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Geotechnology applied to environmental diagnosis: Pinheiro Grosso Biological Reserve, Barbacena – Minas Gerais - Brazil

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Keywords

Protected Area
Environmental Legislation
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Abstract

The Protected Areas (PAs) are territorial spaces that present natural resources with relevant characteristics. Such areas are used as strategy for the environment protection. The use of geotechnologies, such as Geographic Information System and Remote Sensing, optimizes diagnosis and environmental monitoring. The study aimned to analyzed the use and soil occupation as well as the fragility of the current scenario of the Pinheiro Grosso Biological Reserve (ReBio – ReBio, in Portuguese), located in Barbacena - Minas Gerais state - Brazil. Currently, ReBio areas presents 66.18% occupied by Vegetation and 33.82% by Anthropized area. Multicriteria Analysis revealed that 4.19% of the ReBio are strongly subject to anthropization. Due to the great anthropic pressure and existing socio-environmental conflicts, its category of Integral Protection does not match its current situation. So, it is suggested the delimitation of unit Damping Zone, the emergency implementation of environmental education programs for the local community, as well as greater supervision and monitoring of the area, as well as its recategorization as a Sustainable Use unit.

INTRODUCTION

Brazil's Federal Law No. 9,985 of July 18, 2000 (BRASIL, 2000) established the Sistema Nacional de Unidades de Conservação (SNUC, in Portuguese), which establishes criteria and standards for the creation, implementation and management of Protected Areas (PAs). The PAs

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are spaces in the Brazilian territory where their natural resources have relevant characteristics, legally delimited by the public power. The purpose of these areas is conservation, under special management regime, to which adequate guarantees of protection apply (BRASIL, 2000).

The SNUC, if effectively implemented, contributes to the protection of nature and the conservation of biodiversity in the national territory (RIBEIRO et al., 2010). However, Brazil faces difficulties in managing environmental issues. The attempt to update the Forest Code with the improper exploitation of natural resources in the Brazilian territory – mainly in the Amazon, and the government's inefficiency in compliance with the law, are examples that illustrate this scenario. The repeal of the former Forest Code (Federal Law No. 4,771/1965) (BRASIL, 1965) and the approval of Federal Law No. 12,651/2012 (BRASIL, 2012) evidenced significant environmental setback and a situation of legal uncertainty in the country (BARROS, 2016; BRASIL, 1965; 2012; GOMES; MARTINELLI, 2012). This softening of protection of native vegetation areas reinforces the existing political-economic bias to the detriment of maintaining environmental integrity (SANTOS, 2012).

Although the creation of SNUC is considered a progress in the Brazilian environmental legislation, it is possible to observe by the works of Bellinassi et al. (2011), Gonçalves et al. (2011), Silva et al. (2006), Simon (2001), Terra and Rozely (2011) that only the successive creation of PAs does not guarantee the fulfillment of the goals and plans stipulated by law and that, in most cases, such units end up being poorly managed (DOUROJEANNI; PÁDUA, 2001). Thus, the creation of PAs itself is not enough to protect the natural and cultural heritage of a nation (DEBETIR, 2006), and its effective implementation and enforcement are required (FARIA, 1997).

In the municipality of Barbacena, located in Minas Gerais, Brazil, the Municipal Law No. 2,250 of November 30, 1987 created the Pinheiro Grosso Biological Reserve (ReBio, in Portuguese), which belongs to the PAs Integral Protection Group (BARBACENA, 1987). This ReBio has demanded essential attention regarding its control. Its location is strategic for the protection of fauna and flora, as it is inserted in the devastated Atlantic Forest biome, and is located in one of the headwaters of Rio das Mortes, belonging to the Rio Grande basin. Despite its ecological relevance, this PAs is under significant anthropic pressure and presents elementary problems in its management.

The Geographic Information System - GIS, Digital Cartography, Remote Sensing and the Global Positioning System - GPS are widely used in environmental studies. Several authors, including the PAs researchers, have used these geotechnologies to assist in the management, implementation, delimitation, zoning, management, planning and supervision, optimizing the diagnosis and monitoring of these areas (ARAGÃO; DUARTE,

2016; BALDWIN et al., 2014; KHANDAY; JAVED, 2016; REIS; COSTA, 2017; VENTICINQUE et al., 2016).

In this sense, this study aimed to characterize the current uses of Pinheiro Grosso ReBio using geotechnologies and to present its vulnerability to anthropization.

