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ORIGINAL ARTICLE

CONSERVATION UNITS IN THE SEMIARID REGION OF MINAS GERAIS AND THEIR ROLE IN ENVIRONMENTAL PRESERVATION

Unidade de conservação no semiárido mineiro e seu papel na preservação ambiental

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Abstract
The monitoring of land use and occupation plays a key role in the management of Conservation Units. In this perspective, this paper presents a temporal analysis of land use and land cover for the years 1987, 1997, 2007, 2017 and 2022 in the area of the Caminho dos Gerais State Park (*Parque Estadual Caminho dos Gerais* – PECG) through geographic object-oriented image analysis (GEOBIA) using Landsat-TM/OLI images. The PECG is located in an ecotonal region in the semiarid north of Minas Gerais, between the municipalities of Mamonas, Monte Azul, Gameleiras, and Espinosa. In its history of occupation, this Park has presented territorial dynamics of different interests, including the impact of eucalyptus forests, until 2007, the year of its creation. The results show the effect of creating the PECG for the gradual recovery of vegetation cover in a water recharge area.

Keywords: Remote sensing, Semiarid, Forest, Environmental Preservation.

Resumo
O monitoramento do uso e ocupação da terra tem um papel fundamental na gestão de Unidades de Conservação. Nessa perspectiva, o presente trabalho apresenta uma análise temporal de uso e cobertura da terra para os anos de 1987, 1997, 2007, 2017 e 2022 na área do Parque Estadual Caminho dos Gerais (PECG) por meio de classificação orientada a objeto (GEOBIA) em de imagens Landsat-TM/OLI. O PECG está localizado em uma região ecotonal no semiárido norte mineiro, entre os municípios de Mamonas,

Monte Azul, Gameleiras e Espinosa. Esse Parque possui em seu histórico de ocupação, dinâmicas territoriais de interesses diversos entre eles o impacto da silvicultura do eucalipto, até o ano de 2007, ano da sua criação. Os resultados encontrados evidenciam o efeito da criação do PECG para a recuperação gradual da cobertura vegetal em área de recarga hídrica.

Palavras-chave: Sensoriamento remoto, Semiárido, Silvicultura.

1. INTRODUCTION

The availability and management of natural resources has become one of the most pressing challenges for humanity. Water scarcity is one of these issues, involving various factors related to managing territories and land use and occupation. These, in turn, put pressure on the local drainage network.

This scenario highlights geoecological aspects of the landscape, especially regarding the activities promoted by public and private enterprises that act politically by delimiting areas and reconfiguring territories (CALVALCANTI, 2014). From this perspective, the geographic space of Northern Minas Gerais has been the target of interest both by capitalist enterprises, as is the case of eucalyptus forests, and by those whose focus is nature conservation, such as Conservation Units.

These developments are intrinsically connected to the historical process of occupation in the northern region of Minas Gerais. Linked to the colonial past, with the entry of the *Bandeirantes* – pioneers and explorers of the Brazilian inland regions– in search of fugitive Indians and enslaved people, territorial occupation intensified from the 18^{th} century onwards, with the formation of large properties intended for beef cattle raising (BETHONICO, 2009).

Starting in the 1960s and 1970s, mainly following government actions, there was an incentive for the arrival of enterprises within the scope of the development and modernisation policies of the Office of the Superintendent for the Development of the Northeast (*Superintendência de Desenvolvimento do Nordeste* – SUDENE). Thus, considering the need to produce lumber to supply the steel industries, political strategies focused on the northern region of Minas Gerais as the most suitable for eucalyptus monoculture.

Chaves and Ribeiro (2014) indicate that this decision failed to consider the traditional peoples and communities already established in the region, but rather the attractive geographical conditions of the location, such as the relief, favourable vegetation, low population density, and high poverty rates. Thus, in partnership with the Brazilian Institute

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for Forest Development (Instituto Brasileiro de Desenvolvimento Florestal – IBDF), the Brazilian State Government encouraged planting Eucalyptus with the discourse of a region possessing vacant land.

Faced with this scenario, in recent decades, the creation of Conservation Units has become an instrument of action by the State for the protection of the environment, which, in an imposing way, reorganised the geographic space through environmental legislation, accentuating even more the conflicts by depriving traditional peoples of active participation in the decision-making process regarding their lawful territories (LEITE; SILVA, 2014).

Conversely, the implementation of Conservation Units may take on multiple dimensions, such as the conservation of water sources linked, or not, to a conflict over the use and control of Water, whether due to the implementation of water infrastructure or issues related to community use (VIANNA, 2005).

From this perspective, this study proposes to analyse the land use and land cover time series for the years 1987, 1997, 2007, 2017 and 2022 in the Caminho dos Gerais State Park (PECG) based on the classification of images from the Landsat 8/OLI series, through processing in the QGIS software platform. With that, this study aims to verify the impact of implementing eucalyptus forests in the water recharge area and the environmental effects of creating the PECG.

2. THE OCCUPATION OF THE SEMIARID REGION OF MINAS GERAIS

The occupation of eucalyptus forests in the semiarid north of Minas Gerais reflects a practice of devaluing to occupy, i.e., a practice linked to the pattern of power, domination and exploitation of capitalism. Thus, the development model restricted to market designs tends to devalue ecosystems and other forms of social life (ESTEVA, 2000).

The domination of space by capital excludes the place's culture, identity and power as a possibility of plural or heterogeneous economic practices. This logic is anchored in the devaluation; it is not a recurrent practice in implementing large projects supported by the State (ESCOBAR, 2005).

Based on this premise, Northern Minas Gerais – considered an uninhabited region of natural scarcity due to its rainfall regime and economic scarcity concerning poverty rates – has become an attractive area for implementing large marketing projects.

This region, when compared to the transformations of the State of Minas Gerais in the colonial period, experienced the so-called *isolation of the sertão* (semiarid inland region) until the 17th century, when the practice of using the land for beef cattle and

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artisanal mining began a process of economic integration. This process was intensified with the advent of the Central-South railroad connection to the Northeast in the 20th century (COSTA, 2022).

