http://dx.doi.org/10.18623/rvd.v23.6806

CONSERVATION UNITS: A VIEWPOINT OF MINAS GERAIS, SOUTHEAST BRAZIL

UNIDADES DE CONSERVAÇÃO: UMA PERSPECTIVA DE MINAS GERAIS, SUDESTE DO BRASIL

Article received on: 1/23/2026
Article accepted on: 4/24/2026

Mariana Aparecida de Freitas Abreu*
*Universidade Federal de Lavras (UFLA), Lavras, Minas Gerais, Brasil
Orcid: https://orcid.org/0000-0001-7545-913X
marianafreitasbio@gmail.com

Eduarda Thaís Goulart Lopes*
*Universidade Federal de Lavras (UFLA), Lavras, Minas Gerais, Brasil
Orcid: https://orcid.org/0009-0006-3179-7843
eduarda.lopes2@estudante.ufla.br

Fausto Weimar Acerbi Junior*
*Universidade Federal de Lavras (UFLA), Lavras, Minas Gerais, Brasil
Orcid: https://orcid.org/0000-0002-9553-0148
fausto@ufla.br

Luís Antônio Coimbra Borges*
*Universidade Federal de Lavras (UFLA), Lavras, Minas Gerais, Brasil
Orcid: https://orcid.org/0000-0003-0344-5008
luis.borges@ufla.br

The authors declare that there is no conflict of interest

Abstract

The inefficiency of national and local public policies has proved to be a serious problem in the management of Conservation Units (CUs) in Brazil. The objective of this study was to evaluate the distribution of CUs, their respective administrative spheres, and categories in three Brazilian biomes: Atlantic Forest, Cerrado, and Caatinga. The methodological procedures adopted consisted of a bibliographic survey and consultation of databases made available by the National Registry of Conservation Units (CNC). The results demonstrate that 66% of the Conservation Units (CUs) created after the enactment of Law 9.985/2000 require land regularization and Management Plans for their protected areas. Our results reinforce the fact that Brazilian Conservation Units (CUs) are neglected in practice, science, and conservation policies, directly harming the ecosystem and Brazilian society that depend on these resources. Therefore, incentives are needed for the creation and implementation of effective public policies for environmental protection and conservation in the state of Minas Gerais.

Resumo

A ineficiência das políticas públicas nacionais e locais tem se mostrado um grave problema na gestão das Unidades de Conservação (UCs) no Brasil. O objetivo deste estudo foi avaliar a distribuição das UCs, suas respectivas esferas administrativas e categorias em três biomas brasileiros: Mata Atlântica, Cerrado e Caatinga. Os procedimentos metodológicos adotados consistiram em uma pesquisa bibliográfica e na consulta de bancos de dados disponibilizados pelo Cadastro Nacional de Unidades de Conservação (CNC). Os resultados demonstram que 66% das Unidades de Conservação (UCs) criadas após a promulgação da Lei 9.985/2000 necessitam de regularização fundiária e de Planos de Manejo para suas áreas protegidas. Nossos resultados reforçam o fato de que as Unidades de Conservação (UCs) brasileiras são negligenciadas na prática, na ciência e nas políticas de conservação, prejudicando diretamente o ecossistema e a sociedade brasileira que dependem desses recursos. Portanto, são necessários incentivos para a criação e implementação de políticas públicas eficazes de proteção e conservação ambiental no estado de Minas Gerais.

Keywords: Protected Areas. Brazilian Biomes. Conservation Unit. Management Plan. Land Regularization.

***Palavras-chave**: Áreas Protegidas. Biomas Brasileiros. Unidade de Conservação. Plano de Manejo. Regularização Fundiária.*

1 INTRODUCTION

Brazil is a diverse country with six biomes (Amazon, Caatinga, Cerrado, Atlantic Forest, Pampa, and Pantanal). However, it faces significant challenges in combating the depletion of its resources, especially non-renewable ones. This study will address the conservation of protected areas, particularly Brazilian conservation units (CUs). In this sense, the depletion of renewable and non-renewable resources present in CUs can become a challenge and generate a global economic collapse due to the increasing demands of agribusiness, mining, and the unchecked exploitation of our natural resources, directly compromising Brazilian sustainability. Unfortunately, in Brazil, negative environmental impacts that become environmental liabilities caused by past and present human actions are recurrent, such as land use associated with agroforestry activities, mining, intervention in water resources, deforestation, and suppression of native vegetation, among others (Lopes *et al*., 2020; Lucas *et al*., 2023; Vieira *et al*., 2023; Parras *et al*., 2024).

Although environmental impacts are the current reality, research carried out in different countries has presented and discussed the importance of preserving territorial spaces and environmental protection of these soils in relation to economic activity, soil degradation, and its relationship with climate change (Alves-Pinto *et al*., 2022; Dou *et al*., 2023; Mamedes *et al*., 2023; Pompeu *et al*., 2023; Fernandes and Reydon, 2024). But how can a country expand and develop while preserving its natural resources?

In this context, conservation units (CUs) are territorial areas protected for the conservation of biodiversity and scenic beauty, which provide ecosystem goods and services to the population, contributing to the reduction of deforestation rates and the provision of environmental services, scientific research studies, environmental education practices, and sustainable tourism (Brasil, 2000; Vieira *et al*., 2022; Soares-Filho *et al*., 2023). In Brazil, the CUs are located in dynamic environments, sometimes with private sector interests in natural resources.

To ensure the sustainable use of protected resources within Conservation Units, it is necessary to consider the benefits for the human populations that depend on them. In this sense, Brazilian legislation establishes that Conservation Units must follow an Integrated Management Plan that includes general conservation objectives and human activities carried out in the area, which must be subject to specific rules and restrictions, with the purpose of minimizing negative impacts on the unit. Therefore, protected areas are essential for the preservation, maintenance, and conservation of the environmental resources of Brazilian territory.

According to Brazilian environmental legislation, Conservation Units (CUs), Permanent Preservation Areas (PPAs), and Legal Reserves (LRs) must be preserved and do not necessarily restrict the direct and/or indirect use of their natural resources, as is the case with Sustainable Use CUs (Brazil, 2000; Brazil, 2012). In this sense, research has shown that there is territorial space for the country's development without the need to advance into protected areas, i.e., it is not necessary to deforest, burn irregularly, or use pesticides and chemicals to guarantee production (Farinha *et al*., 2019; Magalhães *et al*., 2020; Maia *et al*., 2021; Luiz *et al*., 2022; Soares-Filho *et al*., 2023; Onyeaka *et al*., 2024).

The southeast of Brazil has a great diversity of native fauna and flora distributed in three important Brazilian biomes: the Atlantic Forest, Cerrado, and Caatinga, as well as important transition zones between them. This research aims to evaluate the conflicts between economic, social, and environmental interests in the state of Minas Gerais.

This study aims to understand the distribution of CUs in the Atlantic Forest, Cerrado, and Caatinga biomes of Minas Gerais, southeastern Brazil. To this end, the following questions were raised: how many CUs exist and what is their spatial distribution in the state of Minas Gerais? Are CUs an important means for the conservation/restoration of the Atlantic Forest, Cerrado, and Caatinga biomes? To answer these questions, temporal analyses of the creation of CUs and their categories in three Brazilian biomes were carried out, covering the period between 1937 and 2000 and, subsequently, between 2001 and 2023, evaluating the spatial and temporal variability of areas designated as CUs before and after the enactment of Law No. 9,985, of July 18, 2000.

2 MATERIALS AND METHODS

A general assessment of the CUs presents in the Atlantic Forest, Cerrado, and Caatinga biomes was carried out using the databases of the National Registry of Conservation Units (CNUC) and the Ministry of the Environment (MMA), where registers of Brazilian Conservation Units are available (data consolidated on 07/07/2023 CNUC/MMA - https://dados.gov.br/dados/conjuntos-dados/unidadesdeconservacao).

The initial reference period for this study is defined as the first year of establishment of the conservation areas registered in the state of Minas Gerais. The oldest records of conservation areas in the Atlantic Forest (1937), Cerrado (1949), and Caatinga (1950) are all included here. Next, a screening was conducted to obtain information on the categories, administrative levels, and respective year of establishment for each conservation unit up to the year 2023. In one of the analyses, we considered the states that encompass these three biomes mentioned in this study. As a result of this analysis, maps were produced that characterize the CUs of these three Brazilian biomes, including information on their category and year of creation.

The state of Minas Gerais was the second focus of our study. We conducted an analysis of the spatial and temporal distribution of protected areas, comparing existing categories and their respective administrative jurisdictions. We used geospatial data to analyze the establishment of protected areas. A map of protected areas was generated to assess their classification by decade of creation, resulting in 10 classes, beginning in the 1930s and ending in 2023. The classified points for each protected area were overlaid onto the boundaries of the three biomes (Atlantic Forest, Cerrado, and Caatinga) and the state of Minas Gerais, allowing us to visualize the distribution of protected areas within each biome and by period of establishment.

