SEMINA
Ciências Agrárias

DOI: 10.5433/1679-0359.2022v43n5p2137

Change in land use and economic dynamics of the Ibirapuitã River Environmental Protection Area of the Brazilian Pampa biome

Mudança no uso da terra e dinâmica econômica da Área de Proteção Ambiental do Rio Ibirapuitã do bioma Pampa brasileiro

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Highlights

Profitability-based production is one of the main drivers of land use change.
The expansion of areas cultivated with rice has more economic impact in the region.
The Ibirapuitã APA fulfilled its role of sustainable use in the Pampa biome.

Abstract

This study analyzed the change in land use in the Environmental Protection Area (EPA) of the Ibirapuitã River in the Pampa biome, Brazil, and its impact on the economic dynamics of the region. The analysis had a descriptive character with a quantitative approach. Methodologically, we constructed a database with macroeconomic and agricultural production variables of the four municipalities that compose the EPA Territory, including remote sensing images to assess the change in land use between 2000 and 2020. Moreover, regression models were used to determine the growth trends in agricultural production and analyze the impact of land-use change on the economic dynamics of the territory. The results indicated a shift in land use in the EPA territorry, resulting from transforming natural pastures into grain cropping systems. Profitability-based production is one of the main factors for change in land use. The expansion of soybean production positively impacted the economic variables of the territory. However, this EPA of the Ibirapuitã was essential to ensure conservation use of the region during this period, maintaining the areas of natural pasture in the biome. Therefore, it is necessary to develop a representative public policy for the Pampa biome that offers incentives and encourages the conservation of ecosystem services in agricultural exploitation.

Key words: Agricultural production. Environmental conservation. Farm income. Land use.

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Received: June 03, 2022 - Approved: July 15, 2022

Resumo

Este estudo analisou a mudança no uso da terra na Área de Proteção Ambiental (APA) do Rio Ibirapuitã no bioma Pampa, Brasil, e seu impacto na dinâmica econômica da região. A análise teve caráter descritivo com abordagem quantitativa. Metodologicamente, construímos um banco de dados com variáveis macroeconômicas e de produção agrícola dos quatro municípios que compõem a APA do Rio Ibirapuitã, incluindo imagens de sensoriamento remoto para avaliar a mudança no uso da terra entre 2000 e 2020. Além disso, modelos de regressão foram utilizados para determinar as tendências de crescimento da produção agrícola e analisar o impacto da mudança do uso da terra na dinâmica econômica do território. Os resultados indicaram uma mudança no uso da terra na APA, resultante da transformação de pastagens naturais em sistemas de produção de grãos. A produção baseada na rentabilidade é um dos principais fatores de mudança no uso da terra. A expansão da produção de soja impactou positivamente as variáveis econômicas do território. No entanto, essa APA foi essencial para garantir o uso sustentável do território nesse período, mantendo as áreas de pastagens naturais no bioma. Portanto, é necessário desenvolver uma política pública representativa para o bioma Pampa que ofereça incentivos e estimule a conservação dos serviços ecossistêmicos na exploração agropecuária.

Palavras-chave: Conservação ambiental. Produção agropecuária. Renda agrícola. Uso da terra.

Introduction

Acca sellowiana (O. The conservation is essential for the maintenance of agricultural production and the global regulation of biological cycles (T. E. de Oliveira et al., 2017a). Protected areas have been incorporated to protect ecosystems, which are constantly transformed due mainly to land-use change linked to increasing agricultural production systems (U. Oliveira et al., 2017b; International Union for Conservation of Nature's [IUCN], 2010). The units are defined according to the International Union for Conservation of Nature's -IUCN, maintained according to the Laws of each country, and assume the role of conserving biodiversity and maintaining sustainable meat production amidst the intensification of production segments and expansion of production areas of agriculture (IUCN, 2010, 2013; Bryan et al., 2009).

In recent decades, significant changes have contributed to the expansion of grain production systems, especially in Brazil, which has 60% of its vegetation remaining with several species and ecosystems in its territory (Costa et al., 2018). These changes are associated with technological gains in several areas, such as infrastructure, machinery and equipment, management techniques, and biochemical technologies for crop adaptations (Costa et al., 2018). One of the most notable changes was the incorporation of grain production, mainly soybean cultivation, in areas of the Brazilian Pampa biome (Silveira et al., 2017).

The Pampa is a biome composed of natural pastures with significant biodiversity, located in Argentina, Uruguay, and Brazil, with an area of approximately 750,000 km² (Boldrini, 2009). It is recognized for its abundance of water, vegetation, and soil, containing about 3,000 species of plants, including legumes

and grasses, in addition to several species of birds and terrestrial animals (Andrade et al., 2018) Moreover, the Pampa houses most of the Guarani aquifer, it is a natural, genetic, and cultural heritage of national and global importance (Andrade et al., 2018; Ministério do Meio Ambiente [MMA], 2021).

