership regularization of rural properties with up to 4 MF, especially those with surplus environmental reserves, in an integrated manner for the creation of environmental corridors.

However, it was verified that the official database of validated perimeters registered in SIMCAR represent only 5.3% of registers found for the municipality of Rondonópolis. Additionally, a small representation of rural registers already analyzed was identified, compared to the estimate made in this study, based on georeferencing images. Therefore, the effectiveness of this compensation mechanism requires that this previous step of normative

validation be completed by the competent environmental agency (SEMA).

In summary, the compensation for the preservation of legal reserves through ERQ can constitute an essential mechanism for the adjustment of rural properties to the environmental norms in the municipality of Rondonópolis. Additionally, the potential of its implementation was shown, contributing to the preservation of rural properties with less than four tax modules that currently do not have sources of income generation and consistent agricultural productivity. Finally, it should be highlighted that the use of ERQ, alone, without effectively combating illegal deforestation, does not have the capacity to resolve the trend towards an increase in the loss of pristine forest cover in areas covered by this survey.

References

Alves, G. B. M., Mendonça, V. M., Martarello, A. P., Pessi, D. D., Vieira, A., & Loverde-Oliveira, S. M. (2020). Análise ambiental do desmatamento em área de assentamento rural no Cerrado (Mato Grosso, Brasil). *Terr@ Plural*, 14, 1-13. Retrieved from: https://doi.org/10.5212/terraplural.v.14.2015189.060

Alves, G. B. M, Mendonça, V. M., & Loverde-Oliveira, S. M. (2022). Influência do ritmo das águas no manejo da pecuária no pantanal de Mato Grosso. In D. Pessi, et al. (Eds), *Perspectivas ambientais no âmbito das geociências e ecologia do pantanal.* (pp 60-79) Uniedusul Editora. Retrieved from: https://www.uniedusul.com.br/wp-content/uploads/2022/03/e-book-perspectivas-ambientais-no-ambito-das-geociencias-e-ecologia-do-pantanal-1.pdf

Alves, G. T. (2003). O planejamento governamental e seus reflexos na estrutura fundiária de Mato Grosso. *Caminhos de Geografia*, 4, 17-30.

Angelini, L. P., Silva, S. P. C. B., Fausto, M. A., Machado, N. G., & Biudes, M. S. (2017) Balanço de Energia nas Condições de Mudanças de Uso do Solo na Região Sul do

Estado de Mato Grosso. *Revista Brasileira de Meteorologia*, 32(3), 353-363. Retrieved from: https://doi.org/10.1590/0102-77863230003

Assis, T. (2020). *Dinâmica espaço-temporal da cultura de soja no Cerrado, analisada por meio de estatística espacial e dados físicos, socioeconômicos e ambientais*. [Doctoral Dissertation, Universidade de Brasília]. Retrieved from: https://repositorio.unb.br/handle/10482/39125

Bernasconi, P. (2013). *Custo-efetividade ecológica da compensação de reserva legal entre propriedades no estado de São Paulo*. [Master Dissertation, Universidade Estadual de Campinas]. Retrieved from: https://repositorio.enap.gov.br/handle/1/4915

Biudes, M. S., Vourlitis, G. L., Machado, N. G., Arruda, P. H. Z., Neves, G. A. R., Lobo, F. A., Neale, C. M. U., & Nogueira, J. S. (2015). Patterns of energy exchange for tropical ecosystems across a climate gradient in Mato Grosso, Brazil. *Agricultural and Forest Meteorology*, 202, 112-124. Retrieved from: https://doi.org/10.1016/j.agrformet.2014.12.008.

Bonini, I. (2019). *Transição Amazônia-Cerrado: desmatamento e colapso do ciclo hidrológico*. [Doctoral Dissertation, Universidade do Estado de Mato Grosso]. Retrieved from: http://portal.unemat.br/media/files/isabelle-bonini.pdf

Brasil. Decreto nº 9.640/2018, de 27, de dezembro, regulamenta a Cota de Reserva Ambiental, instituída pelo art. 44 da Lei nº 12.651, de 25 de maio de 2012. Retrieved from: http://www.planalto.gov.br/ccivil_03/_ato2015-2018/2018/decreto/D9640.htm

Brasil. Lei complementar nº 124/2007, de 03 de janeiro, institui, na forma do art. 43 da constituição federal, a superintendência do desenvolvimento da Amazônia - SUDAM; estabelece sua composição, natureza jurídica, objetivos, área de competência e

instrumentos de ação; dispõe sobre o fundo de desenvolvimento da Amazônia - FDA; altera a medida provisória n.º 2.157-5, de 24 de agosto de 2001; revoga a lei complementar num. 67, de 13 de junho de 1991; e dá outras providências. Retrieved from: https://legislacao.presidencia.gov.br/atos/?tipo=LCP&numero=124&ano=2007&ato=ce1k3YU1ENRpWT819