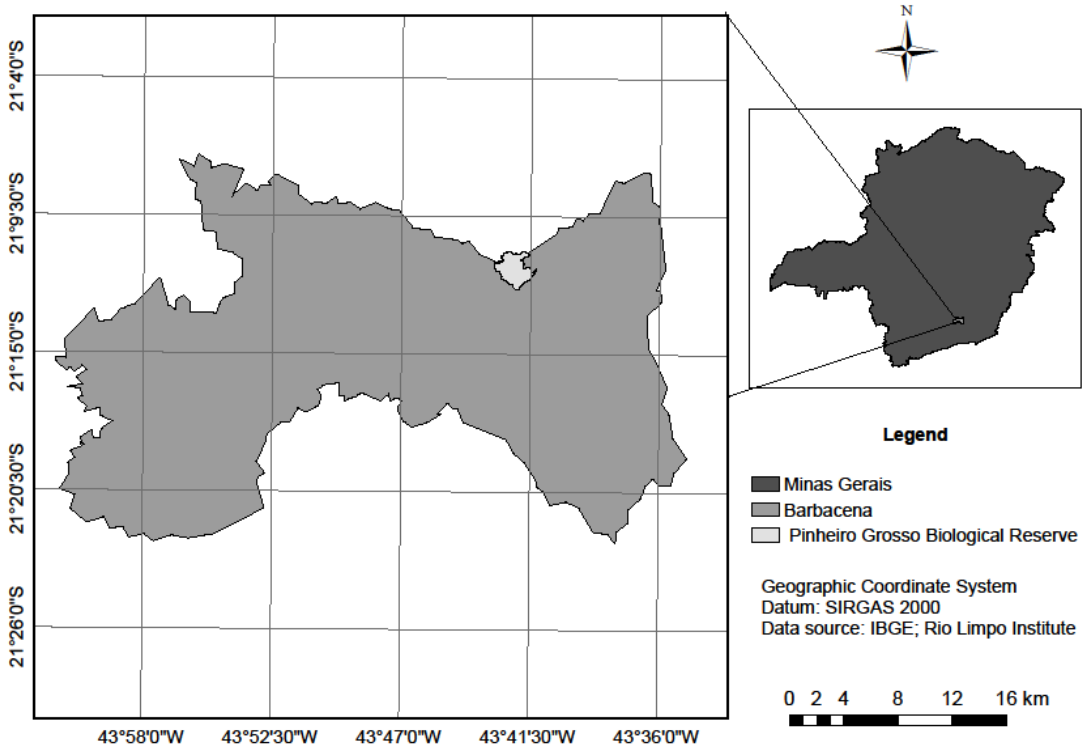
MATERIAL AND METHODS

The Pinheiro Grosso ReBio is located in Barbacena - MG, in the Pinheiro Grosso District (Map 1), between latitude 21° 15' South and longitude 43° 45' West, this ReBio covers an area of 479 hectares (ha), with an average altitude of 1,126 m.

Study Area Delimitation

The delimitation of the study area was based on information from the Management Plan and documents related to the PAs, consultations with municipal agencies and on-site visits. A navigation device (Garmin® *eTrex* 30 GPS signal receiver) was used in on-site visits. The coordinates of the study area were initially processed in a spreadsheet and later in ArcGIS software, version 10.5.1. The coordinate and reference systems adopted were, respectively, the Geographic Coordinate System and the Geocentric Reference System for the Americas, Datum - SIRGAS 2000. The coordinates were processed in the ArcGIS ArcMap component through the Projections and Transformations - Define Projection tool contained in the Data Management Tools module.

Map 1 - Location of Pinheiro Grosso Biological Reserve, Barbacena-Minas Gerais.



Org.: from the Author, 2019.

Obtaining and Classifying Digital Images

The study area was characterized by the classification of high-resolution digital images, which are spatial resolution in multispectral mode (Blue, Green, Red and Near Infrared) of 2.0 m to nadir, available by ArcGIS software in the DigitalGlobe/Esri collection, coming from the satellite: GeoEye/Multispectral sensor.

The image was processed and the area of interest extracted using ReBio polygonal coordinates as reference. In this process, the ArcMap component was used through the Extraction - Extract by Mask tool, contained in the Spatial Analyst Tools module.