In Brazil, the Pampa biome is located entirely in the Rio Grande do Sul, occupying 63% of the state's territory (Silveira et al., 2017; MMA, 2021). However, in the last 20 years, approximately 50% of the natural vegetation of the biome has been transformed into agricultural land (Le Féon et al., 2016). This transformation occurred due to natural pastures being considered less profitable, and they did not contribute significantly to the economic development of the region (Viana et al., 2021a). Thus, the incorporation of grains associated with intensive livestock farming in these regions was associated with high profitability and the development of the economy of southern Brazil (Viana et al., 2021a).

The maintenance of conservation units is a possible way to conserve the biome. However, only 0.5% of the Brazilian Pampa biome area is included in a conservation unit, namely, the Environmental Protection Area (EPA) of the Ibirapuitã (MMA, 2021; Overbeck et al., 2007). The EPA of the Ibirapuitã is a federal conservation unit of sustainable use as classified by the IUCN and maintained by the governmental legislation of Brazil (IUCN, 2010; Conselho da Área de Proteção Ambiental do Ibirapuitã [CONAPA], 2012). It is an area composed of unmodified ecosystems, which are managed to maintain biodiversity protected in the long term and provide products in a sustainable way to society (CONAPA, 2012).

The EPA of the Ibirapuitã is in the southern half of the state of Rio Grande do Sul, Brazil, in the municipalities of Alegrete, Quaraí, Rosário do Sul, and Santana do Livramento (Alonso et al., 1994). In the municipalities that are part of the EPA of the Ibirapuitã, beef cattle have historical importance. It varies according to the size of the farms and the characteristics of the landscape typical for cattle raising. Beef cattle and sheep farming are the traditional economic activities of the fields comprised of the Brazilian Pampa biome, and these activities were the main form of economic exploitation in the region for more than 200 years (Gonçalves, 1999; Miguel et al., 2017). The coexistence of livestock production and the ecosystems, when managed well, is one of the few world examples of economically viable and sustainable activity in terms of territorial conservation of biological and social diversity (Crawshaw et al., 2007).

The municipalities of Alegrete and Santana do Livramento hold the two largest herds in the Rio Grande do Sul. Conversely, they have the potential to produce grains, such as rice and soybeans, the latter with significant growth in areas planted in recent years. Rice and soybean have become the main crops of agricultural production, transforming traditional natural pasture areas into crops and resulting in a change in land use (Silveira et al., 2017; T. E. de Oliveira et al., 2017a; Kuplich et al, 2018; Mengue et al., 2020). Martinelli et al. (2017), when analyzing the expansion of soybean production in Brazil, detected that it is not yet defined whether soy production only drives economic growth or contributes to socioeconomic development, promoting improvements in education and health in the Brazilian municipalities where it is cultivated.

Thus, there are intertemporal trade-offs, considering the short, medium and long term, resulting in a impasse between environmental preservation and economic growth, involving multiple stakeholders. On the one hand, the grasslands of the Pampa biome participate in essential ecological processes, such as water cycle maintenance, erosion control, and biodiversity conservation (Viana et al., 2021a). On the other hand, extensive production systems are associated with the low economic development of the municipalities in this region (Viana et al., 2021b).

Therefore, in addition to ecosystemic and environmental aspects, it is essential to analyze the impact of land-use change on the economic dynamics of the only conservation unit of the Pampa biome in Brazil: the EPA of the Ibirapuitã. In this regard, the following questions are raised: to what extent change in land use has changed the productive dynamic of the EPA of the Ibirapuitã and the areas adjacent to the conservation unit? Have these changes economically impacted the conservation unit? Therefore, this study aims to understand the relationship between environmental preservation in protected areas and economic growth, especially by quantifying the economic impact of land-use change on the production segments of goods and services of the economy of EPA of the Ibirapuitã.

In Brazil, the production segments together form the synthesis of the economy and help to understand the economic dynamics at both the national and municipal levels, but do not express factors such as income distribution, quality of life, education, and health (Instituto Brasileiro de Geografia e Estatística [IBGE], 2021a). Thus, changing land use would be a way to reverse the low economic development. However, the Pampa is one of the Brazilian biomes with the lowest geographic coverage by conservation units, and farms assume the primary responsibility for its environmental preservation in the region (U. Oliveira et al., 2017b; MMA, 2021). Therefore, the analysis of the relationship between land use and economic growth can contribute to the development of public policies, especially considering that conservation units replicate the growth conditions of agricultural production systems in the face of the global economic scenario.