Brasil. Lei n. 12.651/2012, de 25 de maio, dispõe sobre a proteção da vegetação nativa; altera as Leis nos. 6.938, de 31 de agosto de 1981, 9.393, de 19 de dezembro de 1996, e 11.428 de 22 de dezembro de 2006; revoga as leis nos 4.771, de 15 de setembro de 1965, e 7.754, de 14 de abril de 1989, e a Medida Provisória nº 2.166-67, de 24 de agosto de 2001; e dá outras providencias. Retrieved from: http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2012/lei/l12651.htm

Brasil. Lei n. 4.771/1965, de 15 de setembro, institui o novo Código Florestal. Retrieved from: http://www.planalto.gov.br/ccivil_03/leis/l4771.htm

Brasil. Lei nº 11.952/2009, de 25 de junho, dispõe sobre a regularização fundiária das ocupações incidentes em terras situadas em áreas da União, no âmbito da Amazônia Legal; altera as Leis nos 8.666, de 21 de junho de 1993, e 6.015, de 31 de dezembro de 1973; e dá outras providências. Retrieved from: http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2009/lei/L11952complilado.htm

Brasil. Lei nº 13.465/2017, de 11 de julho, dispõe sobre a regularização fundiária rural e urbana, sobre a liquidação de créditos concedidos aos assentados da reforma agrária e sobre a regularização fundiária no âmbito da Amazônia Legal; institui mecanismos para aprimorar a eficiência dos procedimentos de alienação de imóveis

da União. Retrieved from: http://www.planalto.gov.br/ccivil_03/_ato2015-2018/2017/lei/l13465.htm.

Brasil. (1982). Ministério de Minas e Energia. Projeto RADAM Brasil: Folha SE. 21 Corumbá e parte da folha SE.20: geologia, geomorfologia, pedologia, vegetação, uso potencial da terra. Retrieved from: https://biblioteca.ibge.gov.br/index.php/biblioteca-catalogo?id=281409&view=detalhes.

Brasil. (2010). Ministério Do Meio Ambiente. ARPA Desmatamento e mudanças climáticas. Brasília. Retrieved from: https://d3nehc6yl9qzo4.cloudfront.net/downloads/desmatamento_e_mudancas_climauticas.pdf.

Brito, R. de O., & Marques, C. F. (2017). Pagamento por serviços ambientais: uma análise do ICMS ecológico nos estados brasileiros. *Planejamento e Políticas Públicas*, 49, 357-383.

Cánepa, M. (2003). Economia da poluição. In P. May, M. C. Lustosa, V. Vinha (Eds), *Economia do meio ambiente. Teoria e prática* (pp. 62-63). Elsevier.

Carneiro, L. (2019). *A financeirização da preservação ambiental no Brasil e as Cotas de Reserva Ambiental*. [Master Dissertation, Universidade Federal de Goiás]. Retrieved from: https://repositorio.bc.ufg.br/tede/handle/tede/9859

Cechin, A. (2016). *A natureza como limite da economia: A Contribuição de Nicholas Georgesku*. SENAC.

Coase, R. (1960). The problem of social cost. *Journal of Law and Economics*, 3, 1-20.

Cunha, S. S. A. (2013). *Cota de reserva ambiental*. 2013. [Trabalho de conclusão de curso, Universidade Federal Fluminense]. Retrieved from: https://app.uff.br/riuff/bitstream/handle/1/8575/Monografia%20-%20Cota%20de%20Reserva%20Ambiental%20-%20Monografia%20Final%20-%20Solange%20Silva%20Alvares%20da%20Cunha%20.pdf;jsessionid=41E3D55F00C4C664BCD3797D9B2BB551?sequence=1

Daly, H. E., & Farley, J. (2011). *Ecological Economics: Principles and Applications. Washington*. Island Press.

Fausto, M. A., Angelini, L. P., Marques, H. O., Filho, A. S., Machado, N. G., & Biudes, M. S. (2016). Impacto da alteração do uso do solo no saldo de radiação no Cerrado do sul de Mato Grosso. *Revista Ambiente & Água*, 11 (2), 350-361. Retrieved from: hhttps://doi.org/10.4136/ambi-agua.1843

Ferreira, Z. R., Sousa, L. V. C., Santos, A. B., & Ferreira, M. A. C. (2021) Cotas de reserva ambiental: um estudo por meio dos critérios de avaliação de política pública ambiental. *Revista Gestão e Sustentabilidade Ambiental*, 10(3), 219-246. Retrieved from: https:// doi.org/10.19177/rgsa.v10e32021219-246

Fitz, P. R. (2018). *Geoprocessamento sem complicação*. Oficina de textos.