To determine the classes, the Supervised Classification Method was adopted. The classifier used was Maximum Likelihood. Two classes were determined: 1) Anthropized area, corresponding to human occupation, such as houses, streets, bare soil, cropland or pasture; e 2) Vegetation**,** referring to those areas formed by native or planted vegetation, since the classifier was not able to differentiate them. From training samples, the process was performed using the Image Classification tool, found in Toolbars, of the Spatial Analyst module.

Thematic map generation and Multicriteria Analysis

The Multicriteria Analysis (MA) was guided by Hierarchical Weight Analysis (HWA), a method developed by Thomas Saaty (1978). This methodology assists in assigning the weights of information plans to determine their influence on each of the established criteria (MOURA, 2007).

Therefore, the data were organized and processed in a GIS environment, through the establishment of criteria. The weights associated with the criteria were assigned based on their level of influence on the environmental weakening (Table 1).

Table 1 - Weights assigned to influence levels for Multicriteria Analysis.

Weight	Influence level on environmental weakening
1	Little
2	Low
3	Average
4	Strong
5	Very Strong

Source: Adapted from MOURA, 2007.

Buffers were generated for the servitude zones contained within the PAs, standardized by each company, being: 60 m from the cleaning strip of Minas Gerais Energy Company (CEMIG), for voltages above 345 Kv; 20 m to the Brazilian Oil Pipeline SC (PETROBRAS) and 15 m to the MG-132 Highway. Such areas, as well as the area occupied by the community inside the ReBio received the highest weight in the MA, Weight 5. This attribution was justified by the fact that these areas already have consolidated anthropogenic occupation and, consequently, present, in the surrounding areas, a greater vulnerability to environmental change (Table 2).

To extract the slope a Digital Elevation Model (DEM) was generated from Shuttle Radar Topography Mission (SRTM) data. The interpolator used was Topo to Raster, located in the Spatial Analyst Tools - Interpolation

module. Later, through the Reclassify tool, the slope was extracted from DEM. Areas with slopes below 20º were selected and, in MA, assigned to them Weight 4, because they are areas of preferential occupation of both the population for housing and agricultural activity. Through this same justification, Weight 5 was assigned to the Hydrography criterion. This criterion adopted a 30m buffer from existing watercourses (Table 2).

Table 2 - Weights according to influence by analysis of influence levels.

Criterion	Weight
Anthropized Area	5
CEMIG	5
Slope	4
Pipeline	5
Hydrography	5
Highway	5
Vegetation	1

Org.: from the Author, 2019.

Regarding vegetation, it received Weight 1, with a level of influence characterized in "Little," in view of both the Atlantic Forest Law (Federal Law No. 11,428, of December 22, 2006) that protects the remnants of this biome as well as the own purpose of a ReBio. Thus, among all classes, vegetation is the least vulnerable to environmental change (Table 2). All these weights were assigned using the Reclassify tool.

Then, using the Weighted Overlay tool of the Spatial Analyst module, the criteria were weighted overlapping according to the predefined weights. Thus, a map with the classes: High anthropization risk, Low anthropization risk and Anthropized area was generated. At this stage, all infrastructures and the area occupied by the community were identified through photointerpretation.

RESULTS AND DISCUSSIONS

From the delimitation made, Pinheiro Grosso ReBio has 479 ha. It is noteworthy that there is no official document formalizing the limits of this ReBio. This fact shows the precariousness of information about the unit, since the delimitation of a PAs is something elementary for any action to be taken, including its own creation.