3 RESULTS AND DISCUSSION

3.1 Public policies applied to brazilian conservation units

In Brazil, various legal instruments have been implemented as part of public policies designed to support the sustainable use of areas rich in natural resources.

Environmental compensation in CUs has been one of the initiatives to develop and implement laws designed to encourage public and private landowners to protect these CUs. This action leads to enabling the provision of ecosystem services that minimize the environmental impacts caused by human activities (Bustamante *et al*., 2019).

Deforestation in Brazil associated with the expansion of agriculture has become a conflict over the conservation of forest resources (Batista *et al*., 2026). The protection of native vegetation, Permanent Preservation Areas, and Legal Reserve Areas, as well as forest exploitation, is addressed in national laws that seek to regulate the direct and indirect use of natural resources, taking into account economic interests (Brasil, 1934; 1965; 2012).

Brazil began to highlight the limits of its economic growth in the face of the depletion of nature's resources in 1972, after the United Nations Conference on the Environment in Stockholm. At that time, the need to create protected areas and a single, integrated nationwide system for these areas was noted, thus enhancing the environmental and political agendas in relation to the creation and management of protected areas (Giunchi *et al*., 2023).

Despite this, the Brazilian government was marked by an authoritarian and centralized regime until 1988, when Brazil became a federal republic, which represented an important step in forest conservation policies (Brasil, 1988; de Souza Cunha *et al*., 2016). That said, Brazil began to implement legislation aimed at conservation and protection of CUs area, as well as the regularization of potentially polluting activities.

In 2000, the National System of Nature Conservation Units (SNUC) Law was regulated, Law No. 9.985/2000, which seeks to conserve the areas implemented, manage, and, above all, protect the areas destined for CUs (Brasil, 2000). It is worth noting that, although the law was regulated in 2000, the first area set aside for environmental conservation in Brazil was defined in 1937, in the Itamonte National Park.

An important point to consider is that Law 9.985/2000 divides CUs into two groups: Full Protection Units, which have the objective of preserving nature with only indirect use of its natural resources allowed, and Sustainable Use Units, which aim to make nature conservation compatible with the sustainable use of a portion of its natural resources (Brasil, 2000). Table 1, shows the five categories of Full Protection Conservation Units provided for in Law 9.985/2000.

Table 1. Types of Conservation Unit (CU) categories in the Full Protection group with their respective objectives, owners, visitation and scientific research.

Full Protection Units				
Category	**Objective**	**Owner**	**Visitation**	**Scientific research**
Ecological Station	Nature conservation and scientific research	Public domain[1]	No public visitation[2]	Subject to authorization[3]
Biological Reserve	Full preservation of biota and other natural attributes, without direct human interference or environmental modifications, with the exception of measures to recover altered ecosystems and management actions necessary to recover and preserve the natural balance, biological diversity and natural ecological processes	Public domain[1]	No public visitation[2]	Subject to authorization[3]
National Park	Preservation of natural ecosystems of great ecological importance and scenic beauty, enabling scientific research and the development of environmental education and interpretation activities, recreation in contact with nature and ecological tourism	Public domain[1]	Public visitation allowed[4]	Subject to authorization[3]
Natural Monument	Preserving rare, unique or of great scenic beauty natural sites	May have private properties[5]	Public visitation allowed[4]	Subject to authorization[3]
Wildlife Refuge	Protect natural environments where conditions are ensured for the existence or reproduction of species or communities of local flora and resident or migratory fauna	May have private properties[5]	Public visitation allowed[4]	Subject to authorization[3]

[1] Private areas within its boundaries will be dispossessed.
[2] Except when for educational purposes, in accordance with the unit's Management Plan or specific regulations.
[3] It will depend on prior authorization from the organ responsible for the administration of the unit and is subject to the conditions and restrictions established by the latter, as well as those provided for in regulations.
[4] It is subject to the conditions and restrictions established in the unit's Management Plan, the rules established by the body responsible for its administration and those provided for in regulations.
[5] As long as it is possible to make the unit's objectives compatible with the owners' use of the land and natural resources.

Source: Information according to the text of Law No. 9.985/2000 (Brasil, 2000).

Despite being in the same group of units, the five categories differ in their objectives, properties, and access to the public. We can see that the Ecological Station category has similarities with the Biological Reserve, which refers to possible alterations

to its ecosystem, in accordance with the law. The Sustainable Use Units have seven different categories, as shown in Table 2.

Table 2. Types of Conservation Unit (CU) categories in the Sustainable Use group with their respective objectives, owners, visitation and scientific research.

Sustainable Use Units				
Category	**Objective**	**Owner**	**Visitation**	**Scientific research**
Full Protection Area	Protect biological diversity, regulate the occupation process and ensure the sustainable use of natural resources	May have public or private properties	Public visitation allowed [1,2]	Subject to authorization [1, 2]
Area of Relevant Ecological Interest	Maintain natural ecosystems of regional or local importance and regulate the permissible use of these areas, making them compatible with nature conservation objectives	May have public or private properties	Public visitation allowed [1, 2]	Subject to authorization [1, 2]
National Forest	Sustainable multiple use of forest resources and scientific research, with an emphasis on methods for the sustainable exploitation of native forests	It is in public ownership and domain [3]	Public visitation allowed [4]	Subject to authorization [5]
Extractive Reserve	Protect the livelihoods and culture of these populations, and ensure the sustainable use of the unit's natural resources	It is in public ownership and domain [6]	Public visitation allowed [7]	Subject to authorization [5]
Wildlife reserve	Check the objective in the management plan manual	It is in public ownership and domain [6]	Public visitation allowed [4]	
Sustainable Development Reserve	Ensuring the conditions and means required for the reproduction and exploitation of natural resources by traditional populations.		Public visitation allowed [4]	Allowed and encouraged [5]
Private Natural Heritage Reserve	Conserving biological diversity	Private area	Visitation for tourist, recreational and educational purposes	Allowed and encouraged

[1] The conditions for scientific research and public visitation in areas under public domain will be established by the unit's management body.
[2] In areas under private ownership, it is up to the owner to establish the conditions for research and public visitation, subject to legal requirements and restrictions.
[3] In the case of private areas included in its boundaries, they must be expropriated in accordance with the law.

[4] Subject to the rules established for the management of the unit by the body responsible for its administration.
[5] Subject to the prior authorization of the body responsible for the administration of the unit, the conditions and restrictions established by it and those provided by regulations.
[6] With use granted to traditional extractivist populations in accordance with the provisions of art. 23 of this Law and specific regulations, and the private areas included in its boundaries must be expropriated, in accordance with the law.
[7]As long as it is compatible with local interests and in accordance with the provisions of the area's Management Plan.

Source: Information according to the text of Law No. 9.985/2000 (Brasil, 2000).

In addition to their various purposes, these areas can be used for visits and scientific research. However, their natural resources must be used sustainably.

Since the enactment of the law establishing the National System of Nature Conservation Units (SNUC), which sets forth criteria and standards for the creation, implementation, and management of CUs, there has been a significant increase in the creation of protected areas in Brazil. However, their distribution is not uniform but marked by differences across Brazilian biomes and states, which explains why private properties exhibit higher deforestation rates in the Atlantic Forest and Cerrado biomes (Vieira *et al*., 2019; Da Silva *et al*., 2023a). When assessing the conservation of an area, we must consider not only forest resources but all ecosystem services present in the area.

Currently, protected areas have common objectives in national and international efforts to conserve biodiversity, since they guarantee habitat for species at risk of extinction, preserve threatened ecosystems, provide maintenance and environmental services, allow research and development of strategies to control climate change, and encourage sustainable forms of exploitation of natural resources (Brasília, 2014; Oliveira *et al*., 2021; Bradbury *et al*., 2023). The individual land regularization process, which carries out the indemnification of improvements and expropriation of rural properties located in federal CUs in the public domain, is regulated by ICMBIO Normative Instruction No. 02/2009 (Brasil, 2009). Therefore, the categories of CUs should be chosen according to the intended objectives and the ecosystem to be protected.

In this regard, the creation of protected areas can only achieve its conservation objectives if management restrictions and rules are effectively enforced within the respective protected area (Brazil, 2017). Specific land-use planning is essential at the time of establishing each protected area to prevent the development of activities incompatible with the objectives of the protected area and its respective Management Plan (Brasília,

2018). Consequently, Brazil must be cautious, enacting legislation that goes beyond mere formalities but ensures the implementation, management, protection, and preservation of protected areas. Therefore, Brazilian laws are not just strategic numbers that go into making each protected area; they also show a commitment to protecting, conserving, and preserving Brazil's biodiversity.