Materials and Methods

The study site was the EPA of the Ibirapuitã (Figure 1). The municipalities of Quaraí, Alegrete, Santana do Livramento, and Rosário do Sul form this EPA Territory totaling an area of 22,271.70 km². The EPA of the Ibirapuitã corresponds to 3,167.9 km² of this EPA Territory and is the only conservation unit in the Brazilian Pampa biome (MMA, 2021).

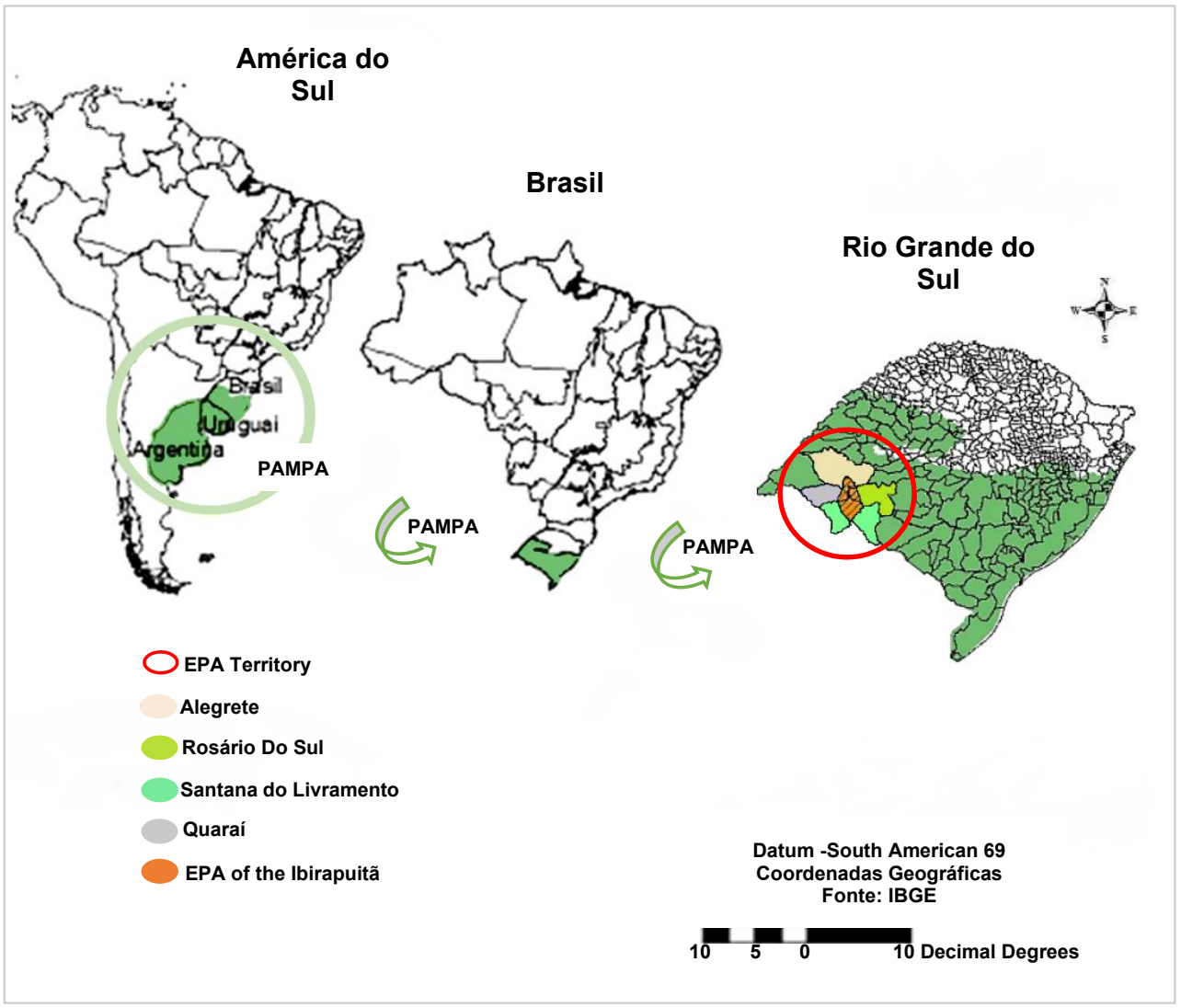

Figure 1. Location of the Pampa biome and the EPA of the Ibirapuitã - study region.
Source: Adapted from Azevedo (2013).

The analysis of change in land use and its economic impact on the study region had a descriptive character, with a quantitative approach, and used a secondary data collection method. A database was built from open-access macroeconomic information and information on agricultural production from the four municipalities that composed the EPA Territory (Table 1). The period considered for data collection was between 2000 and 2020, which was the period marked by the main changes in land use in the Brazilian Pampa (Silveira et al., 2017; Boldrini, 2009).