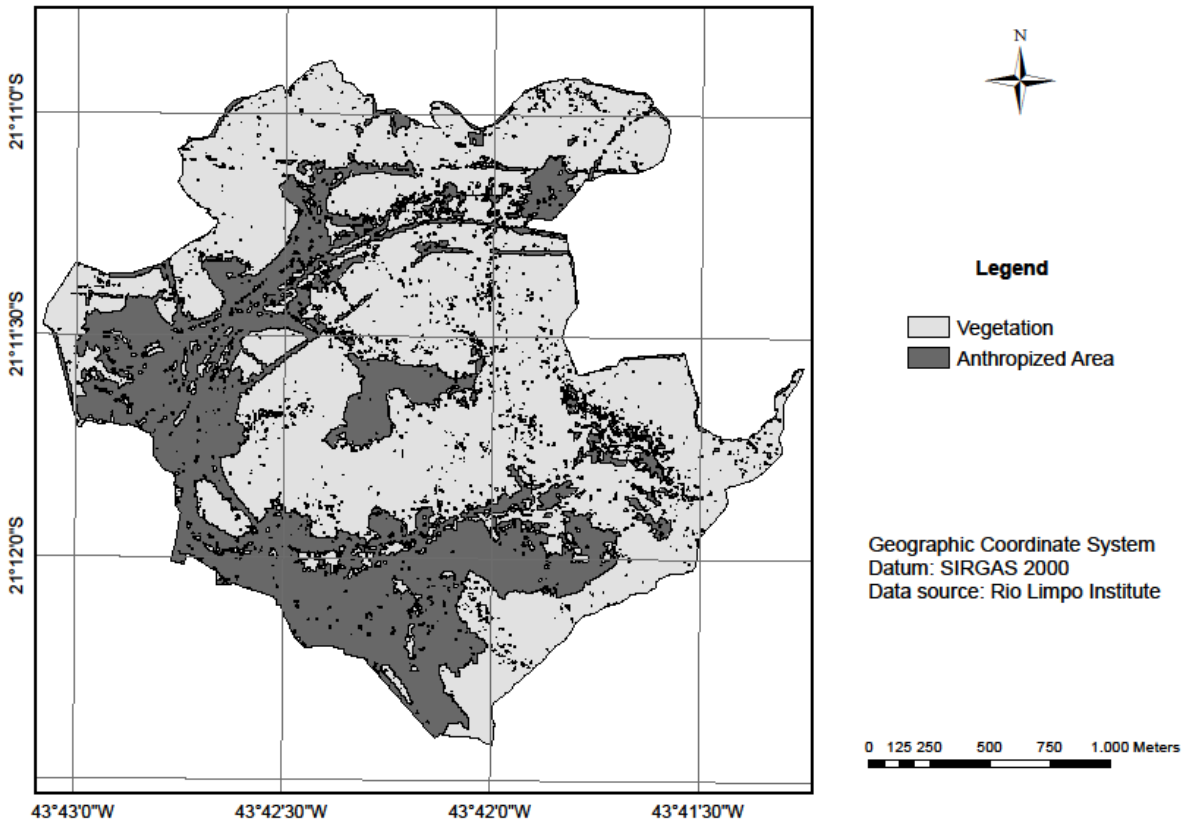
Of the 479 ha of Pinheiro Grosso ReBio, 66.17% (317 ha) correspond to the Vegetation class and 33.82% (162 ha) to the Anthropized Area class (Map 2). Considering these values, it is possible to assume the great anthropic pressure and the numerous socio-environmental conflicts that exist in ReBio. Biological Reserves, as they belong to the most restrictive category of SNUC, do not allow the exploitation of their natural resources or even housing within their limits.

Most of the district's population is within the unit, occupying an area of 41.55 ha, representing 8.67% of the total area (Map 3). Although the Buffer Zone (BZ), correspond to an area that aims to minimize negative impacts on the unit, such an area has not yet been established for Pinheiro Grosso ReBio. It is worth highlighting that, like the interior of a PAs, the BZ also has specific rules and restrictions regarding the development of human activities. Either inside or within a

ReBio range that corresponds to a potential BZ of the unit, there are several private properties, with the predominance of pastures, which would also lead to conflicts when defining the BZ (Map 3). In this context, it is worth mentioning that, although the Pinheiro Grosso ReBio Management Plan was created only in 2006 and is not yet being implemented, the SNUC determines that the BZ can be defined at the creation of the unit or later (art. 23, § 2) (BRASIL, 2000).