Regarding this fact, Neves (2020) argues that, during the period of Portuguese commercial exploration, the area designated as *sertão* was not marked by a population void but was rather a territory already inhabited by native groups. These peoples, however, were relegated, being subjected to violence and the establishment of cattle raising, an activity that propelled the economy due to the favourable geographical conditions in that region (Costa, 2006).

According to Nogueira (2017), this occupation process is also characterised by a historical devaluation of the ecotonal landscape, as is the case of the Cerrado and Caatinga biomes, to the detriment of ecosystems of political force, as is the case of the Atlantic Forest and Amazon biomes.

First came the expansion of railroads alongside the demarcation of land. Subsequently, in the 1960s, through incentives from SUDENE, economic projects for enterprises began to emerge, aimed at strengthening agriculture and livestock and eucalyptus monocultures (NEVES, 2020).

These transformations promoted by public or private enterprises in the Northern Minas Gerais region were the stage of resistance movements of local populations. In this sense, Dayrell (2000) notes that the eucalyptus monoculture activity, a result of the agricultural modernisation process, has become an example of the exclusion of peasant agriculture from disastrous State policies. Consequently, areas that once provided strategic social and environmental services have become large eucalyptus forests.

According to Anaya (2014), reforestation projects represent the “cornering” of traditional populations, including the *Geraizeiros* (native Northern Minas Gerais rural communities), from the productive processes in the plateaus. These areas were converted into eucalyptus monoculture, forcing traditional communities to produce in other geomorphological contexts and depriving them of cultural practices of collective land use (GALIZONI; RIBEIRO, 2011).

Thus, installing these reforestation projects brought significant changes to the landscape. Residents noticed the water scarcity, the felling of the pequi trees, and the impacts caused by productive activities that only benefited those outside the community. To minimise these environmental impacts, the government’s environmental agenda reached the region by creating conservation units (DAYRELL, 2019).

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In the temporal categorisation outlined by Araújo (2009), conservation units were implemented in the 1990s, configuring new territorial conflict scenarios between State action and local populations. Regarding this matter, Anaya (2014) indicates that the conservation units are created as compensatory measures to offset the activities of environmental impacts of large enterprises, such as the Jaíba project. This measure creates restrictions and curtails traditional soil management practices, generating resistance movements, among which the *“Movimento dos Encurralados pelos Parques”* (“Movement of those Cornered by the Parks”) stands out.

These entrepreneurial alternatives show social and environmental challenges in conflict scenarios for access to natural resources. Costa (2020) characterises environmental conflicts in the social and cultural dimensions in the different forms of interactions and adaptations that each social group has when addressing nature. In this way, the social and environmental aspects as a dynamic, evolutionary and hierarchical element becomes a phenomenon of human actions.

Given the above, studies aimed at the knowledge of social and environmental particularities in an ecotonal profile of the semiarid region of Minas Gerais are essential. The transition between the Caatinga and Cerrado biomes is configured in environments of aesthetic landscape, ecological and hydric value, and social and territorial nature. For this purpose, using geotechnologies allows for robust analysis and interpretations of impacts promoted by installing enterprises responsible for the territorial reorganisation in Northern Minas Gerais, whether capitalist or conservationist.

3. STUDY AREA

Located in the semiarid north of Minas Gerais, between the municipalities of Mamonas, Monte Azul, Gameleiras and Espinosa, in the coordinates of 14º48’S, 43º06’W and 15º18’S, 42º50’W (Figure 1); The PECG was established on 3/28/2007, with an area of 56,237.37 hectares, under the responsibility of the State Forest Institute (*Instituto Estadual de Florestas* – IEF, 2023). This Park has transitional characteristics representative of the Caatinga, Cerrado and Atlantic Forest domains, also called an ecotonal region due to the morphological and phytogeographic patterns common to the Middle São Francisco region (AB’SÁBER, 2003).

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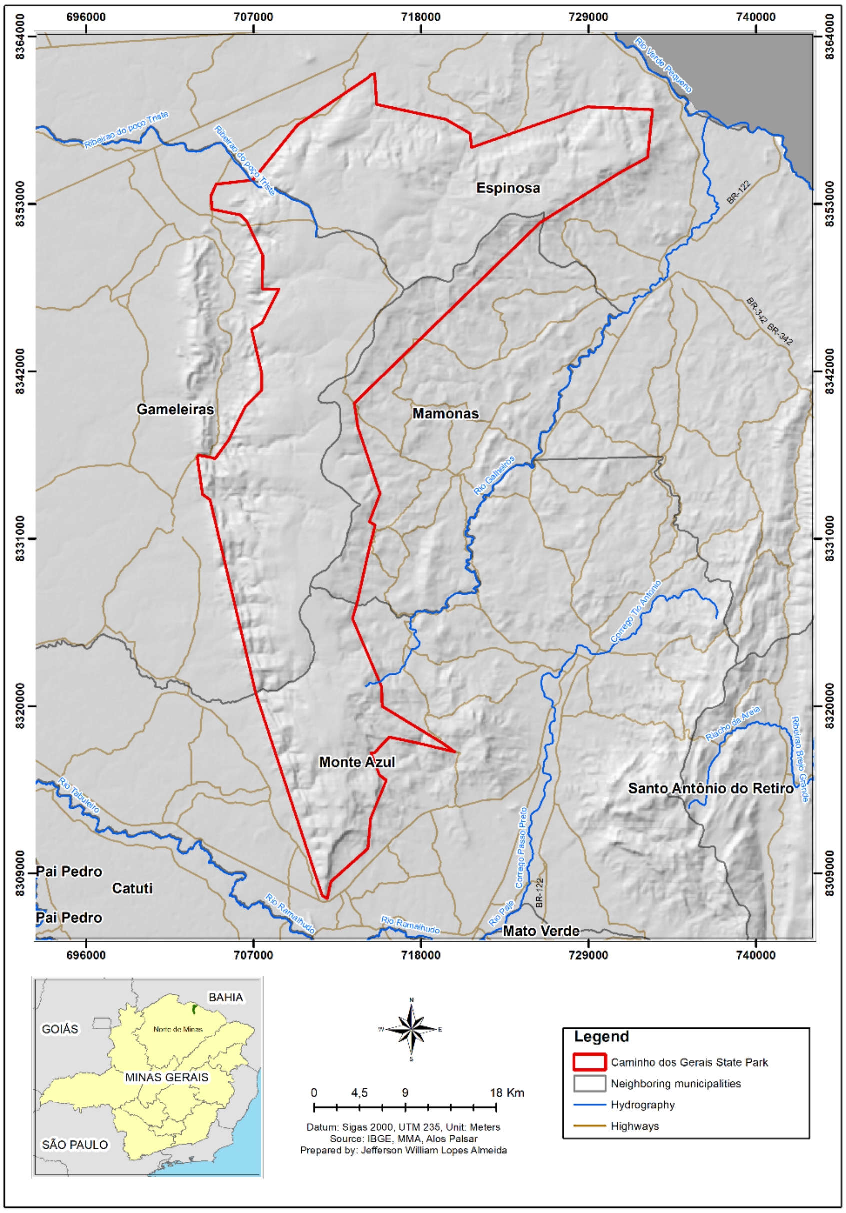