Table 1
Macroeconomic and agricultural variables

Agricultural Variables	Unit	Source	Period
Cattle herd (CH)	Number of animals	IBGE (2020a)	2000 to 2020
Sheep herd (SH)			
Soybean Planted Area (SPA)	Hectares		
Rice Planted Area (RPA)			
Macroeconomic			
Gross Domestic Product (GDP)	x 1,000 dollars (US$)	IBGE (2021b)	2000 to 2018
Gross Value Added - Agriculture (GVAagr)			
Gross Value Added - Industry (GVAind)			
Gross Value Added - Services (GVAser)			

The individual data for each municipality were added together to form a single set of macroeconomic and agricultural production variables for determining the economic dynamics of the EPA Territory Thus, the change in land use was assessed by the evolution of the cattle and sheep herd variables (traditional activities of the Brazilian Pampa biome) and the planted areas composed of rice, soybean, and temporary crops (in hectares; agricultural activities introduced in the biome). The monetary data of the macroeconomic variables were transformed from reais (R$) to US dollars (US$) according to the annual average of the nominal exchange rate (Instituto de Pesquisa Econômica Aplicada [IPEA], 2022) to update data and compare between the variables that involve international commodities. Macroeconomic variables express the state of the economic system of a given region or country (Gujarati, 2006; Dassow et al., 2011). These variables are represented in this study by the Gross Domestic Product, which is an indicator of economic growth of all segments of production of goods and services at the municipal or national level, as well as of the three main economic sectors in Brazil: Industry, Services, and Agriculture represented by the Gross Value Added (Dassow et al., 2011; IBGE, 2021b).

A geometric growth rate estimated from a log-linear regression model (ln), as specified in Equation 1, was used to analyze the trend and growth behavior of agricultural production variables between 2000 and 2020 (Gujarati, 2006).

$$ln\, Y_i = \alpha + \beta t_i + \varepsilon \quad (1)$$

where $ln\ Y_i$ is the natural logarithm of the agricultural variable in period *i*; α is the regression constant or intercept; β is the slope of the regression trend; t_i is the value of the time variable in period *i*; ε is the random error term, under classical statistical assumptions; (with 21 observations and 20 degrees of freedom).

The geometric growth rate *"r"* of the historical series was determined by calculating the antilogarithm of the regression trend coefficient "b" using the base *"e"* natural logarithm, according to Equation 2 (Gujarati & Porter, 2011).

$$r = \left[(e)^{\beta}\right] - 1 \quad (2)$$

The geometric growth rate allowed us to identify the annual growth of cattle herd variables and rice and soybean planted area in the EPA Territory of the Ibirapuitã River. The evolution of these variables helps to identify the change in land use in the EPA Territory. However, changes in use efficiency and productivity can occur, leading to changes in herd structure without noticeable changes in land use (Varella et al., 2018). This analysis was complemented using remote sensing images from the Annual Land Use and Cover Mapping Project in Brazil-MapBiomas (MapBiomas Brasil [MapBiomas], 2022) to evaluate the change in land use and cover in the EPA of the Ibirapuitã and EPA Territory between 2000 and 2020, analyzing the evolution of the cover with rice and soybean cultivation and agriculture in general. Mapbiomas is an initiative that involves a collaborative network of experts in biomes, land uses, remote sensing, GIS, and computer science, which uses cloud processing and automated classifiers developed and operated from the Google Earth Engine platform to generate a historical series of annual maps of land use and land cover in Brazil (MapBiomas, 2022).

Subsequently, four multiple linear regression models were estimated to identify the impact of change in land use on the economic dynamics of the EPA Territory. The models determined the impact of variations in the cattle herd and rice and soybean planted area on four different macroeconomic variables (MACR), namely: Gross Domestic Product (GDP), Gross Value Added for Agriculture (GVAagr), Gross Value Added for Industry (GVAind), and Gross Value Added for Services (GVAser). The models were estimated by the Ordinary Least Squares Method according to Equation 3:

$$MACR = \alpha + \beta_1 RPA + \beta_2 SPA + \beta_3 CH + \varepsilon \qquad (3)$$

where MACR is the macroeconomic variables of the EPA Territory; α is the constant or intercept; β is the slope; RPA is the rice planted area (in hectares) in the EPA Territory; SPA is the soybean planted area (in hectares) of the EPA Territory; CH is the cattle herd (in the number of animals) of the EPA Territory; (with 19 observations and 15 degrees of freedom).

The validity of the regression models was tested using analysis of variance (ANOVA). The individual significance of the slope was tested using Student's t-test. For both tests, a significance level of 5% was used.

Results and Discussion

The land use and land cover in the EPA Territory for the period from 2000 to 2020, presented in Figure 2, shows the expansion of the area of grain crops over the areas of natural grasslands. This expansion was mainly characterized by the growth of soil cover with soybean cultivation. The agriculture in the EPA Territory expanded in areas where the landscape and soil allowed, mainly the cultivation of grains such as soy and rice.