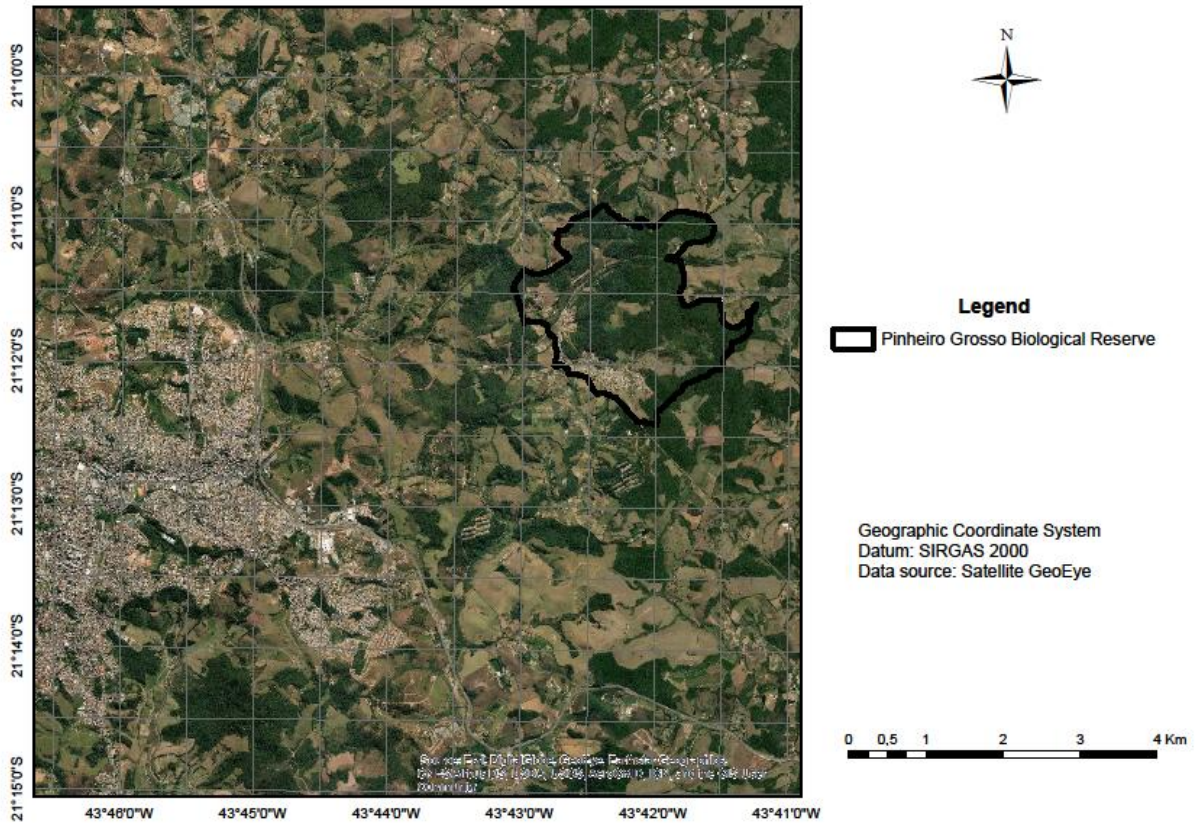
In another perspective it's possible to analyze in Map 3 is the fragmentation of native vegetation near the Pinheiro Grosso ReBio. However, it is possible to notice large fragments of forest even already connected to the unit, as well as other very close fragments with great connection potential.

Map 2 - Land use and occupation in the Pinheiro Grosso ReBio, Barbacena – MG.



Org.: from the Author, 2019.

Map 3 – Satellite image of the Pinheiro Grosso Biological Reserve, Barbacena - MG and the surrounding area.



Org.: from the Author, 2019.

Other PAs have also demonstrated cases of land use and occupation conflicts, such as those found at Pinheiro Grosso ReBio. An example can be demonstrated by the work of Santiago et al. (2007) in a study carried out at ReBio Mata do Poço D'anta, located in Juiz de Fora (Minas Gerais state), where the existence of conflicts within the unit was pointed out, with paved roads, a soccer field, a City Hall concrete factory and a seedling nursery, making it difficult to manage. Barros and Barbosa (2015) reported the situation of Gurupi ReBio (Maranhão state) that, in addition to suffering from the low volume of studies and information available, such as the PAs studied in this work, it has a high rate of deforestation, as indicated by the Report on Deforestation and Climate Change between 2000 and 2004. Iwama et al. (2014), in a study carried out in the Pedra Branca State Park (Rio de Janeiro state), identified the increase of housing and people over the years, with upper and lower class residents and the development of agriculture within the park boundaries. In Rio Grande do Sul state, Flores et al. (2009) presented, among other aspects, the issue of land use conflicts in the Lagoa do Peixe National Park and the Tupancy Municipal Natural Park. Activities such as agriculture, extensive livestock, fishing, afforestation with exotic vegetation (pine), uncontrolled tourism and the urbanization associated with real-

estate pressure were pointed by the authors as responsible for generating conflicts in these units that are also Integral Protection.