Freitas, F. L. M. de, Sparovek, G., & Matsumoto, M. H. (2016). A adicionalidade do mecanismo de compensação de reserva legal da Lei n. 12.651/2012: uma análise da oferta e demanda de cotas de reserva ambiental. In A. P. M. da Silva, H. R. Marques, R. H. R. Sambuichi (Eds) *Mudanças no código florestal brasileiro: desafios para a implementação da nova lei* (pp 125-158). Ipea.

Freitas, L. G. de. (2021). Brazilian Environmental Law: An Overlook. *Journal of Agricultural and Environmental Law*, 16(30), 74-85.

Gasparinetti, P., & Vilela, T. (2018). *Implementando Mercados de Cotas de Reserva Ambiental (CRA) nos Estados Brasileiros: Desafios e Oportunidades para as Regulamentações Estaduais*. Good energies: power for a better world. Retrieved from: https://www.conservation-strategy.org/sites/default/files/field-file/PORT_documento_de_discussao_CRA_CSF_Fev2018.pdf

Instituto Brasileiro De Geografia E Estatística - IBGE. (2021) Censo Brasileiro de 2021. Retrieved from: https://cidades.ibge.gov.br/brasil/mt/rondonopolis/panorama.

Jordani, A. (2013) *Análise diagnóstica do desmatamento em comparação com resultados da fiscalização do IBAMA na região oeste do estado de Mato Grosso*. [Trabalho de especialista em Gestão Florestal, Universidade Federal do Paraná]. Retrieved from: https://www.acervodigital.ufpr.br/bitstream/handle/1884/50713/R%20-%20E%20-%20ALLAN%20VALEZI%20JORDANI.pdf?sequence=1

Klink, C., & Machado, R. (2005). A conservação do Cerrado brasileiro. *Megadiversidade*, 1(1), 148-155.

Mato Grosso. Decreto 1031/2017, de 02 de junho, regulamenta a Lei Complementar nº 592, de 26 de maio de 2017, no que tange o Programa de Regularização Ambiental, o Sistema Mato-grossense de Cadastro Ambiental - SIMCAR, a inscrição e análise do Cadastro Ambiental Rural. Retrieved from: http://app1.sefaz.mt.gov.br/0325677500623408/7C7B6A9347C50F55032569140065EBBF/950801C5453562B984258137006C104B.

Mato Grosso. Decreto Nº 1025/2021, de 29 de julho, regulamenta os artigos 62 e 62-B da Lei Complementar Estadual nº 38, de 21 de novembro de 1995, que dispõe sobre o Código Estadual do Meio Ambiente e dá outras providências. Retrieved from: https://www.legisweb.com.br/legislacao/?id=417993.

Mato Grosso. Lei complementar Nº 592/2017, de 26 de maio, dispõe sobre o Programa de Regularização Ambiental - PRA, disciplina o Cadastro Ambiental Rural - CAR, a Regularização Ambiental dos Imóveis Rurais e o Licenciamento Ambiental das Atividades poluidoras ou utilizadoras de recursos naturais, no âmbito do Estado de Mato Grosso, e dá outras providências. Retrieved from: http://app1.sefaz.mt.gov.br/0425762E005567C5/9733A1D3F5BB1AB-384256710004D4754/2934486634343A9C8425812F005B9C6E

Merten, G. H., & Minella, J. P. (2002). Qualidade da água em Bacias Hidrográficas Rurais: um desafio atual para a sobrevivência futura. *Agroecologia e Desenvolvimento Rural Sustentável*, 3(4), 103-132.

Nusdeo, A. M. de O. (2006). O uso de instrumentos económicos nas normas de proteção ambiental. *Revista da Faculdade de Direita da Universidade de São Paulo*, 101, 357-378.

Penha, T. V., & Francisco, C. N. (2017). Análise da dinâmica da cobertura vegetal no estado de Mato Grosso utilizando índices de vegetação do Sensor MODIS. In *XVII Simpósio Brasileiro de Geografia Física Aplicada, I Congresso Nacional de Geografia Física*. Retrieved from: https:// doi.org/10.20396/sbgfa.v1i2017.2077

Picoli, M. C. A., Rorato, A., Leitão, P., Camara, G., Maciel, A., Hostert, P., & Sanches, I. D. (2020). Impacts of Public and Private Sector Policies on Soybean and Pasture

Expansion in Mato Grosso—Brazil from 2001 to 2017. *Land*, 9(1), 1-15. Retrieved from: https:// doi.org/10.3390/land9010020