The EPA of the Ibirapuitã consists of a greater proportion of basaltic rocks, which mainly compose the western half. To a lesser extent, there are sandstones and outcrops in the eastern portion. The predominant soil types are neosol and ultisol, which occupy the natural fields. This can be observed in the EPA of the Ibirapuitã, where agriculture did not expand (Figure 2). Areas traditionally intended for livestock production were replaced by crops, resulting in the growth of areas planted with grains (Table 2).

From 2000 to 2020, the area planted with grain crops showed an annual growth

of 2.77%. This growth was fundamentally due to the expansion of soybean cultivation in the region. In 2000, the soybean planted area in the EPA of the Ibirapuitã was 12,840 ha. In 2020, this area increased to 155,400 ha, an increase of 1,110.28%. In the last two decades, soybean cultivation grew at a rate of 9.69% per year.

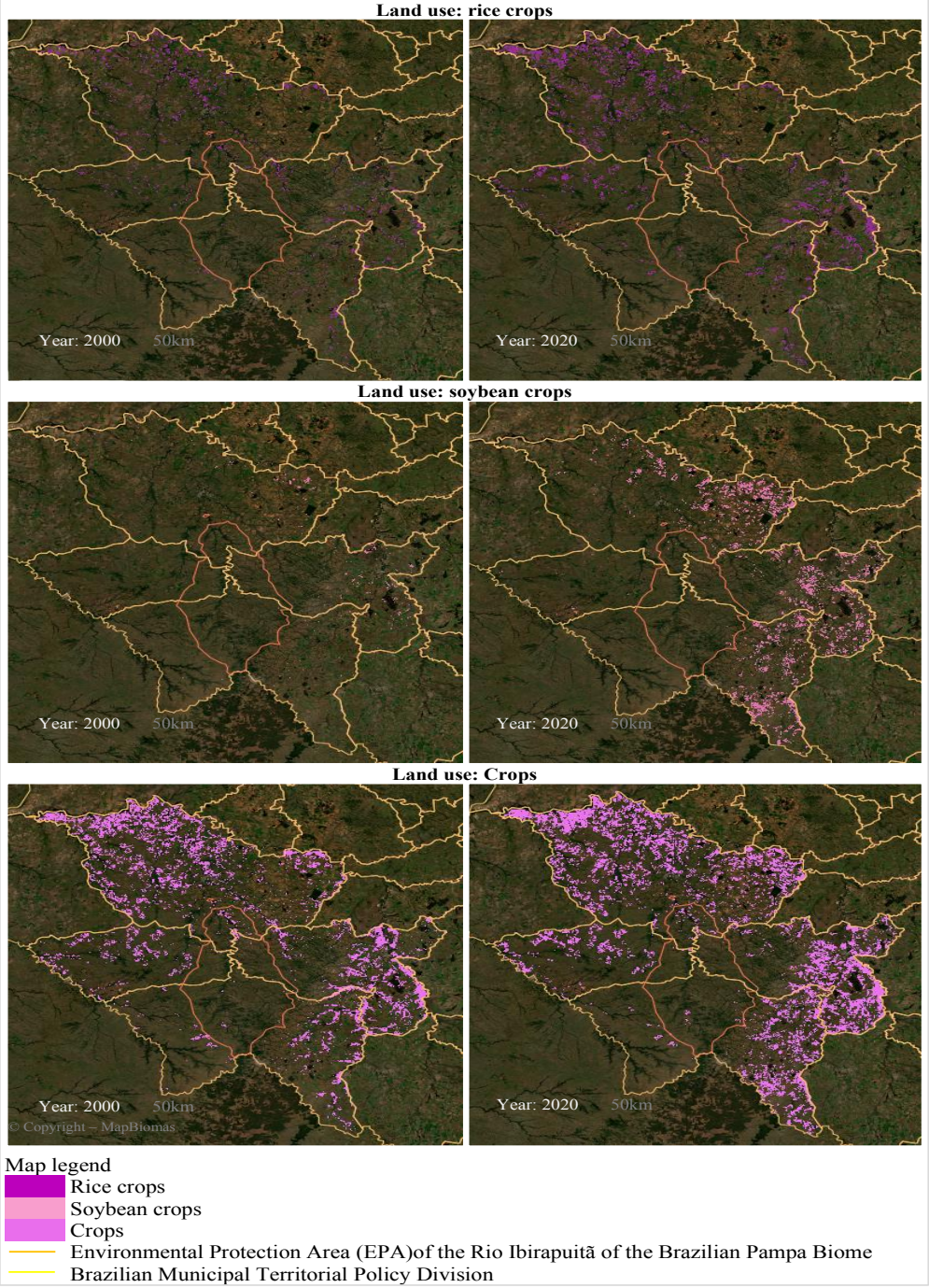

Figure 2. Land use and land cover in the EPA of the Ibirapuitã, Brazil, between 2000 and 2020.
Source: Developed by the authors based on MapBiomas (2022).