3.2 Where are Brazil's protected areas located?

Known worldwide as Nature Conservation Units, Protected Areas (PAs) are special territories that are fundamental for biodiversity conservation. Brazil is one of the largest centers of biodiversity and ecosystem services in the world (Guerra *et al*., 2020). Therefore, preserving its environmental resources is essential for fauna, flora, and human life.

These places are divided into two groups: the Strict Protection (SP) group and the Sustainable Use (SU) group. This is because they are managed differently. Thus, in FP-CU areas, the objective is to keep ecosystems free from changes caused by human interference and to ensure greater preservation of nature. Indirect use of natural resources is permitted in FP areas, while in SU areas the goal is to reconcile nature conservation with the sustainable use of natural resources.

We can see that, as of July 2023, 1,186 sites had been designated as Private Natural Heritage Reserves (RPHN), managed by the federal and state governments, followed by 545 national, state, and municipal natural parks; 441 sites designated as Environmental Protection Areas (EPA); 108 national, state, and municipal forest units; 104 ecological and forest station units; 98 Wildlife Refuge units; 96 Extractive Reserve units; 87 Areas of Relevant Ecological Interest; 81 Natural Monuments; 67 Biological Reserves; and 46 Sustainable Development Reserves (Table 3). When looking at data on Brazilian protected areas, it's important to note that only 895 of them are classified as Strict Protection areas and 1,694 as Sustainable Use areas. Only 1,396 of these areas have a Management Plan (Brazil, 2024a).

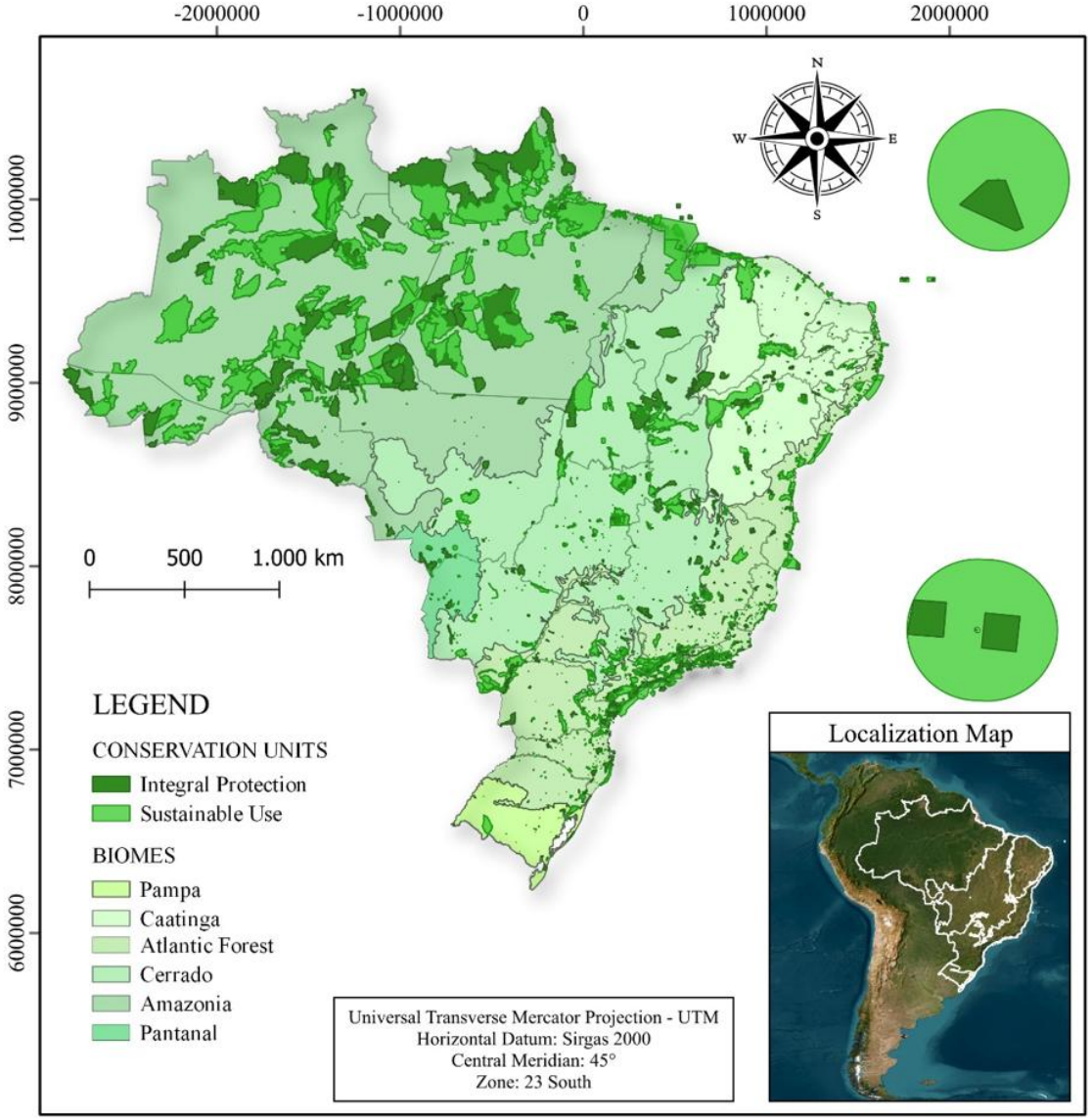
Table 3. Consolidated presentation of the Federal, State and Municipal Conservation Units (CUs) in Brazil.

Group/ Category	**Scope**						**TOTAL**	
	Federal		**State**		**Municipal**			
Integral Protection	**N°**	**Area (Km²)**	**N°**	**Area (Km²)**	**N°**	**Area (Km²)**	**N°**	**Area (Km²)**
Ecological Station	30	72.085	63	49.976	11	49	104	122.109
Natural Monument	5	115.316	37	1.214	39	282	81	116.812
National/State/Municipal Park	75	268.648	231	97.262	239	932	545	366.843
Wildlife Refuge	9	2.982	61	3.682	28	410	98	7.074
Biological Reserve	31	42.683	27	13.525	9	52	67	56.259
Total Integral Protection	**150**	**501.715**	**419**	**165.659**	**326**	**1.725**	**895**	**669.098**
Sustainable Use	**N°**	**Area (Km²)**	**N°**	**Area (Km²)**	**N°**	**Area (Km²)**	**N°**	**Area (Km²)**
National/State/Municipal Forest	67	178.193	41	135.863	0	0	108	314.056
Extractive Reserve	66	135.122	29	21.126	1	682	96	156.930
Sustainable Development Reserve	2	1.026	39	135.026	5	171	46	136.223
Fauna Reserve	0	0	0	0	0	0	0	0
Environmental Protection Area	37	896.900	205	329.692	199	72.870	441	1.299.462
Relevant Ecological Interest	13	342	32	626	42	287	87	1.256
Private Natural Heritage Reserve	752	4.928	431	1.285	3	0	1186	6.213
Total Sustainable Use	**937**	**1.216.512**	**777**	**623.617**	**250**	**74.011**	**1964**	**1.914.140**
Overall Total	**1087**	**1.718.227**	**1196**	**789.276**	**576**	**75.735**	**2859**	**2.583.238**
Total Considering Mapped Overlap	**1087**	**1.712.943**	**1196**	**782.634**	**576**	**75.617**	**2859**	**2.536.593**

[1]the areas of overlap considered were obtained from the files with spatial data registered and validated at CNUC/MMA - Information updated on 07/07/2023.

Brazil's environmental conservation units have a spatial distribution that is not necessarily associated with their biome but rather with their territorial space, the purpose that their area can serve, and their respective objectives. The creation and implementation of the CU aims to preserve the environment and its biodiversity, minimizing the environmental, economic, and social impacts in their areas of coverage (Cardoso *et al*., 2023). Table 3 shows that, in Brazil, SP-CUs not only have a lower number but also a smaller territorial area than Sustainable Use Areas. It is therefore necessary to evaluate, map, and implement the creation of SP-CUs in Brazil. In Figure 1, SP-CUs stand out in the Amazon biome, covering 7.4% of its territory. In addition, SP-CUs cover 2% of the Cerrado biome, 1.9% of the Caatinga biome, 1.1% of the Atlantic Forest biome, 1.0% of the Pantanal biome, and 0.3% of the Pampa biome.

Figure 1. Distribution of Federal, State and Municipal Conservation Units in Brazilian biomes.



According to the National Register of Conservation Units (NRCU), the distribution of SP-CUs and SU-CUs corresponds to 28.41% of the Amazon biome, 10.38% of the Atlantic Forest biome, 9.16% of the Caatinga biome, 8.62% of the Cerrado biome, 4.98% of the Pantanal and 2.95% of the Pampa biome, as shown in Table 4. Brazil has therefore not yet achieved Objective 11 of the Aichi Target, nor Objective 15.1.br (Brasil, 2013; Brasil, 2019), which aimed to preserve and conserve at least 30% of the Amazon and 17% of each of the other terrestrial biomes by 2020. Thus, the current percentage of conservation is lower than the Aichi targets.