Figure 1 - Location Map of Caminho dos Gerais State Park.
Elaboration: The authors, 2023.

Ecotonal regions are transitional areas between ecological communities, with a high biodiversity of rare species with floristic transitions or edaphic contacts. Ecotonal areas should be prioritised for conservation, as they have a high biological diversity and may be important for adapting species to climate change (ANÁDON *et al*., 2014).

According to Rodrigues (2015), the PECG presents a vegetational mosaic in ecotonal conditions, which form a complex landscape, with the presence of the following phytophysiognomies: steppe savannah, rupestrian grassland, forested steppe savannah + seasonal deciduous forest, Cerrado Stricto Sensu, Rupestrian Cerrado, Campo Cerrado, and seasonal deciduous forest + marshy field + palm swamp.

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The Seasonal Deciduous Forests, located on the edges of Serra Geral, are associated with nutrient-rich soils, being, however, dystrophic and transitional in areas adjacent to the escarpment. These characteristics are conditioned to the process of lithological formation, comprising sedimentary rocks in the depression of Serra do Espinhaço.

These rocks from the Precambrian period, mainly sandstone in the context of Serra Geral, where the PECG is located, originated an elevated tabular surface, a unique structure, in the middle of the depressed zone of Serra do Espinhaço in Northern Minas Gerais (RODRIGUES, 2015).

In the PECG, soils are characterised, for the most part, as sandy with medium texture, subdivided into Haplic Cambisol, Quartzarenic Neosol, Litholic Neosol, Regolitic Neosol, and Haplic Organosol. Concerning the climate classification, the BSw predominates in the region, featuring a semiarid climate, with dry winters and rainy summers, often below 750 mm, and an average monthly temperature that varies from about 27.5ºC in the summer to 23ºC in the winter (ANTUNES, 1994).

4. DATA AND METHODS

4.1. Pre-Processing and Processing of Remote Sensing Data

This section lists the steps and operational procedures to achieve the objectives proposed for the study, as represented in the flowchart in Figure 2.

In the first stage, Landsat images were acquired via the image catalogue made available by the Image Generation Division (*Divisão de Geração de Imagens* – DIDGI) of the National Institute for Space Research (*Instituto Nacional de Pesquisas Espaciais* – INPE), through the institution's website (http://www.dgi.inpe.br/catalogo/). The scenes that cover the study area correspond to orbit 218, points 70 and 71. These images are specified according to Chart 1:

For the instrumentation of geotechnology data, the QGIS software platform, version 3.16, was used. Thus, in the Digital Image Processing (DIP) stage, the images from the TM (Thematic Mapper) sensor were georeferenced through control points via the "georeferencing" tool routine. Atmospheric correction, pixel resampling, band composition and stacking were performed via the SCP (Semi-Automatic Classification Plugin) routine. Following that step, with the cartographic base of the PECG limit, made available by the ICMBio Conservation Units system and the Ministry of the Environment (MMA), the calculation of the buffer zone, with five kilometres of distance, was carried out to delimit the study area and cut out the raster layers.