Pivetta, M. (2022). Emissões recentes de dióxido de carbono, principal gás de efeito estufa, dobram na Amazônia. *Pesquisa Fapesp*, 321(11), 16-23. Retrieved from: https://revistapesquisa.fapesp.br/emissoes-recentes-de-dioxido-de-carbono-principal-gas-de-efeito-estufa-dobram-na-amazonia/?utm_source=facebook&utm_medium=social&utm_campaign=Ed321

Porto, A. J. M., & Santos, L. M. (2017). Cotas de reserva ambiental: uma interpretação da análise econômica do direito. *Revista Estudos Institucionais*, 3(2), 922-948. Retrieved from: https://www.estudosinstitucionais.com/REI/article/view/228

Projeto MapBiomas. (2019). Coleção 6.0 da Série Anual de Mapas de Cobertura e Uso de Solo do Brasil. Retrieved from: https://mapbiomas.org/download. Acesso em 05 de outubro de 2021.

Rajão, R. (2015). *Cotas de reserva ambiental (CRA): viabilidade econômica e potencial do mercado no Brasil*. IGC/UFMG. Retrieved from: https://www.csr.ufmg.br/mercadocra/Rajao_Soares_15_CRA%20no%20Brasil_lowres.pdf

Richards, P. D., Myers, R. J., Swinton, S. M., & Walker, R. T. (2012). Exchange rates, soybean supply response, and deforestation in South America. *Global Environmental Change*, 22(2), 454-462. Retrieved from: https://doi.org/10.1016/j.gloenvcha.2012.01.004

Salles, A. O. T., & Matias, A. L. (2022). Uma análise da teoria das externalidades de Pigou e Coase e suas aplicações na abordagem teórica da Economia Ambiental. *Informe Econômico* (PI), 44(1), 146-175.

Scariot, A., Sousa-Silva, J. C., & Felfili, J. M. (2005). *Cerrado: Ecologia, Biodiversidade e Conservação*. Ministério do Meio Ambiente. Retrieved from: https://files.cercomp.ufg.br/weby/up/284/o/Cerrado_Parte1.pdf

Scoton, L. (2016). *A cota de reserva Ambiental no Novo Código Florestal Brasileiro: propostas para a efetividade*. [Master Dissertation, Universidade de São Paulo]. Retrieved from: https://teses.usp.br/teses/disponiveis/107/107131/tde-07072017-174128/publico/LuisEBScotonOriginal.pdf

Secretaria Especial de Assuntos Fundiários - SEAF. (2020). Portaria Conjunta nº 1, de 2 de dezembro de 2020. Retrieved from: https://www.in.gov.br/en/web/dou/-/portaria-conjunta-n-1-de-2-de-dezembro-de-2020-291801586

Silva, J. S., & Ranieri, V. E L. (2014). O mecanismo de compensação de reserva legal e suas implicações econômicas e ambientais. *Ambiente & Sociedade*, 17 (1). Retrieved from: https://www.scielo.br/j/asoc/a/6GzhNYnScryYHRbyJNcFNtq/?lang=pt Acesso em 14/05/2022

Spera, S. A., Cohn, A. S., VanWey, L. K., Mustard, J. F., Rudorff, B. F., Risso, J., & Adami, M. (2014). Recent cropping frequency, expansion, and abandonment in Mato Grosso, Brazil had selective land characteristics. *Environ. Res. Lett.*, 9(6). Retrieved from: https:// doi.org/10.1088/1748-9326/9/6/064010

Vicentini, R. (2021). *Prefeitura elabora documento para regularização de assentamentos rurais*. Prefeitura Municipal de Rondonópolis. Retrieved from: http://www.rondonopolis.mt.gov.br/noticias/prefeitura-elabora-documento-para-regularizacao-de-assentamentos-rurais. Acesso em 10 de março de 2022.

Young, C. E. F., Alvarenga Júnior M., Gandra, F., Costa, L. de A., & Mendes, M. (2017). Custos e Benefícios da Implementação de um Mercado de Cotas de Reserva Ambiental (CRA) no Brasil. In *Anais XII Encontro Nacional da Sociedade Brasileira de Economia Ecológica*.

Zeneratti, F. L. (2022). O acesso à terra no Brasil: reforma agrária e regularização fundiária. *Revista Katálysis*, 24(3), 564-575. Retrieved from: doi.org/10.1590/1982-0259.2021.e79558.

Zerwes, L. C., & Schwenk, L. M. (2011). Desmatamento em Mato Grosso: Uma Análise do Processo no Município de Brasnorte em 2009. In *Anais XV Simpósio Brasileiro de Sensoriamento Remoto*. (8536- 8543). INPE.