Table 4. Distribution of Full Protection Conservation Units (FP-CUs) and Sustainable Use Conservation Units (FP-SUs) in the Amazon, Caatinga, Cerrado, Atlantic Forest, Pampa, and Pantanal biomes.

CU area (considering overlaps) [1]	**Amazon**		**Caatinga**		**Cerrado**		**Atlantic Forest**		**Pampa**		**Pantanal**	
	Area (Km²)	%	Area (Km²)	%	Area (Km²)	%	Area (Km²)	%	Area (Km²)	%	Area (Km²)	%
Full Protection (FP)	418.91	9.94	20.32	2.36	51.42	2.59	22.67	2.05	1.05	0.54	4.33	2.87
Sustainable Use (SU)	764.38	18.13	57.550	6.67	115.05	5.80	85.44	7.72	4.49	2.32	2.67	1.77
FP and SU overlap	14.44	0.34	1.134	0.13	4.51	0.23	6.81	0.62	168	0.09	64	0.04
Total UCs in the biome	1197.74	28.41	79.012	9.16	170.98	8.62	114.93	10.38	5.71	2.95	7.07	4.68

[1]the areas of overlap considered were obtained from the files with spatial data registered and validated at CNUC/MMA - Information updated on 07/07/2023.

It should be noted that the area covered by Brazilian protected areas (Table 4), distributed by biome, is very similar to the study by Pacheco *et al*. (2018), in which the authors pointed out that Brazil's conservation values for protected areas were lower than those proposed by the Convention on Biological Diversity (CBD) in the Strategic Plan for Biodiversity 2011-2020. It is important to note that the Brazilian government's objective with the CBD was to preserve and conserve 30% of the Amazon, 17% of each of the other terrestrial biomes, and 10% of marine and coastal areas, mainly areas of special importance for biodiversity and ecosystem services (CDB, 2011; Brasil, 2013; Pacheco *et al*., 2018; Brasil, 2023; Brasil, 2024a; Brasil, 2024b).

In the midst of the interest in preserving and conserving Brazilian territory, there are economic interests. Brazilian land use is characterized by pastures, agriculture, mining, and planted forests, which represent the largest class of private rural properties in the Amazon, Cerrado, and Atlantic Forest biomes (Da Silva *et al*., 2023b; Moura *et al*., 2024).

In Brazil, priority areas for conservation account for 57% (194 million hectares) of the country’s total land area and are legally protected by the Brazilian network of protected areas (Ramos *et al*., 2023). However, according to that the authors, 10.2 million hectares (6.9%) had already experienced some degree of human impact by 2020. In the major Brazilian biomes, the level of anthropization of priority areas for conservation is 12.3% in the Cerrado, 3.3% in the Amazon, 35.7% in the Atlantic Forest, and 10.4% in the Caatinga. The results show that, in a projection for the 2020-2050 periods, the effects

of climate change on the expansion of Brazilian agriculture indicate major losses of native vegetation (Ramos *et al*., 2023). In this sense, the authors suggest that preservation policies in Brazil should be designed at the biome level to increase the effectiveness of their scope.

When deforestation takes place within CU areas, their conservation can be greatly jeopardized (Buchadas *et al*., 2023). Among the Brazilian Biomes, we can see that the Amazon is the biome closest to conservation, since 28.41% of its area is destined for SP-CUs. However, careful management of these areas is needed to stop fires, deforestation, and illegal mining, which is a challenge because they are part of the economic interests of the region covered by this biome.

Another Brazilian biodiversity *hotspot* is the Atlantic Forest biome. However, deforestation is a reality in this biome (Rezende *et al*., 2018). Researchers assessed that the number of fires recorded between 2001 and 2020 amounted to approximately 9450 km² in the Atlantic Forest biome (Benfica *et al*., 2023). The territorial extension of the CU areas in the Atlantic Forest biome is around 108.19 km², of which 9.77% are considered to be FP areas (2.05%) and SU areas (7.72%). However, economic activities such as mining, agriculture, livestock farming, and industry can directly and indirectly encourage interventions in areas destined for the conservation of this biome.

In the Pampa, Cerrado and Caatinga biomes, there are also economic activities that can conflict with areas of conservation interest. Between 2001 and 2020, around 210000 km² in the Cerrado biome were burned (Benfica *et al*., 2023). The intense environmental degradation and consequent loss of biodiversity are due to urban expansion, livestock activities (which help to replace native vegetation with exotic crops), and the intensification of agriculture, which requires an increase in water consumption (Ferreira *et al*., 2020; Jardim *et al*., 2022; Santos *et al*., 2022).

The expansion of agricultural activities associated with livestock and crops, such as soybeans, and eucalyptus forests, has contributed to changes in the hydrological cycle and increased deforestation of native areas due to changes in land use and occupation, leading to the registration of around 420000 km² burned in the last twenty years (Queiroz *et al*., 2021; Da Silva *et al*., 2023; Maia *et al*., 2021; Ribeiro *et al*., 2023). These changes severely compromise natural resources and environmental sustainability, favoring reduced rainfall and intensified drought events, which makes the Caatinga biome the most

threatened and susceptible to desertification in Brazil (Marengo *et al*., 2017; Costa *et al*., 2020; De Moraes *et al*., 2023).

Therefore, CU areas are fundamental for the conservation and variability of biodiversity, and should be considered when planning the conservation of Brazilian biomes (Brasil-Godinho *et al*., 2024). Brazil needs to stop neglecting the fulfillment of conservation goals for these areas, which can compromise and generate environmental, social, and economic impacts.

3.3 Geographical distribution and temporal analysis of environmental conservation units in the state of Minas Gerais

Located in the southeastern region of Brazil, the state of Minas Gerais has been marked by mining since the 16th century. However, the state of Minas Gerais has become known for the biggest environmental tragedies in Brazilian history, recorded by the collapse of mining dams in 2015 and 2019. In both cases, millions of cubic meters of iron ore tailings flooded communities, crops, and waterways and even caused deaths, highlighting the environmental, social, and economic impacts of mining (Minas Gerais, 2020; Minas Gerais, 2024a).

The state of Minas Gerais has three Brazilian biomes of great environmental importance. In the Atlantic Forest Biome, it is estimated that the territorial area of 4.088,747 ha corresponds to CUs. This territorial area reflects the location of the 331 CUs located in Minas Gerais. Among the CU areas, 63.44% are allocated to the Sustainable Use Group and 36.56% to the Full Protection Group. That said, the percentage of protected areas in the state of Minas Gerais is 6.7% in the Atlantic Forest Biome, which represents 194 CUs, 6.3% in the Cerrado Biome, equivalent to 127 CUs, and 8.5% in the Caatinga Biome, which corresponds to 14 CUs. It is important to note that these values correspond to the CUs located in the federation of Minas Gerais. The values of areas that overlap the federations that share CU areas between the other Brazilian states (Rio de Janeiro and São Paulo) are not included in these data. Therefore, the study area for this topic focused on the state of Minas Gerais to assess the distribution of UCs-SP and UCs-SU in the Atlantic Forest, Cerrado, and Caatinga biomes, as shown in Figure 2.

Figure 2. Location of the Full Protection Conservation Units (FP-CUs) and Sustainable Use Conservation Units (SU-CUs) located in the Atlantic Forest, Cerrado and Caatinga Biomes in the state of Minas Gerais.