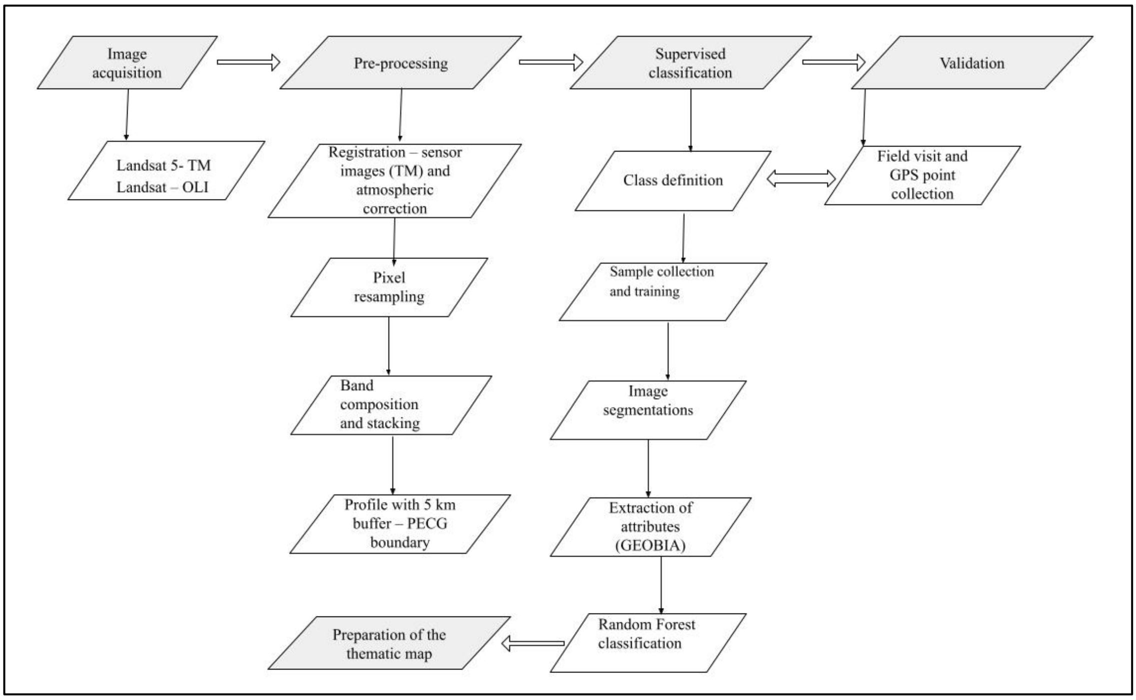

Figure 2 - Flowchart with steps and operating procedures.
Elaboration: The authors, 2023.

Chart 1: Landsat time series used for supervised classification.

Landsat – Sensor Thematic Mapper (TM)	*Landsat – Operational Land Imager (OLI)*
7/10/1987	9/5/2017
6/26/1997	7/1/2022
7/24/2007	

Elaboration: The authors, 2023.

Before starting the classification process, a field visit was carried out between July 21 and 23, 2022, to identify and validate the different plant formations and forms of land use. It included photos being taken onsite and collection of point coordinates via the GPS (Global Position System) signal receiver, as well as a description and annotation of the residents' reports in the scope of the adjacent area of the PECG.

The collections of the training points corresponded to periods close to the dates of the satellite passage of the selected images. In this way, the collected information became fundamental in the definition of training sample sets for classification and to assist in testing and verifying the accuracy of the GEOBIA classification. Based on Congalton (1991), confusion matrices, global accuracy coefficients and the Kappa coefficient were obtained to do this.

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4.2. Location and Definition of the Classes for Mapping

The next step was defining representative land use and land cover classes in the PECG. Figure 3 shows examples of the location and spatial context of the classes defined for the study. The Rupestrian Cerrado (1) is well distributed in the Park, from the center-southern portion to the area further north of the top of the upper tabular surface. Close to this phytophysiognomy, precisely in the “lowlands,” between the regions of the plains and the lower third of the northeast slope, the presence of Pastures can be noted (2). The Exposed Soil class (3) is more evident in the central portion of the PECG, particularly in areas formerly occupied by eucalyptus forests. In this area, both in the onsite visit, recorded through photographs, and through interpretations of Landsat-TM/OLI images, the impact caused by the opening of roads or by deforestation and logging was recorded.

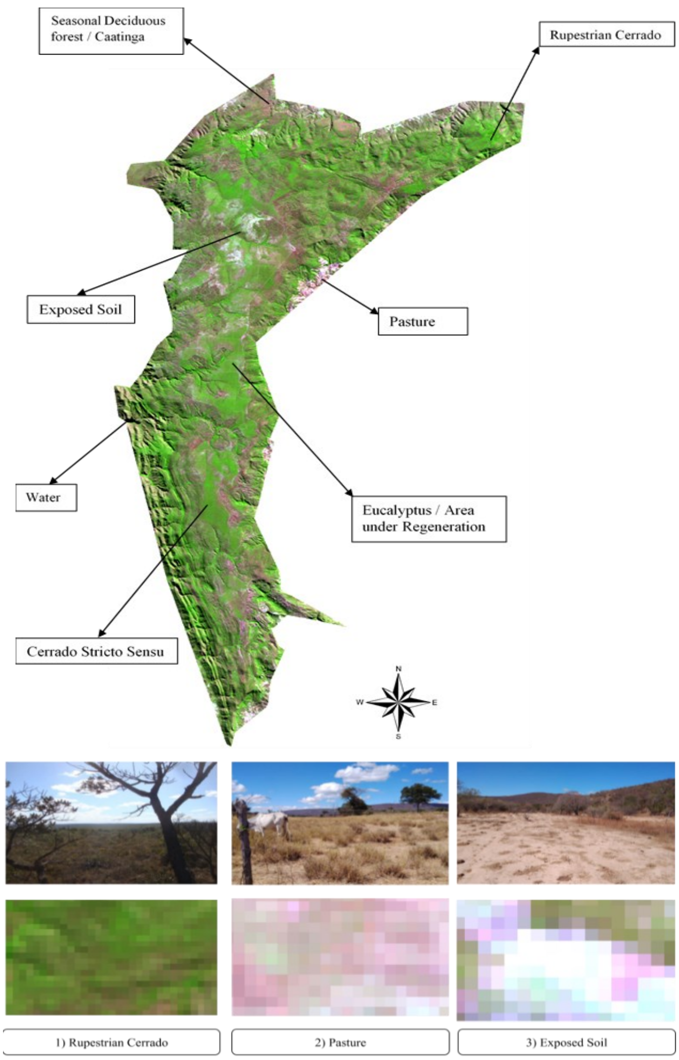

Figure 3 - Location of the classes chosen for the study and landscape fragments verified onsite, with their respective correspondence in the Landsat/OLI image (R6, G5, and B4).
Elaboration: The authors, 2023.

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Given the ecotonal context of the PECG region, the Seasonal Deciduous Forest and Caatinga phytophysiognomies (4) were grouped in the same class given the similarity of spectral response in the images of the Landsat series, whether in terms of shape, texture, or location. Located between the lower third and upper third of the slopes that border the PECG, these phytophysiognomies, represented by Figure 4, present characteristics of herbaceous vegetation in the flatter areas and shrubby-tree species between the slope and the areas of higher altitudes.