Rice cultivation, in turn, remained almost stable. However, it lost participation in the total area of crops in the region. In 2000, rice and soybean cultivation represented 66.5% and 9.8% of the total crop area. In 2020, this share changed, with rice and soybean cultivation representing 33.3% and 58.0% of the crop areas, respectively. Extensive livestock production is predominant in farms located in the EPA of the Ibirapuitã. Cattle farming is the main activity developed, and consequently, the primary income of farmers comes from animal meat.

Table 2
Change in land use in the EPA territory, Brazil, from 2000 to 2020

	Agriculture					
	Planted Area (in hectares)					Growth Rate (% per year)
	2000	2005	2010	2015	2020	2000 - 2020
Rice	86,977	93,935	99,850	101,251	89,170	0.38
Soybean	12,840	68,500	50,000	95,800	155,400	9.69
Crops	130,738	189,856	172,598	210,034	268,087	2.77
	Livestock					
	Herd (in number of animals)					Growth Rate (% per year)
	2000	2005	2010	2015	2020	2000 - 2020
Cattle	1,623,983	1,858,053	1,843,083	1,936,497	1,572,003	0.01
Sheep	1,162,602	923,128	1,000,751	1,028,117	721,995	-1.13

The cattle herd remained stable in the analyzed period. This was possibly due to productivity gains obtained in areas of crop-livestock integration. From 2010 to 2020, the cattle herd in breeding systems in the EPA of the Ibirapuitã increased from 286,706 to 292,162 animals. On the other hand, there was a reduction in the cattle herd in the fattening system from 677,220 animals in 2010 to 449,329 animals in 2020 due to the change in herd structure. Sheep herd, in turn, showed a significant decrease, from 1,162,602 animals in 2000 to 721,995 animals in 2020, a reduction of 37.89% in the period.

The data indicated a significant change in land use starting from the expansion of grain farming areas in the territory of the only conservation unit of the Brazilian Pampa biome, with a substantial increase in the areas of soybean cultivation in the region. This expansion fundamentally occurred in areas of natural fields destined for livestock, which the oscillation can see in the sheep and cattle herd from 2000 to 2020. Table 3 presents the results of the impact of the change in land use agricultural variables on four different economic indicators of the EPA Territory, Brazil. The ANOVA (F-test) indicates

that changes in land use variables impact the economic indicators in the four estimated models (p<0.01). The estimated coefficients of determination (R2), in turn, indicate a high explanation power of the models, with values above 60%.

The analysis of the estimated slopes shows the positive influence of variations in the rice and soybean planted areas on the economic indicators of the EPA Territory (p< 0.05), except for the relationship between RPA and the GAVind. Conversely, there was no significant relationship between the variations of the cattle herd and the economic indicators, except for a negative influence of the herd variations on the Gross Value Added for Industry (GVAind) (p<0.05).

Table 3
Parameters of the estimated regression models for the impact of change in land use on the economic dynamics* of the EPA territory from 2000 to 2018

	GDP		GVAagr		GVAind		GVAser	
	Coef.	p-value	Coef.	p-value	Coef.	p-value	Coef.	p-value
RPA	47.12	0.006	7.38	0.02	4.10	0.093	22.13	0.007
SPA	10.61	0.002	1.65	0.01	2.38	0.000	4.04	0.011
CH	-1.85	0.116	-0.17	0.44	-0.38	0.043	-1.02	0.078
F	12.71	0.000	9.40	0.000	13.81	0.000	8.87	0.000
R2	0.6612		0.6526		0.7342		0.6396	

* Cattle herd (CH), Soybean Planted Area (SPA), Rice Planted Area (RPA), Gross Domestic Product (GDP), Gross Value Added of Agriculture (GVAagr), Gross Value Added of Industry (GVAind), and Gross Value Added of Services (GVAser).

These results indicate that the change in land use, starting from the expansion of farming areas, positively influenced the economic dynamics of the EPA Territory. This relationship can be exemplified by individually analyzing the coefficients of the soybean planted area (SPA) variable; the crop most expanded in the region. Soybean expansion positively influences the four economic indicators studied: each additional hectare in the area planted with soybean results in an increase of US$ 10,610 in the GDP of the EPA Territory (p<0.01), with the other factors remaining constant. When analyzing the economic indicators by economic sector, soybean expansion impacts the indicators of the industry and service sectors considerably, with an increase of US$2,380 in the GAVind and US$4,040 in the GAVserv per additional hectare planted (p<0.05).