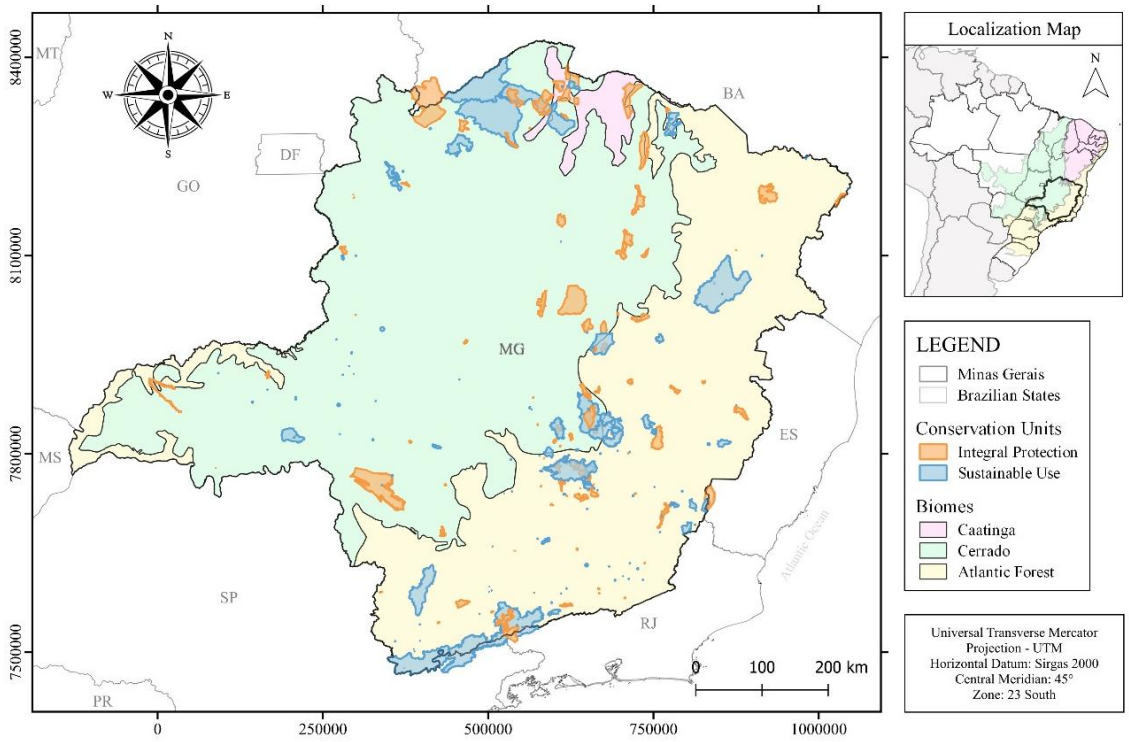
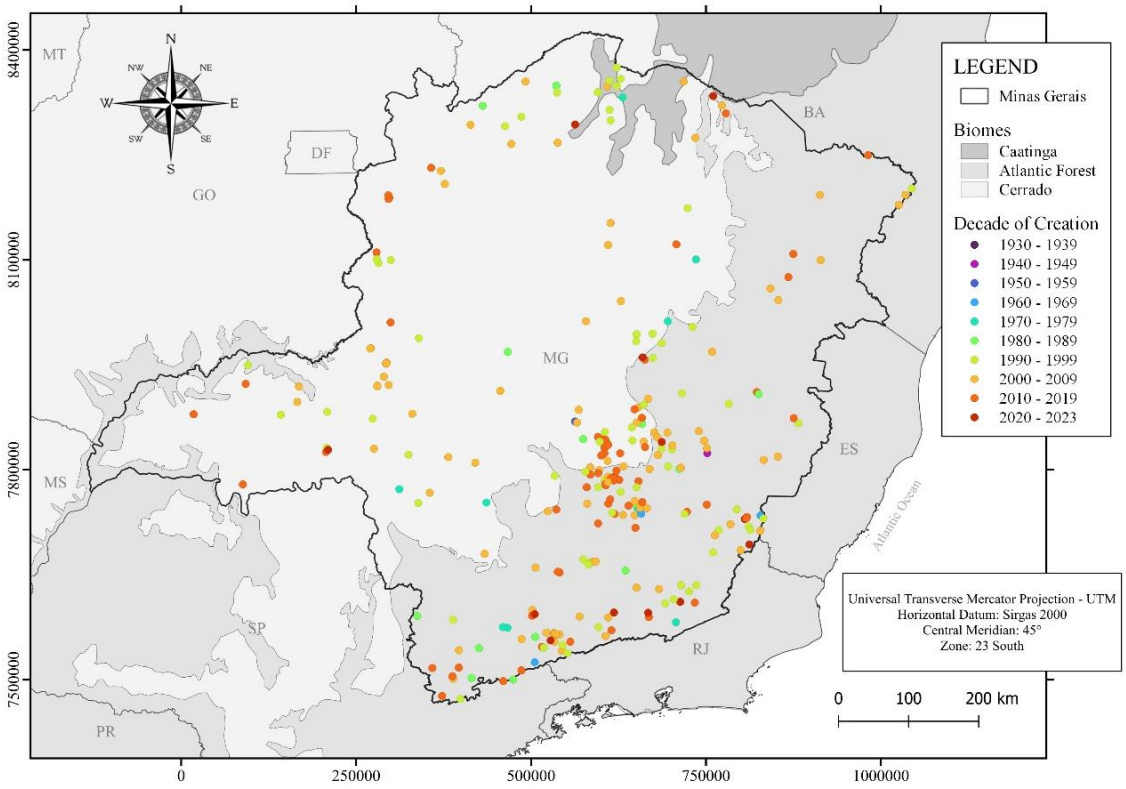


Figure 3 shows the distribution of CUs according to the decades in which they were created in the state of Minas Gerais. If we look at the distribution between 1937 and 1999, 114 CUs were created in the state of Minas Gerais, which shares its territorial areas with Rio de Janeiro and São Paulo. The SNUC Law was regulated in 2000, and since then, considering the period from 2000 to 2023, 217 CUs have been created in Minas Gerais, distributed between the Atlantic Forest, Caatinga and Cerrado biomes.

Figure 3. Distribution of Environmental Conservation Units in the state of Minas Gerais in the Atlantic Forest, Caatinga and Cerrado Biomes.



Covering the municipalities of Itatiaia, Resende (both in the state of Rio de Janeiro), Itamonte, and Bocaina de Minas (both in the state of Minas Gerais), the first National Park established in Brazil was created in 1937 (Brasil, 1937). The first CU located territorially only in the state of Minas Gerais was created on July 14, 1944. Since then, the Conservation areas in this Federation have been marked by the creation of areas distributed between the Sustainable Use group (210 CUs) and the Full Protection areas (121 CUs). Of these CU areas, 45.76% are administered by the state, 33.03% by federal agencies, and 21.21% by municipal entities.

The creation of protected areas is often considered a "barrier" to the practice of economic activities, which means that for years countries like Brazil have not bothered to dedicate space to conserving and preserving their biodiversity (Almeida *et al*., 2022). However, the consequences of failing to establish areas to preserve biodiversity are increasingly reflected in everyday catastrophic events, changes in land use, climate change, and the invasion of exotic species.

The procrastination of the Brazilian state is clear when we look at the negotiations and measures taken by other countries seeking to preserve their natural resources. In the United States, Yellowstone National Park was first created in 1982, which led to the creation of The National Park Service (NPS) in 1916 with the mission of preserving intact the natural and cultural resources and values of the National Park System for the enjoyment and education of future generations (USA, 2024).

The world's second national park was created in 1879 in Australia, known as the Royal National Park, south of Sydney. Today, Australia has 500 national parks covering 28 million hectares (Australia, 2024). In 1885, Banff National Park was created in Canada (Canada, 2023). New Zealand created its first park in 1894, Tongariro National Park, which is a UNESCO World Heritage Site (New Zealand, 2024). In 1924, South Africa passed the National Parks Act and created Kruger National Park (Africa, 2024). However, it was only in 1937 that Brazil registered the Itatiaia National Park, which became the first Brazilian national park (Brasil, 1937).

In this study, we sought to present the distribution and occurrences of records from the CUs located in the state of Minas Gerais, in southeastern Brazil. The first State Park registered in Minas Gerais was in 1944, and the state currently has 329 CUs in its territory. In Table 5, we can see that of the 112 CUs created between 1944-1999, 73% of these units have a Management Plan and 27% have not yet regularized the Management Plans for their areas. In contrast, between 2000 and 2023, 217 CUs were created in the state, 53% of which have a Management Plan. These figures are concerning for the reality of the state of Minas Gerais. Since the expectation was that all protected areas created after the year 2000 would have their respective Management Plans in effect, given that the legislation stipulates that all protected areas must have a Management Plan covering not only the protected area itself, but also its buffer zone (BZ) and potential ecological corridors.

Table 5. Conservation Units (CUs) created in the state of Minas Gerais between 1944 and 2023, and their adherence to the Management Plan.

Year of creation	Number of CUs	Total Area (ha)	No Management Plan	Has a Management Plan
1944	1	35947	-	1
1950	1	203	1	-
1967	1	5996	-	1
1968	1	335	-	1
1972	1	197975	-	1
1973	1	6351	1	-
1974	5	6026	2	3
1978	1	371	1	-
1980	3	2544	-	3
1984	3	32214	-	3
1987	2	1740	1	1
1988	2	298	-	2
1989	3	158700	3	-
1990	5	177136	2	3
1991	1	35	-	1
1992	3	2638	-	3
1993	4	12563	-	4
1994	8	211171	1	7
1995	6	399660	-	6
1996	1	14970	-	1
1997	14	183752	1	13
1998	29	405542	14	15
1999	16	246382	3	13
2000	9	17356	2	7
2001	14	53336	3	11
2002	11	181157	2	9
2003	12	200317	7	5
2004	9	399251	2	7
2005	10	23251	7	3
2006	7	28230	4	3
2007	27	82053	10	17
2008	12	10839	7	5
2009	6	16754	3	3
2010	16	4896	10	6
2011	10	345256	2	8
2012	12	324	7	5
2013	10	9924	8	2
2014	10	70069	8	2
2015	3	120	3	-

2016	5	705	3	2
2017	6	163	5	1
2018	7	69576	6	1
2021	4	120	-	4
2022	12	1267	2	10
2023	5	2313	-	5

One factor that may have contributed to this negative result regarding the CUs' Management Plans was the lack of standardization in the methodological roadmap that addressed planning between the different categories of CUs, concepts and components that each area's Management Plan should address. The lack of information, guidance, and support from technical staff may have delayed and hindered the creation of Management Plans not only for protected areas located in the state of Minas Gerais but also for other Brazilian protected areas.