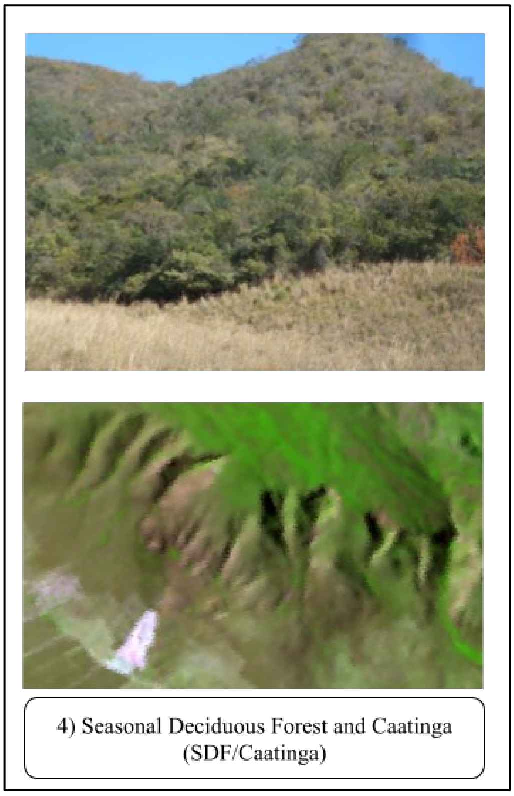

Figure 4 - Example of a characteristic area of the SDF and Caatinga interaction and its respective correspondence in the Landsat/OLI image (R6, G5, and B4).
Elaboration: The authors, 2023.

For the Eucalyptus class (5), the presence of forests stands out on the elevated tabular surface in the central northern portion of the PECG. In the Landsat/TM images, one highlight is the presence of Eucalyptus planted until 2007, when the last cutting occurred due to the decree establishing the PECG. Based on this, the area occupied by eucalyptus trees entered a regenerative state, subsequently giving way to the Cerrado Stricto Sensu class (6), as shown in Figure 5. The Water class (7) refers mainly to the Gameleiras dam built in 1994 in a sloping area located southwest of the Park.

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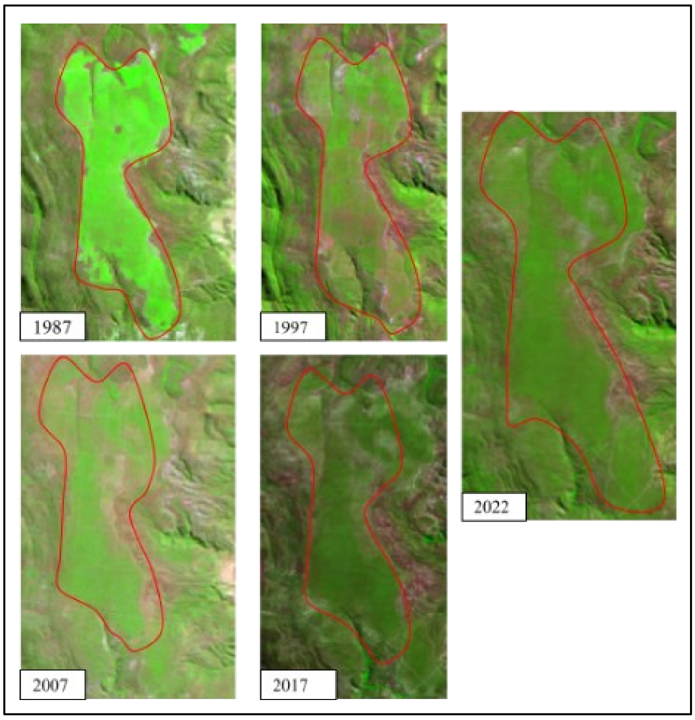

Figure 5 - Eucalyptus planting history and its respective regeneration for Cerrado Stricto Sensu (Landsat/OLI R6, G5, and B4). **Elaboration:** The authors, 2023.

4.3. Geographical Object-Based Image Analysis Method (GEOBIA)

Following the definition of the classes, the next step consisted of the Geographic Object-Based Image Analysis (GEOBIA). This classification technique automatically extracts attributes in remote sensing images through image segmentation to create groups of pixels or spectrally homogeneous objects and their relationship with their neighbouring objects (BRANCO *et al.,* 2018).

Object orientation is characterised by analysing objects by geometric (topology, shape, and position) and thematic (non-spatial attributes) aspects. This way, the analysis focuses on objects (polygons) distributed across the image and is not limited solely to an isolated pixel (point). This procedure becomes advantageous in heterogeneous and complex environments such as ecotonal areas (SANTOS, 2021). To implement this technique in the study area, image segmentation was carried out via the Orfeo ToolBox plugin, which generated segments with little spectral variation within the polygons, reducing the risk of mixing between characteristics of two or more classes.

To obtain better precision, the zonal statistics of the attributes of each segment acquired in the previous step on each image set was performed, i.e., the calculation of the sum, mean, median, standard deviation, and variance of the segments in the red, near-infrared and mid-infrared spectral ranges. In the next stage of image processing, the

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training samples of the segments were chosen for the Random Forest classifier, as this algorithm is of the supervised class.

In this context, the definition of 80 training samples for each class of land use and land cover stands out. Following this action, the classes defined for the study for 1987, 1997, 2007, 2017 and 2022 were obtained using the supervised Random Forest classifier.

5. DISCUSSION

In the dynamics of land use in the PECG area, as shown in Figure 6, the eucalyptus forest is widely prominent in the landscape, located in the central north portion of the PECG both during the planting period of the 1980s and 1990s and after the creation of the PECG, starting in 2007. According to Table 1, the planted eucalyptus forest in 1987 occupied an area of 79 km². As of 1997, the area of this monoculture regressed to 74 km², representing a reduction from 14% to 13% of the total area. As of 2007, with the creation of the PECG, due to the regeneration process, the “Regeneration Stage/Eucalyptus” class was adopted, in which the area now accounts for 12% of the Park’s territory, i.e., 70.4 km².