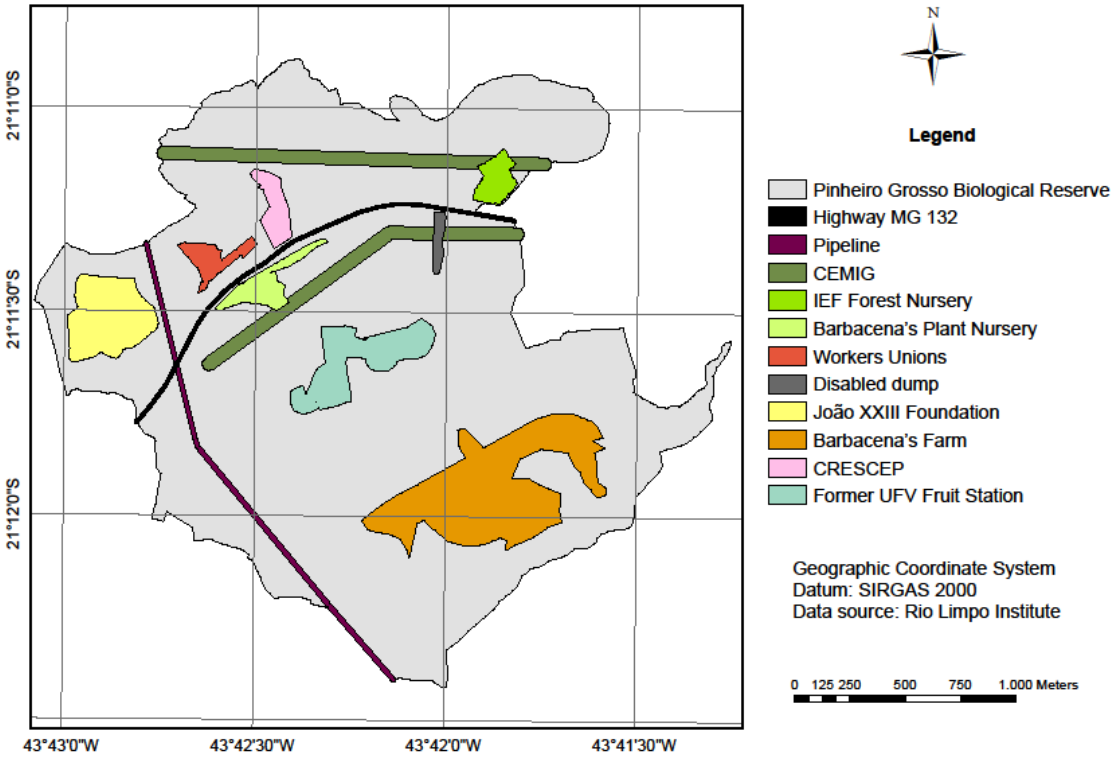
In the case of Pinheiro Grosso Rebio, although more than 60% of the unit corresponds to vegetation, it his whole class is not equivalent to native vegetation, given the existence of planted forests within its limits (Table 3, Map 4).

Table 3 - Infrastructures within Rebio and their respective areas.

Infrastructures	Area (ha)	Total area (%)
Barbacena's Farm	33,14	6,91
CEMIG	20,44	4,26
João XXIII Foundation	11,85	2,47
Former UFV Fruit Station	11,52	2,34
Pipeline	4,68	0,97
Barbacena's Plant Nursery	4,15	0,86
CRESCEP	3,35	0,69
Highway MG 132	3,22	0,67
IEF Forest Nursery	3,07	0,64
Workers Unions	3,00	0,62
Disabled dump	1,21	0,25
TOTAL	**99,63**	**100**

Org.: from the Author, 2019.

Map 4 - Infrastructures at Pinheiro Grosso Biological Reserve, Barbacena-MG



Org.: from the Author, 2019.

The occupation of areas by private agencies within the unit has intensified its fragmentation, causing degradation and damage to the conservation of local nature. However, the fact that it is a public utility activity should require even more attention

from managers regarding the management methods adopted, as this may serve as a justification for the local population to exempt themselves from environmental responsibilities (CRUZ et al., 2013).

Regarding the presence of resident families, either in the surroundings or even within the Pinheiro Grosso ReBio, many of them already resided at the site even before the creation of the reserve. Nevertheless, land irregularity is a reality of these families or those who occupied new areas, even after the creation of ReBio. Relocation and compensation for these families is a City Hall responsibility. However, given the difficulties faced by municipal management, it is unlikely that such measures will become effective, although they are the legal measures for such situation (SILVA; SILVA, 2014). In this context, it is important to note that most Brazilian PAs, especially National Parks, Ecological Stations and Biological Reserves, have faced these land problems since their inception, a real challenge that accumulates and worsens over the years (ROCHA et al., 2010).