The distribution of Environmental Conservation Units in Minas Gerais was heterogeneous over the nine decades of this study (1930/2023). We observed that in seven decades (sixty-nine years) 34% of CU areas were created, while in two and a half decades (twenty-three years), 66% of CU areas in the state of Minas Gerais were created. Therefore, we can say that after the creation of the Federal Law establishing the National System of Nature Conservation Units - SNUC (Law No. 9985/2000), it was possible to establish criteria and standards for the creation, implementation and management of Brazilian CUs, contributing to the notable increase in the number of CUs created in Minas Gerais.

Despite the growing number of PAs, it must be reaffirmed that 69.64% of PA areas in Minas Gerais lack land regularization. This land regularization liability is present in the Atlantic Forest, Caatinga, and Cerrado biomes from the creation of the UCs in 1967 until the year 2022. In this context, 96,951.6091 ha correspond to areas of property available to carry out the necessary environmental compensation in relation to the pending land regularization of CUs in the Minas Gerais domain, thus hindering the country's development, job creation, the sustainability of agribusiness, as well as the conservation and preservation of the areas located around the CUs (Antunes, 2023; de Lima *et al*., 2024; Minas Gerais, 2024 b, c; Schling *et al*., 2024). Therefore, there is a lack

of effective public policies that comply with the implementation, regularization, and application of the Management Plans of their UCs.

4 CONCLUSION

The study highlights a persistent dichotomy between the legal framework, notably driven by the National System of Nature Conservation Units Law (SNUC—Law No. 9.985/2000), and the effectiveness of the management and implementation of these protected areas. The results presented are particularly revealing in indicating that a significant portion of the CUs in Minas Gerais (approximately 69.64%) face obstacles in land regularization and an even some proportion (40%) lack a formally established Management Plan. This scenario intrinsically compromises the capacity of these units to fulfill their primary objectives of conserving biodiversity and natural resources.

Despite a notable increase in the creation of CUs following the enactment of the SNUC Law, the spatial and category distribution of these units in the state of Minas Gerais is heterogeneous between the Atlantic Forest, Cerrado, and Caatinga biomes. This study reinforces the urgency of implementing and monitoring public policies associated with the creation and management of Conservation Units, going beyond simple legal establishment to guarantee the protection and long-term sustainability of these vital areas for Brazilian conservation.

The mismatch between the creation of new protected areas and the formalization of land tenure, as well as the development and implementation of management plans, poses a substantial challenge that requires coordinated and prioritized action on the part of the various responsible administrative bodies. Overcoming these obstacles is essential if the Conservation Units are to play their strategic role in conserving Brazil's rich but threatened biodiversity in the face of growing human pressure.

ACKNOWLEDGEMENTS

This study was carried out with the support of the Minas Gerais State Research Foundation (FAPEMIG) in accordance with the PD&I Grant Agreement Nº. 5.02/2022.

REFERENCES

Africa, 2026. Siyabona Africa. **Kruger Park Proclamation**. https://www.krugerpark.co.za/proclamation-of-kruger-national-park.html. [Accessed 21 Fev 2026].

ALMEIDA, L.M.L.D.D., Fontoura, A.G.D.C., Vasconcelos, I.M.D., Brito, D.M.C., Hilário, R.R. 2022. Current status, attractions, and obstacles for ecotourism in protected areas of Amapá, Brazil. **Ambient. Soc.** 25, e00061. https://doi.org/10.1590/1809-4422asoc20220006r1OA

ALVES-PINTO, H.N., Cordeiro, C.L., Geldmann, J., Jonas, H.D., Gaiarsa, M.P., Balmford, A., Watson, J.E.M., Strassburg, B., 2022. The role of different governance regimes in reducing native vegetation conversion and promoting regrowth in the Brazilian Amazon. **Biol. Conserv.** 267, 109473. https://doi.org/10.1016/j.biocon.2022.109473.

ANTUNES, P.D.B., 2023. The Rights of the Indigenous People and the Amazon: A Road Ahead+. **Environmental Policy and Law**, 53(2-3), 153-163. 10.3233/EPL-239004.

Australia, 2024. National Museum Australia. **Natural beauty and grandeur**. 2024. https://digital-classroom.nma.gov.au/defining-moments/australias-first-national-park#:~:text=Australia's%20first%20national%20park%2C%20now,national%20park%20in%20the%20world. [Accessed 29 may 2024].

BENFICA, N.S., da Silva Gomes, A., Zanchi, F.B., 2023. Twenty years of net photosynthesis, climatic and anthropic factors from biomes of Bahia State, Brazil. **J. S. Am. Earth Sci.** 131, 104636. https://doi.org/10.1016/j.jsames.2023.104636.

BRADBURY, D., Binks, R.M., Webb, Byrne, Margaret., 2023. Defining conservation units in a species complex with genomic-taxonomic discordance: a case study of Conospermum caeruleum (Proteaceae). **Biodivers. Conserv.** 32, 1949–1975 (2023). https://doi.org/10.1007/s10531-023-02585-z

Brasil, 1934. Decreto Nº 23.793, de 23 de janeiro de 1934. http://www.planalto.gov.br/ccivil_03/decreto/1930-1949/d23793.htm. [Accessed 11 May 2025].

Brasil, 1937. Decreto nº 1.713, de 14 de junho de 1937. https://www.planalto.gov.br/ccivil_03/atos/decretos/1937/d01713.html. [Accessed 12 May 2025].

Brasil, 1965. Lei Nº 4.771, de 15 de setembro de 1965. https://www.planalto.gov.br/ccivil_03/leis/l4771.htm. [Accessed 15 May 2025].

Brasil, 1988. **Constituição da República Federativa do Brasil de 1988**. https://www.planalto.gov.br/ccivil_03/constituicao/constituicao.htm. [Accessed 11 May 2025].

Brasil, 2000. Lei Federal nº 9.985, de 18 de julho de 2000. https://www.planalto.gov.br/ccivil_03/leis/l9985.htm. [Accessed 11 May 2025].

Brasil, 2012. Lei Nº. 12.651, de 25 de maio de 2012. https://www.planalto.gov.br/ccivil_03/_ato2011-2014/2012/lei/l12651.htm. [Accessed 12 May 2025].

Brasil, 2013. Resolução CONABIO n. 6, de 3 de setembro de 2013. https://www.gov.br/mma/pt-br/assuntos/biodiversidade-e-ecossistemas/ecossistemas/economia-dos-ecossistemas/resolucao_conabio_no_06_de_03_de_set_de_2013.pdf. [Accessed 12 May 2025].

Brasil, 2019. Instituto de Pesquisa Econômica Aplicada. https://www.ipea.gov.br/ods/ods15.html. [Accessed 15 June 2024].

Brasil, 2023. Ministério do Meio Ambiente e Mudança Climática. **Brasil: 6º Relatório Nacional para a Convenção sobre Diversidade Biológica** / Ministério do Meio Ambiente e Mudança do Clima, Secretaria da Nacional de Biodiversidade, Florestas e Direitos Animais. https://www.gov.br/mma/pt-br/assuntos/biodiversidade-e-ecossistemas/publicacoes/6rn. [Accessed 11 May 2025].

Brasil, 2024a. **Unidades de Conservação**. https://dados.gov.br/dados/conjuntos-dados/unidadesdeconservacao. [Accessed 15 april 2024].

Brasil, 2024b. Ministério do Meio Ambiente. **Cadastro Nacional de Unidade de Conservação**, 2024. https://antigo.mma.gov.br/areas-protegidas/cadastro-nacional-de-ucs. [Accessed 21 May 2024].

Brasil. 2009. Instrução Normativa ICMBio nº 2 de 03/09/2009. https://www.legisweb.com.br/legislacao/?id=77974. [Accessed 11 May 2025].

Brasil. 2017. Instrução Normativa nº 7/2017/GABIN/ICMBIO, de 21 de dezembro de 2017. https://www.gov.br/icmbio/pt-br/assuntos/biodiversidade/unidade-de-conservacao/roteiros-metodologicos/intrucao_normativa_07_2017.pdf. [Accessed 11 May 2025].