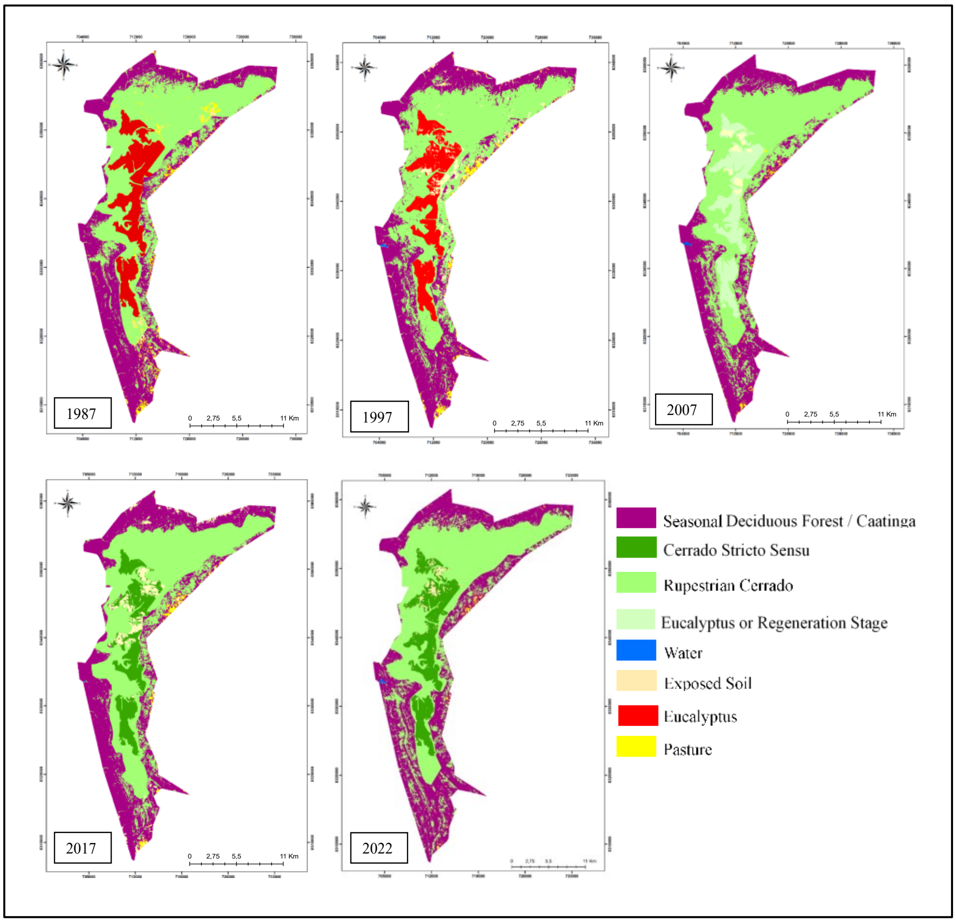

Figure 6 - Land use and land cover classification of the Caminhos dos Gerais State Park. **Elaboration:** The authors, 2023.

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The choice of this class as representative of the area is due to the gradual process of natural succession of Cerrado Stricto Sensu vegetation. The values corroborate the closure of forestry activities and the beginning of the regeneration of the degraded area. The Cerrado Stricto Sensu, conditioned by the climatic variables of the region, features shrub species and small trees with deep roots (RIBEIRO; WALTER, 1998).

In the PECG, this phytophysiognomy is mostly located in the place once occupied by the eucalyptus planting process. Two well-defined strata characterise the Cerrado Stricto Sensu – the first with subshrub species of grasses and the second composed of tree species ranging from 01.7 to 3 meters in height and dense, woody vegetation, with tortuous trunks and twisted branches (RODRIGUES, 2015).

Table 1: Area of land use classes in 1987, 1997, 2007, 2017 and 2022.

Use Classes	Period				
	1987	1997	2007	2017	2022
	Area (km^2)				
Water	0	0,3	0,4	0,07	0,3
Pasture	14	5	6,3	6,3	6,4
Exposed Soil	9	22	9,5	25	6
Seasonal Deciduous Forest / Caatinga	160	164	165	165	165
Rupestrian Cerrado	300	297	311	299	310
Eucalyptus	79	74	0,0	0	0
Eucalyptus/regeneration stage	0	0	70,4	0	0
Cerrado Stricto Sensu	0	0	0,0	67	75

Elaboration: The authors, 2023.

As a result of the classification, the Cerrado Stricto Sensu class began to appear in the year 2017 since the area was occupied in previous decades by eucalyptus forests, reaching an average area of 74.3 km² from 1987 to 2007. After the creation of the PECG, the Cerrado Stricto Sensu species entered the regeneration process, totalling an area of 67 km² in 2017.

In 2022, the recovery of the species reached values close to the area occupied by eucalyptus forest in 1987, i.e., 12% of the PECG area with a value of 75 km². In this context, recovering an area with soils of the Quartzarenic Neosol type stands out. The soil is deep, dystrophic, and acidic, with a sandy texture in all horizons (SiBCS, 2018).

In the PECG, the Quartzarenic Neosol is located at about 1,059 to 1,202 meters of altitude, as shown in Figure 7, in the portion of the elevated decks in an area of water

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recharge, with the potential for percolation and infiltration of rainwater, in an area occupied for decades by the impact of planting eucalyptus forests.