However, the expansion of areas cultivated with rice impacts more intensely the economic dynamics of the region compared to the expansion of soybean cultivation; each increase of 1 ha in the rice planted area results in an addition of US$ 47,120 in GDP of the EPA Territory (p<0.01), which is four times higher than the variation of the soybean unit area. This result can be explained by the greater intensity of the use of labor and capital in rice

cultivation compared to soybean cultivation, requiring more inputs and local services. However, this leads to a higher production cost for rice cultivation, which impacts the activity's profitability in the region. This can be confirmed by the data from the National Supply Company of Brazil (Companhia Nacional de Abastecimento [CONAB], 2022) expressed in Table 4.

Table 4
Production cost and estimated profitability of rice and soybean crops in the Rio Grande do Sul, Brazil, in 2021

	Total production cost (US$/hectare)	Productivity (kg/hectare)	Production value (US$/kg)	Gross revenue (US$/hectare)	Profitability (%)
Rice	1,634.77	8,000	0.304	2,435.68	49,0
Soybean	577.71	2,700	0.474	1,278.84	121,4

Source: Estimated profitability from CONAB (2022) production cost data and EMATER (Instituto de Assistência Técnica e Extensão Rural [EMATER], 2022) production cost for March 2021. Values are in US dollar by IPEA (2022).

Although higher productivity and revenue per hectare were observed in rice cultivation, the return on invested capital was higher in soybean cultivation. Thus, despite rice cultivation having a more significant impact on macroeconomic indicators (Table 3), soybean cultivation expanded more than rice cultivation because it fundamentally promotes higher profitability per hectare to the farmer (Table 4). These data help to explain the crop growth rates obtained in Table 2.

The economic impact of land-use change analysis identified that between 2000 and 2020, the EPA of the Ibirapuitã guaranteed the sustainable use of the Pampa biome (Figure 2). However, external global economic factors have encouraged the implementation of production systems with higher profitability that favor the growth of grain agriculture, especially soybean. The agricultural and livestock indicators (Table 2) explained how land-use change altered the productive dynamics of the EPA of the Ibirapuitã River, together with its adjacent areas (EPA Territory). In the same way, the macroeconomic indicators (Table 3) showed that land-use change (Table 2) had an economic impact on the territory of the protected area.

In the context of the EPA Territory of the conservation unit of the Brazilian Pampa biome, results indicate that land-use change has generated an economic impact on the territory, although the EPA of the Ibirapuitã has fulfilled its function of sustainable use (IUCN, 2010; Dassow et al., 2011). The data also point to an impasse between economic growth and environmental preservation in the territory of the Ibirapuitã River (Viana et al., 2021a; Gonçalves, 1999; Vargas et al., 2020; Patrick, 2013). Intensive land-use changes have mainly occurred in the past two decades (T. E. de Oliveira et al., 2017a; Kuplich et al., 2018; Perkins & Millington, 2020). The cultivation of grains, mainly rice and soybean,

has replaced areas of natural pasture, leading to changes in vast areas of the biome; these changes reduced the number of wild species of natural native pasture and determined new economic dynamics in the region (Viana et al., 2017).

Soy cultivation has expanded predominantly in pasture areas that were used exclusively for cattle and sheep, which explains the reduction in the number of these animals in the period (Malafaia et al., 2014; Varella et al., 2018). Since 2010, cattle herd structure showed greater reproductive efficiency by focusing on breeding systems, with improved reproductive efficiency, increased birth rates, and decreased time to slaughter (Varella et al., 2018); this helped to keep the total cattle herd stable, even as the herd in fattening systems declined.

However, cattle farming conventionally explored extensively in the EPA Territory does not guarantee an increase in financial profit and economic reproduction for the farmers. Thus, whenever the natural landscape and soil conditions allow it, the areas are transformed into crops because they enable greater profitability of extensive cattle farming (Vargas et al., 2020). According to Vargas et al. (2020) e Viana et al., 2017) livestock production systems, when associated with grain production, present superior profitability results and provide economic growth that can be observed with increasing GDP, which contributes to the intensification of land use in the EPA Territory. Conversely, when animals are reared in natural fields, farmers can promote and maintain biodiversity by conserving natural pastures. This reinforces trade-off between economic growth and environmental preservation. (Bryan et al., 2009; MMA, 2021; Viana et al., 2021b).

Regarding the economic impact, the magnitude of land-use change is related to the search for greater profitability in agriculture, driven by economic factors characterized by the global dynamism of soybean (Silveira et al., 2017; Martinelli et al., 2017). The increase in international grain prices, productivity gains, and the strengthening of credit policies for agricultural production contributed significantly to expanding land cover with soybean cultivation (Martinelli et al., 2017; Von Witzke & Noleppa, 2014).