BRASIL-GODINHO, M., Diele-Viegas, L., Bolochio, B.E., Nogueira, C.D.C., Sawaya, R.J., 2024. Climate refugia for Atlantic Forest widespread endemic anurans will persist in future climate change scenarios. **Journal for Nature Conservation**, https://doi.org/10.1016/j.jnc.2024.126610.

Brasília. 2014. Ministério Público Federal. Câmara de Coordenação e Revisão, 4 **Regularização fundiária em unidades de conservação** / 4. Câmara de Coordenação e Revisão. – Brasília: MPF, 2014. 73 p.

Brasília. 2018. **Roteiro metodológico para elaboração e revisão de planos de manejo das unidades de conservação federais**. Instituto Chico Mendes de Conservação da Biodiversidade: ICMBio, 2018. 208 p. https://www.gov.br/icmbio/pt-br/centrais-de-conteudo/publicacoes/roteiros/roteiro_metodologico_elaboracao_revisao_plano_manejo_ucs.pdf. [Accessed 01 July 2024].

BUCHADAS, A., Jung, M., Bustamante, M., Fernández-LLamazares, Á., Garnett, S.T., Nanni, A.S., Meyfroidt, P., Kuemmerle, T., 2023. Tropical dry woodland loss occurs disproportionately in areas of highest conservation value. **Glob. Change Biol.** 29(17), 4880-4897. https://doi.org/10.1111/gcb.16832.

BUSTAMANTE, M.M., Silva, J.S., Scariot, A., Sampaio, A.B., Mascia, D.L., Garcia, E., Sano, E., Fernandes, G.W., Durigan, G., Roitman, I., Figueiredo, I., Rodrigues, R.R., Pillar, V.D., De Oliveira, A. O., Malhado, A.C., Alencar, A., Vendramini, A., Padovezi, A., Carrascosa, H., Freitas, J., Siqueira, J.A., Shimbo, J., Generoso, L.G., Tabarelli, M., Biderman, R., Salomão, R.D.P., Valle, R., Junior, B.,Nobre, C., 2019. Ecological restoration as a strategy for mitigating and adapting to climate change: lessons and challenges from Brazil. **Mitig. Adapt. Strat. Gl.** 24, 1249-1270. https://doi.org/10.1007/s11027-018-9837-5.

Canada, 2023. Canada Rail Vacations. **History of Banff National Park**. https://canadarail.ca/history-of-banff-national-park/. [Accessed 20 May 2024].

CARDOSO, M.N., Shimano, Y., Cruz, P.V., Boldrini, R., Mariano, R., Nessimian, J. L., Molineri, C., Salles, F.F., De Andrade, A. F. A., DeMarco Jr, P., Juen, L. 2023. Assessing the distribution of mayflies (Ephemeroptera: Insecta) in the Brazilian Amazon to guide more effective conservation. **Aquat. Conserv.: Mar. Freshw. Ecosyst.** 33(4), 337-348. https://doi.org/10.1002/aqc.3934.

Convention on Biological Diversity - CBD, 2011. **COP decision X/2: strategic plan for biodiversity 2011–2020**. Conversion on Biological Diversity. https://www.cbd.int/decision/cop/?id=12268. [Accessed 20 May 2024].

COSTA, M.D.S., Oliveira-Júnior, J.F.D., Santos, P.J.D., Correia Filho, W.L.F., Gois, G.D., Blanco, C.J.C., Teodoro, P.E., Sa Silva Junior, C.A., Santiago, D.D.B., Jardim, A.M.D.R.F., 2020. Rainfall extremes and drought in Northeast Brazil and its relationship with El Niño–Southern Oscillation. **Int. J. Climatol.** 41, E2111-E2135. https://doi.org/10.1002/joc.6835.

DA SILVA, C.F.A., Dos Santos, A.M., de Melo, S.N., Rudke, A.P., de Almeida Junior, P.M. 2023a. Spatial modelling of deforestation-related factors in the Brazilian semi-arid biome. **International J. Environ. Sci. Stud.** 80(4), 1021-1040. https://doi.org/10.1080/00207233.2022.2099109.

DA SILVA, R.F.B., de Castro Victoria, D., Nossack, F.Á., Viña, A., Millington, J.D.A., Vieira, S.A., Batistella, M., Liu, J., 2023b. Slow-down of deforestation following a Brazilian forest policy was less effective on private lands than in all conservation areas. **Commun. Earth Environ.** 4(1), 111. https://doi.org/10.1038/s43247-023-00783-9.

DE MORAES, J.B., Wanderley, H.S., Delgado, R.C., 2023. Areas susceptible to desertification in Brazil and projected climate change scenarios. **Nat. Hazards** 116(2), 1463-1483. https://doi.org/10.1007/s11069-022-05724-x.

DE LIMA, D.M.D.F., Dalla Nora, G.G., Rossetto, O.C., Durante, L.C., da Silva Teixeira, R. F., Venere, P.C., da Silva Rabelo, O., 2024. Analysis of Methodology to Subsidy Environmental Regularization and Analysis of Informal Rural Settlements: Case Study Vale Do Mangaval–MT–Brazil. **EJTAS** 2(2), 396-411. https://doi.org/10.59324/ejtas.2024.2(2).34.

DE SOUZA CUNHA, F.A.F., Börner, J., Wunder, S., Cosenza, C.A.N., Lucena, A.F.P., 2016. The implementation costs of forest conservation policies in Brazil. **Ecol. Econ.** 130, 209-220. https://doi.org/10.1016/j.ecolecon.2016.07.007.

DOU, Y., Da Silva, R.F.B., Batistella, M., Torres, S., Moran, E., Liu, J., 2023. Mapping crop producer perceptions: The role of global drivers on local agricultural land use in Brazil. **Land Use Policy** 133. https://doi.org/10.1016/j.landusepol.2023.106862.

FARINHA, M.J.U.S., Bernardo, L.V.M., Soares Filho, A., Berezuk, A.G., da Silva, L.F., Ruviaro, C.F., 2019. Opportunity cost of a private reserve of natural heritage, Cerrado biome–Brazil. **Land use policy** 81, 49-57. https://doi.org/10.1016/j.landusepol.2018.08.028.

FERNANDES, V.B., Reydon, B.P., 2024. An exploration of the relationship between land governance and development through a systematic review of interventions. **Land Use Policy** 138. https://doi.org/10.1016/j.landusepol.2023.107032.

FERREIRA, T.R., Da Silva, B.B., De Moura, M.S.B., Verhoef, A., Nóbrega, R.L.B., 2020. The use of remote sensing for reliable estimation of net radiation and its components: A case study for contrasting land covers in an agricultural hotspot of the Brazilian semiarid region. **Agric. For. Meteorol.** 291. https://doi.org/10.1016/j.agrformet.2020.108052.

GIUNCHI, V., Fusaroli, M., Linder, E., Villén, J., Wettermark, B., Nekoro, M., Raschi, E., Lunghi, C., Poluzzi, E. 2023. The environmental impact of pharmaceuticals in Italy: Integrating healthcare and eco-toxicological data to assess and potentially mitigate their diffusion to water supplies. **Br. J. Clin. Pharmacol.** 89(7), 2020-2027. https://doi.org/10.1111/bcp.15761.

GUERRA, A., Reis, L.K., Borges, F.L.G., Ojeda, P.T.A., Pineda, D.A.M., Miranda, C.O., Maidana, D.P.F.D.L., Santos, T.M.R.D., Shibuya, P.S., Marques, M.C.M., Laurance, S.G.W., Garcia, L.C., 2020. Ecological restoration in Brazilian biomes:

Identifying advances and gaps. **For. Ecol. Manag.** 458. https://doi.org/10.1016/j.foreco.2019.117802.

JARDIM, A.M.D.R.F., Araújo Júnior, G.D.N., Silva, M.V.D., Santos, A.D., Silva, J.L.B. D., Pandorfi, H., Oliveira-Junior, J.F.D., Teixeira, A.H.D.C., Teodoro, P.E., Lima, J.L.M.P.D., Junior, C.A.D.S., Souza, L.S.B.D., Silva, E.A., Silva, T.G.F.D., 2022. Using remote sensing to quantify the joint effects of climate and land use/land cover changes on the caatinga biome of northeast Brazilian. **Remote Sens.** 14(8). https://doi.org/10.3390/rs14081911.

LOPES, V.C., Parente, L.L., Baumann, L.R.F., Miziara, F., Ferreira, L.G., 2020. Land-use dynamics in a Brazilian agricultural frontier region, 1985-2017. **Land Use Policy** 97. https://doi.org/10.1016/j.landusepol.2020.104740.

LUCAS, F.M.F., Araujo, E.C.G., Fiedler, N.C., da Silva Santana, J.A., Tetto, A.F., 2023. Perspective: Scientific gaps on forest fires in Brazilian protected areas. **For. Ecol. Manag.** 529. https://doi.org/10.1016/j.foreco.2022.120739.