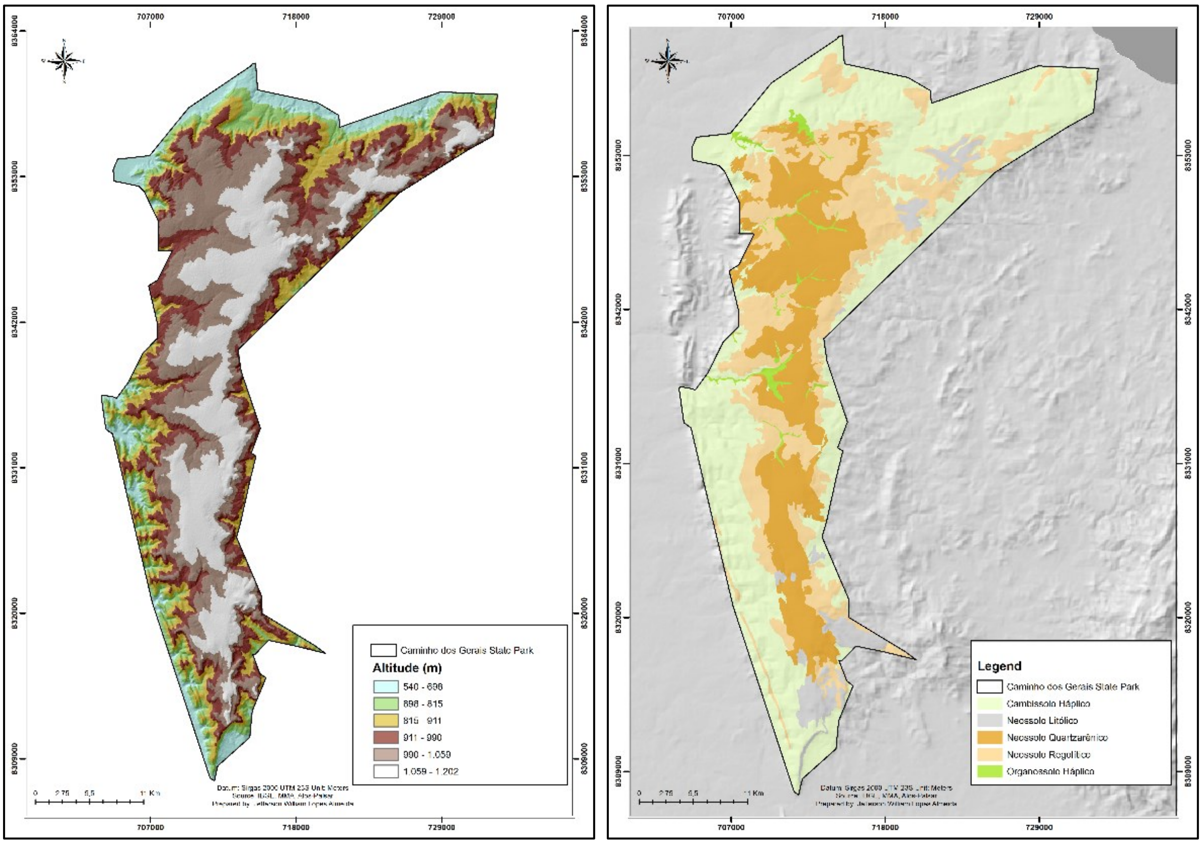

Figure 7 - Hypsometry of the Caminhos dos Gerais State Park and Soil Map of the Caminhos dos Gerais State Park, adapted from UFV by Rodrigues (2015).
Elaboration: The authors, 2023.

The Rupestrian Cerrado is another phytophysiognomy located in the high and flat areas of the PECG, at an altitude ranging from 911 to 1,059 meters, with Regolithic Neosols, particularly on the slopes. According to Rodrigues (2015), this soil is poor in nutrients and features a predominance of sandy texture throughout its domain, i.e., it is susceptible to erosion on steeper slopes.

In the vegetational context, the Rupestrian Cerrado varied little in the area due to the time series. As seen in Table 2, this phytophysiognomy in 1987 corresponded to about 53% of the area, equivalent to 300 km² of the PECG area. This value decreased to 297 km² in 2007 and was extrapolated to 311 km² and 310 km² in 2017 and 2022, respectively, or about 55% of the total area.

In this case, the oscillation of this margin is due to a series of factors, in particular, the inaccuracies in the spectral variability of ecotonal regions in medium-spatial-resolution images. Even with the segment-based method, as opposed to the pixel-based one, the

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spectral context and the colour tend to be preponderant to not discriminate vegetation with specific characteristics.

Therefore, for a more precise distinction, overcoming the spectral proximity in Landsat series images, it is necessary to use other geomorphometric variables, such as slope (FRANCISCO; ALMEIDA, 2012).

In this perspective, due to the adopted GEOBIA classification method, it was impossible to disassociate vegetations with spectral similarities, as is the case of the phytophysiognomies Seasonal Deciduous Forest and Caatinga. Thus, in the ecotonal amplitude of the area, it was decided to join these phytophysiognomies, which originated a representative class in the PECG, with approximately 160 km² to 165 km². For the year 1987, this value represented 28% of the total area, while in the following decades (1997, 2007 and 2017), there was an increase of between 4 and 5 km², which resulted in the value of 165 km² in 2022, i.e., 29% of the total area of the Park.

This vegetation complex occurs at an altitude of 540 to 990 meters, inserted in a geomorphological region that varies from plains regions to the steep slopes of the elevated tabular surface of the PECG. According to Rodrigues (2015), Haplic Cambisols predominate in this region covered by the Seasonal Deciduous Forest and Caatinga. These are acid-reaction soils that have medium texture throughout the profile. Nevertheless, in the areas of Deciduous Forests, the environment has soils with a more accentuated fertility, with higher proportions of clays compared to other soil profiles in the vicinity.

The presence of Pasture or abandoned Pasture is clear in the plains areas, resulting from the socioeconomic process based on cattle raising. Under these conditions, the Pasture in 1987 corresponded to about 2.5% of the total area of the PEC, equivalent to 14km². In 1997, this anthropic component regressed to 5 km² and began to occupy 1% of the area. For the period after the creation of the PECG, there are no considerable variations in the pasture area, totalling 6.4 km² in 2022.

According to IEF (2021), the presence of Pasture in the northeastern region of the PECG consists of a divergent use zone. This area is characterised by unpossessed properties, with the presence of subsistence practices from the surrounding community, something common in the history of use and occupation in flat areas close to the slope of the PECG.

In addition to eucalyptus silviculture and Pasture, as evidenced in the use and occupation time series, other factors have impacted or degraded natural environments in the area of what is now the PECG, among which the following stand out: construction of roads, construction of dams, disorderly use of fire, deforestation with stump removal, removal of gravel, and crops. These factors corroborate soil exposure and the triggering of erosion processes.