Therefore, productive systems with greater economic profitability, coming from the expansion of the area planted with soybeans and the dynamism of the rice cultivation system, are associated with the increase in GDP and impact the economic growth of the EPA territory (Von Witzke & Noleppa, 2014; Feix et al., 2016). The results indicate that the provision of services, the supply of inputs, and labor in the region are directed to livestock and grain production. Thus, the intensification of farming systems associated with land-use modification impacts the increase of the territory's GDP (Dassow et al., 2011; Feix et al., 2016). In this context, soybean cultivation resulted in a positive economic impact on GDP. However, rice cultivation promotes greater economic dynamics due to the financial circulation of local processing and transformation (Souza et al., 2017). Thus, when soybean expands over the area planted with rice, the GDP tends to decrease in the territory of the EPA Territory

However, farmers are not only influenced by economic and productive factors but also by non-economic factors, such as habits and patterns of behavior that shape the decisions of individuals (Silva &

Viana, 2020). In this perspective, the greater the search for the preservation of the Pampa biome, represented by the search to strengthen the sustainability, cooperation, and social responsibility of rural organizations, the smaller the expansion of soybean cultivation in these organizations (Silva & Viana, 2020). This scenario led to a restructuring of the local productive space, previously dedicated almost exclusively to beef cattle farming, changing the economic aspects of the region (Kuplich et al., 2018; Viana et al., 2017; Souza et al., 2017; Miguel et al., 2017).

Thus, although the EPA of the Ibirapuitã has fulfilled its role of ensuring the sustainable use of the Pampa biome (IUCN, 2010; MMA, 2021; MapBiomas, 2022), external global economic factors have encouraged the implementation of grain production systems (Von Witzke & Noleppa, 2014). Therefore, a conflict remains in the EPA of the Ibirapuitã: although cattle farming on natural grasslands contributes to the maintenance of the Pampa biome and its essential environmental functions for future generations, it has a low economic impact on the region (Vargas et al., 2020; Viana et al., 2017; Miguel et al., 2017). On the other hand, a significant portion of the biome area is being transformed into agriculture, mainly for soybean cultivation, contributing to the economic growth of the region but resulting in environmental and social impacts on the biome (U. Oliveira et al., 2017b; Silveira et al., 2017; Overbeck et al., 2007). In this perspective, besides economic growth, one of the main challenges of the EPA of the Ibirapuitã is the development of economic and social activities related to the conservation of its natural resources (MMA, 2021; CONAPA, 2012; Vargas et al., 2020; Miguel et al., 2017).

Promoting the sustainability of economic activities in protected areas should be a fundamental principle for decision-makers at local and regional levels for farmers (Viana et al., 2021a; Miguel et al., 2017). Thus, developing representative public policies (Viana et al., 2021b; Silveira et al., 2006) for the EPA territory is the main primaryer native for promoting economic growth together with environmental preservation (Viana et al., 2021b; Silveira et al., 2006; Nascimento et al., 2020).

These policies should provide incentives that stimulate the sustainable use of natural resources, encourage social awareness, and guide the conservation of ecosystem services in agricultural exploitation. Also, the results indicate an opportunity for future research regarding the impact of land-use change on socio-economic development. However, the limitation of data supply in historical series of the public domain at the local and regional level may restrict the analysis scale of social variables.

Conclusions

The results showed that the change in land use is associated with the transformation of natural pastures into grain production systems, initially for rice production and, more recently, for soybean production. Profitability-based production is one of the main factors for change in land use. It is associated with the low economic result of livestock production systems in natural fields compared to grain production, like other regions of the world. Thus, the commodity globalization process influences local development.

Although the EPA of the Ibirapuitã contributes to the conservation of the territory, the intensification, and change in land use are associated with grain production and livestock production in the EPA territory, which encourages the transformation of extensive systems into intensive agricultural production systems. It is necessary to develop a representative public policy for the Ibirapuitã River Environmental Protection Area that offers subsidies and encourages the sustainable use of natural resources, supporting the conservation of ecosystem services in agricultural exploitation. These policies can be a model for similar protected areas in Brazil and worldwide.

Finally, the analysis carried out in this study allowed us to understand the relationship between environmental preservation in protected areas and economic growth, in addition to quantifying the economic impact of land-use change on the productive segments of goods and services in the economy of the EPA of the Ibirapuitã. It is important to discuss in future studies the changes in prices, production costs and productivity over time, structural features that were not considered in the research.

Acknowledgments

The authors acknowledge the CNPq for providing financial support for this study. This research was funded by National Council for Scientific and Technological Development (Conselho Nacional de Desenvolvimento Científico e Tecnológico, CNPq, projects 441428/2017-7 and 428709/2018-4) Brazil.

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