LUIZ, C.H.P., Steinke, V.A., 2022. Recent environmental legislation in Brazil and the impact on Cerrado deforestation rates. **Sustainability** 14(13). https://doi.org/10.3390/su14138096.

MAGALHÃES, I.B., de Paula Pereira, A.S.A., Calijuri, M.L., do Carmo Alves, S., dos Santos, V.J., Lorentz, J.F., 2020. Brazilian Cerrado and Soy moratorium: Effects on biome preservation and consequences on grain production. **Land use policy**, 99. https://doi.org/10.1016/j.landusepol.2020.105030.

MAIA, A.G., dos Santos Eusebio, G., Fasiaben, M. D.C.R., Moraes, A.S., Assad, E.D., Pugliero, V.S., 2021. The economic impacts of the diffusion of agroforestry in Brazil. **Land use policy** 108. https://doi.org/10.1016/j.landusepol.2021.105489.

MAMEDES, I., Guerra, A., Rodrigues, D.B.B., Garcia, L.C., de Faria Godoi, R., Oliveira, P.T.S., 2023. Brazilian payment for environmental services programs emphasize water-related services. **Int. Soil Water Conserv. Res.** 11(2), 276-289. https://doi.org/10.1016/j.iswcr.2023.01.001.

MARENGO, J.A., Torres, R.R., Alves, L.M. 2017. Drought in Northeast Brazil - past, present, and future. **Theor. Appl. Climatol.** 129, 1189-1200. https://doi.org/10.1007/s00704-016-1840-8.

Minas Gerais, 2020. Ministério Público do Estado de Minas Gerais. Superintendência de Comunicação Integrada. **Rompimento da barragem de Fundão, em Mariana: resultados e desafios cinco anos após o desastre**. https://www.mpmg.mp.br/portal/menu/comunicacao/noticias/rompimento-da-barragem-de-fundao-em-mariana-resultados-e-desafios-cinco-anos-apos-o-desastre.shtml. [Accessed 21 May 2024].

Minas Gerais, 2024a. **Histórico do rompimento das barragens da Vale na Mina Córrego do Feijão**. https://www.mg.gov.br/pro-brumadinho/pagina/historico-do-rompimento-das-barragens-da-vale-na-mina-corrego-do-feijao. [Accessed 21 May 2024].

Minas Gerais, 2024b. **Regularização Fundiária de Unidades de Conservação**. http://www.ief.mg.gov.br/unidades-de-conservacao/regularizacao-fundiaria. [Accessed 21 June 2024].

Minas Gerais, 2024c. **Infraestrutura de Dados Espaciais do Sistema Estadual de Meio Ambiente e Recursos Hídricos (IDE-Sisema)**. https://idesisema.meioambiente.mg.gov.br/webgis. [Accessed 21 June 2024].

MOURA, A.C.M., Morais, C.F.D., Gonçalves Mello, T.A. 2024. Geodesign and Sustainable Development Goals in the environmental parameterization of the Iron Quadrangle region, Brazil: an academic experience. **Int. J. Build. Pathol. Adapt.** 42(2), 294-317. https://doi.org/10.1108/IJBPA-11-2021-0143

New Zealand, 2024. Departament of Conservation te Papa Atawbai. **History of Tongariro National Park**. https://www.doc.govt.nz/parks-and-recreation/places-to-go/central-north-island/places/tongariro-national-park/history-of-tongariro-national-park/#:~:text=This%20led%20to%20the%20establishment,and%20fourth%20in%20the%20world. [Accessed 20 May 2024].

OLIVEIRA, G.C.D.S., Henriques, N.R., Clemente, M.A., Souza, M.M.D., 2021. Conservation Units as a protection tool for social wasps in Minas Gerais state, Brazil. **Pap. Avulsos Zool.** 61. https://doi.org/10.11606/1807-0205/2021.61.25.

ONYEAKA, H., Ghosh, S., Obileke, K., Miri, T., Odeyemi, O. A., Nwaiwu, O., Tamasiga, P., 2024. Preventing chemical contaminants in food: Challenges and prospects for safe and sustainable food production. **Food Control** 155. https://doi.org/10.1016/j.foodcont.2023.110040.

PACHECO, A.A., Neves, A.C.O., Fernandes, G.W., 2018. Uneven conservation efforts compromise Brazil to meet the Target 11 of Convention on Biological Diversity. **Perspect. Ecol. Conserv.** 16(1), 43-48. https://doi.org/10.1016/j.pecon.2017.12.001.

PARRAS, R., de Mendonça, G.C., da Costa, L.M., Rocha, J.R., Costa, R.C.A., Valera, C.A., Fernandes, L.F.S., Pacheco, F.A.L., Pissarra, T.C.T., 2024. Land use footprints and policies in Brazil. **Land Use Policy** 140. https://doi.org/10.1016/j.landusepol.2024.107121.

POMPEU, N., Vilpoux, O.F., 2023. Who wants to pay for Pantanal? Experiences of payment for environmental services in the preservation of a single biome. **Environ. Dev.** 47. https://doi.org/10.1016/j.envdev.2023.100903

QUEIROZ, M.G.D., Silva, T.G.F.D., Souza, C.A.A.D., Jardim, A.M.D.R.F., Araújo Júnior, G.D.N., Souza, L.S.B.D., Moura, M.S.B.D., 2021. Composition of Caatinga species under anthropic disturbance and its correlation with rainfall partitioning. **Floresta e Ambiente**, 28. https://doi.org/10.1590/2179-8087-FLORAM-2019-0044

RAMOS, R.G., Scarabello, M., Soterroni, A.C., Andrade, P.R., Simões, R., Ruivo, H.M., Kraxner, F., Ramos, F.M., 2023. Current policies are insufficient to protect or restore Brazil's cost-effective conservation priority zones. **Environ. Res. Lett.** 18(6), 065006. https://doi.org/10.1088/1748-9326/acd209.

REZENDE, C.L., Scarano, F.R., Assad, E.D., Joly, C.A., Metzger, J.P., Strassburg, B.B.N., Tabarelli, M., Fonseca, G.A., Mittermeier, R. A., 2018. From hotspot to hopespot: An opportunity for the Brazilian Atlantic Forest. **Perspect. Ecol. Conserv.** 16(4), 208-214. https://doi.org/10.1016/j.pecon.2018.10.002.

RIBEIRO, F.P., Gatto, A., Oliveira, A.D.D., Pulrolnik, K., Valadão, M.B.X., Araújo, J.B. C.N., Carvalho, A.M.D., Ferreira, E.A.B., 2023. Carbon Storage in Different Compartments in Eucalyptus Stands and Native Cerrado Vegetation. **Plants** 12(14), 2751. https://doi.org/10.3390/plants12142751.

SANTOS, N.O., Machado, R.A.S., González, R.C.L., 2022. Identification of levels of anthropization and its implications in the process of desertification in the Caatinga biome (Jeremoabo, Bahia-Brazil). **Cuad. Investig. Geogr.** 48(1), 41-57. https://doi.org/10.18172/cig.5212.

SCHLING, M., Somarriba, M.S., de Dios Mattos, J., 2024. **Land Regularization and Technical Efficiency in Agricultural Production: An Empirical Study in Andean Countries**. http://dx.doi.org/10.18235/0012945.

SOARES-FILHO, B.S., Oliveira, U., Ferreira, M.N., Marques, F.F.C., de Oliveira, A.R., Silva, F.R., Börner, J., 2023. Contribution of the Amazon protected areas program to forest conservation. **Biol. Conserv.** 279. https://doi.org/10.1016/j.biocon.2023.109928.

USA. United States of American, 2024. **National Park System**. https://www.nps.gov/aboutus/national-park-system.htm. [Accessed 29 May 2024].

VIEIRA, L.T.A., Azevedo, T.N., Castro, A.A.J.F., Martins, F.R., 2022. Reviewing the Cerrado's limits, flora distribution patterns, and conservation status for policy decisions. **Land Use Policy** 115. https://doi.org/10.1016/j.landusepol.2022.106038.

VIEIRA, R.M.D.S.P., Tomasella, J., Cunha, A.P.M.D.A., Barbosa, A.A., Pompeu, J., Ferreira, Y., Santos, F.C., Alves, L.M., Ometto, J., 2023. Socio-Environmental Vulnerability to Drought Conditions and Land Degradation: An Assessment in Two Northeastern Brazilian River Basins. **Sustainability** 15(10). https://doi.org/10.3390/su15108029.

VIEIRA, R.R.S., Pressey, R.L., Loyola, R., 2019. The residual nature of protected areas in Brazil. **Biol. Conserv.** 233, 152-161. https://doi.org/10.1016/j.biocon.2019.02.010.