These factors are grouped in the exposed soil class to quantify these anthropic activities' outlines. In this context, in 1987, the class accounted for nine km², or 1.6% of the total area of the PECG, while ten years later, there was an increase of 13 km², totalling 4% of the area. From the period of creation of the PECG to 2022, there was an oscillation, i.e., the area decreased in 2007 (9.5 km²), increased in 2017 to 25 km², and reached its greatest decrease in 2022, with 6.4 km², or about 1% of the total PECG area.

This effect, among other factors, can be explained by the erosive processes operating in the area, such as laminar erosion, which, over time, results in the formation of ravines and gullies, particularly near roads to access eucalyptus plots (Figure 7).

Finally, the water class indicated in the classification represents another prominent anthropic component. In this case, the water blade is evidenced in the classification from the year 1997 due to the construction of the Gameleiras dam in 1994, where the landscape was defragmented to give way to the masonry structure of the dam.

In evaluating the classification accuracy, it was decided to analyse 2022 as a form of adherence, both for the seasonal period of the Landsat 8/OLI image and the reality seen in the field. Thus, the global accuracy of the mapping, producer accuracy (or omission error), user accuracy (or commission error) and the Kappa coefficient were calculated using the error matrix.

In evaluating the errors or divergences between the classes, the few sample points of the Water, Exposed Soil and Pasture classes stand out, to the detriment of the classes related to plant phytophysiognomies. This difference is explained by the need to acquire more sample points related to vegetation to obtain, in a laboratory setting, a greater representativeness of the ecotonal context of the PECG.

In the matrix, the global accuracy represents the calculation of dividing the sum of the main diagonal by the total number of samples. Thus, the value found for the set of thematic classes was 85.8%. In turn, the Kappa coefficient aims to show the effectiveness of the grouping of pixels in each of the thematic classes defined for the classification by calculating all elements of the error matrix. The result found for the study was 77.2%.

Compared with producer and user accuracy, these values indicate the probability that a classified pixel in the image represents that category in the field (Congalton, 1991). In

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this case, the classes with the highest error percentages in the study were Exposed soil (44.4%), Pasture (50%), and Water (66.6%). The result of the error matrix for the thematic classes, focused on the phytophysiognomies of the vegetation, shows excellent performance and adherence with what was verified in the field.

This difference between the thematic classes related to anthropic and natural phenomena can be explained by the discrepant sample universe between them, i.e., of 404 samples, only 14 are intended for anthropic elements. Despite this, the validation was satisfactory, as one of the study's objectives was to verify the natural recovery of the area after the creation of the PECG.

Table 1: Error matrix for land use and land cover classification – 2022.

Class	Sample (n)	Water	Exposed soil	Pasture	Cerrado Stricto Sensu	Rupestrian Cerrado	Seasonal Deciduous Forest / Caatinga	Producer accuracy (%)
Water	6	**4**	0	0	0	2	0	66.6
Exposed soil	4	0	**4**	0	0	0	0	44.4
Pasture	4	0	0	**4**	0	0	0	50
Cerrado Stricto Sensu	55	0	1	0	**51**	3	0	86.4
Rupestrian Cerrado	224	2	1	3	8	**187**	23	92.5
Seasonal Deciduous Forest / Caatinga	111	0	3	1	0	10	**97**	80.3
Total	404	6	9	8	59	202	120	
User accuracy (%)		66.6	100	100	92.7	83.4	87.3	
Overall accuracy (404/111) = 85.8 % – Kappa = 77.2 %								

Elaboration: The authors, 2023.

Therefore, the land use and land cover classification in the bordering area of the PECG for the years 1987, 1997, 2007, 2017 and 2022 shows the effect of the creation of this CU for the gradual recovery of the Rupestrian Cerrado phytophysiognomy. It should also be noted that it was possible, during the analysed period, to visualise and quantify the impact of planting eucalyptus forests on the smoothed surfaces of the PECG.

The recovery and preservation of this area are essential, as it concentrates several springs in the PECG area. Minas Gerais (2021) highlights the relevance – not only at the local level but also regionally – of the CU for maintaining water bodies in the semiarid region of Minas Gerais.

Thus, the temporal availability of the different sensors of the Landsat series, coupled with the GEOBIA approach of supervised classification of images, proved effective for the identification and social and environmental monitoring within the limits of the PECG.

6. CONCLUSION

Through the methodology adopted, based on the GEOBIA method, it was possible to identify the dynamics of land use and land cover in the Caminho dos Gerais State Park. In this context, the time frame used (1987, 1997, 2007, 2017, and 2022) shows two predominant episodes: the first consists of the environmental impact of the implementation of eucalyptus forests in a water recharge area, which triggered several other degrading processes, as is the case with laminar erosion.

The second represents the effect of the creation of the PECG not only for the preservation of ecotonal biodiversity but also for the protection of fundamental water sources for the geosystemic guarantee, i.e., the interrelationship and integration between man and nature, which comprises the surroundings of the Park.

In addition to the analysis of the anthropic component, anchored in the methodological framework of remote sensing, the vegetation cover dynamics were also verified throughout the historical period defined for the study. From this perspective, there were few variations in the Rupestrian Cerrado and Seasonal Deciduous Forest/Caatinga vegetation types that did not suffer the direct impact of the removal of their cover for silviculture.

The ecotonal characteristics of the PECG gathered intrinsic aspects of the Caatinga, Cerrado and Atlantic Forest biomes. Given this unique context, the guarantee of ecosystem services permeates the understanding of the territorial dynamics of an environment alien to natural and anthropogenic vulnerabilities.

Despite not separating all the phytophysiognomies in this ecotone, the proposed mapping provides a background for managing and developing future actions to conserve this environment, which a wide variety of interests has historically weakened.

To fulfil its proposed objectives, the study did not intend to exhaust the discussion on the anthropic impacts and the effects of the creation of the PECG but rather to provide information on the dynamics at work in this process. Additionally, it aimed to open up other possibilities and developments on the topics raised here and encourage new approaches in future studies.

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