Given this complex scenario regarding the presence of residents, especially within the limits of a Integral Protection PAs, Coelho and Rezende (2016) suggest that the expropriation of areas should be done before the establishment of the unit, based on planning, aiming to avoid subsequent conflicts between public and private authorities. According to these authors, the diffuse right to the ecologically balanced environment prevails over private property, that is, expropriation is meant to safeguard environmental guarantees.

In this context, Pivoto (2019) analyzed the land situation of the Serra do Cipó National Park (Minas Gerais state) and pointed out that, despite being created in 1989, there are still territorial conflicts between the government and the local population. The author point the case of the Lençois Maranhenses (Maranhão state) and Tumucumaque Mountains National Parks (Amapá and Pará states) where traditional populations are collaborators for the protection of biodiversity and not an obstacle to the protection of the country's natural heritage. In this sense, Flores et al. (2009), although they consider the relationship of the local community with the PAs as delicate, they highlighted the importance of involving the population in the conservation process as well as the constant work of environmental education that must be carried out. In both PAs analyzed by these authors, the Tupancy Park and the Lagoa do Peixe Reserve (Rio Grande do Sul state), the importance of the participation of the local community was evidenced, either in the creation or conservation of nature. In addition, the authors also pointed to the need for continuous maintenance of the units, with monitoring of the areas as well as the development of scientific research. Barros and Barbosa (2015) also highlighted environmental education as a relevant instrument in raising public awareness regarding the preservation of natural resources.

In the study by Santiago et al. (2007) at Mata do Poço D´antas ReBio, Juiz de Fora (Minas Gerais state), the possibility of

reclassifying the unit to the Municipal Natural Park was raised, due to anthropic interference in the PAs, as previously mentioned. The authors pointed out that this other category is still a Integral Protection PAs, aimed at preserving natural ecosystems, with permission for use in the case of scientific research, environmental education activities in addition to recreation in contact with nature and ecological tourism. According to the authors, the unit's problems are not only solved by changing the PAs category, but with this initial change, the Management Plan becomes more flexible, allowing the legal integration of the community. Likewise, Silva and Silva (2014), for Pinheiro Grosso ReBio, based on the analysis of interviews, the need to recategorize the unit so that it is possible to exploit natural resources in a sustainable manner, reconciling the right to property of traditional populations with environmental protection. Such a change becomes timely given the degree of anthropic interference in the unit and the complexity of the land issues intrinsic to the ReBio in question. Thus, given the reality presented by Pinheiro Grosso ReBio, it is pointed as fundamental and primordial for its management, the work of environmental education, especially to be carried out with neighboring communities so that there is the beginning of a process of awareness about conservation of the nature of unity.

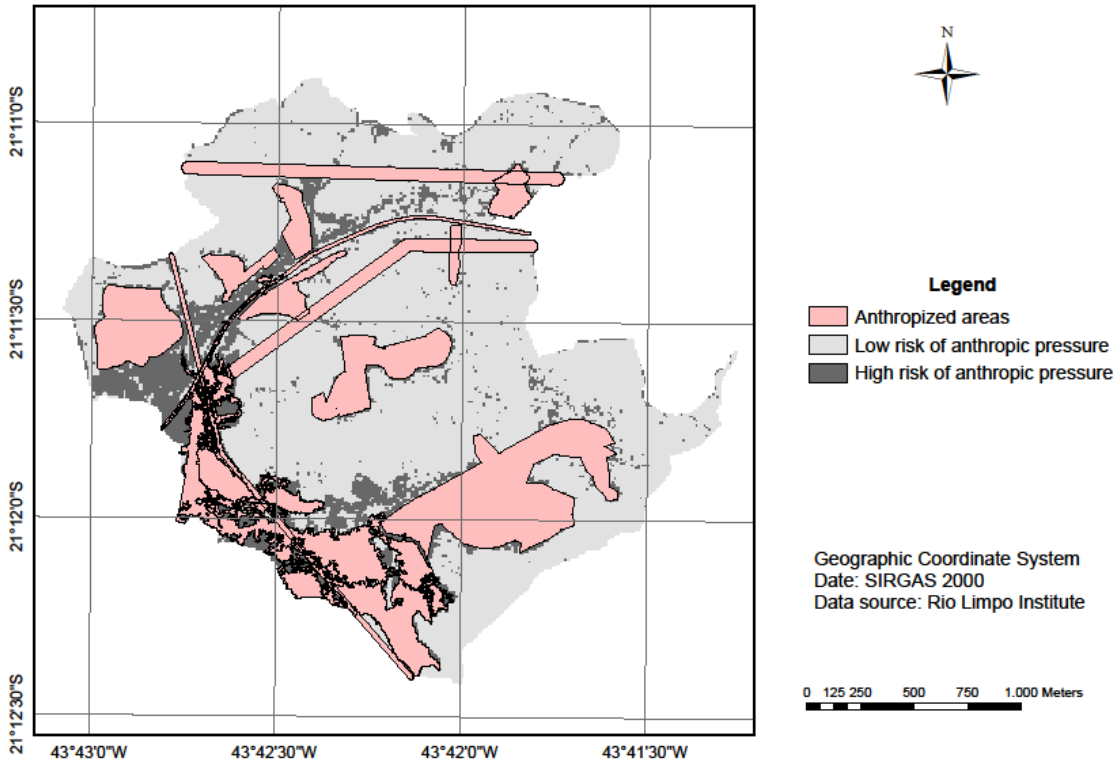
With High risk were identified 20.1 ha of anthropic pressure, representing 4.19% of ReBio, while 317.43 ha (66.26%) with Low risk (Map 5). At this stage of the Multicriteria Analysis (MA), the anthropized area, identified by the photointerpretation method, had a value of 141.56 ha (29.55%). This value was different from that found by the classifier (162 ha), because the classifier identified pixels with a value close to that class, where possibly much of it corresponds to clearings inside the forest (Map 2). This fact also determines the robustness of the classification method that was able to identify these peculiarities, not visually detected by the photointerpretation method. When comparing Map 2 with Map 5, many of these pixels, not considered as an anthropized area in photointerpretation, were classified by MA as High risk. The justification for this difference is also supported by the use of criteria for the generation of results by the MA, which goes beyond just the spectral response of the target, used by the classifier.

Although the High risk class for anthropogenic pressure was apparently low (20.1 ha), it should be remembered that the PAs under analysis is a ReBio, from the Comprehensive Protection group.

Pina (2017) used the MA in the elaboration of maps, in order to indicate the need to recover potential areas for the implementation of ecological corridors, demonstrating such an effective technique for environmental analyzes.

Thus, the result obtained with the Multicriteria Analysis for Pinheiro Grosso ReBio contributing to the knowledge of the areas that are most vulnerable to anthropic pressure, and this information is valuable to be used in an environmental zoning of the unit.

Map 5: Risk of Anthropic Presure at Pinheiro Grosso Biological Reserve, Barbacena-MG.



Org.: from the Author, 2019.

FINAL CONSIDERATIONS

Although over 66% of this unit (317 ha), were classified as Vegetation, some of them do not correspond to native vegetation, but rather to planted eucalyptus forest. With regard to the remaining 35% of the ReBio area, approximately 160 ha, which correspond to areas already anthropized, it's necessary to consider the fact that a rural community falls within its limits and also in the bordering area, which tends to put the ReBio in question in a further situation to anthropic changes. Thus, in regard to land use and occupation, Pinheiro Grosso ReBio current scenario is alarming from the point of view of its preservation as a PAs belonging to the Integral Protection group. Such reality hinders the purpose of the Biological Reserve category, which is the conservation of nature.

Although there are conflicts related to private property in the vicinity of ReBio, which areas correspond to a possible Damping Zone, it is suggested the official delimitation of this area for the unit.

Thus, emergency and continuous environmental education programs should be implemented throughout the district to which ReBio belongs. Thus, it is possible to transform the local population that has negatively impacted ReBio since its creation into an active population, participant and defender of the natural resources of this PAs.

The supervision and monitoring of the Pinheiro Grosso ReBio is essential to prevent new occupations of the population or any other

infrastructure that exists near or within the limits of this PAs, and thus aggravate the current situation. Therefore, the result of the Multicriteria Analysis of this work indicated the areas with the greatest potential to be anthropically altered.

Finally, it is recommended for Pinheiro Grosso ReBio to recategorize, transforming it into a Sustainable Use Unit, so that its management objectives can be met according to Brazilian legislation.

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