ANALYSIS OF LAND USE CHANGE IN PEDRA BRANCA STATE PARK BUFFER ZONE, RIO DE JANEIRO CITY - BRAZIL

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ABSTRACT

The urban pressure on protected areas in large urban centers makes it urgent to discuss the land use and occupation around conservation units (CU). The Pedra Branca State Park (PEPB) is a fully protected Conservation Unit (CU) which, according to the National System of Conservation Units (SNUC), is intended to preserve natural ecosystems of great ecological relevance and scenic beauty. The PEPB presents in its management plan the delimitation of the Buffer Zone (BZ), which has the function of minimizing impacts and ordering the land use surrounding the Park, protecting the fauna and flora inside. The present work aims to analyze the reduction of vegetation cover between the years 2004 and 2018 in the BZ of the PEPB, with the help of the Land Change Modeler (LCM) tool, of the IDRISI software. In addition to, identifying how legislation and land use changes in the municipality of Rio de Janeiro, contributed to encourage residential occupation of this territory.

Keywords: Conservation units. Urban area. Legislation. LCM.

ANÁLISE DE MUDANÇA NO USO DO SOLO NA ZONA DE AMORTECIMENTO DO PARQUE ESTADUAL DA PEDRA BRANCA, CIDADE DO RIO DE JANEIRO – BRASIL

RESUMO

A pressão urbana sobre as áreas protegidas nos grandes centros urbanos, torna urgente o debate sobre o uso e ocupação do solo no entorno das unidades de conservação (UC). O Parque Estadual da Pedra Branca (PEPB) é uma Unidade de Conservação (UC) de proteção integral que, de acordo com o Sistema Nacional de Unidades de Conservação (SNUC), destina-se à preservação de ecossistemas naturais de grande relevância ecológica e beleza cênica. O PEPB apresenta em seu plano de manejo a delimitação da Zona de Amortecimento (ZA), a qual tem a função de minimizar impactos e ordenar o uso e a ocupação do solo do entorno do Parque, protegendo a fauna e a flora do seu interior. O presente trabalho visa analisar a redução da cobertura vegetal entre os anos de 2004 e 2018 na ZA do Parque Estadual da Pedra Branca, com o auxílio da ferramenta Land Change Modeler (LCM), do software IDRISI, e identificar como as legislações e as mudanças de uso do solo no município do Rio de Janeiro, contribuíram para incentivar a ocupação residencial deste território.

Palavras-chave: Unidade de conservação. Área urbana. Legislação. LCM.

INTRODUCTION

The growing urban pressure on forest remnants makes it urgent to discuss changes in land use around conservation units (CU), especially those located in urban areas of large cities. In Brazil, according to the National System of Conservation Units (SNUC), the CU aim is to preserve natural ecosystems of great ecological relevance and scenic beauty. On its management plan the CU presents the delimitation of the Buffer Zone (BZ). According to Trzyna (2017) in many urban protected areas there is no possibility of creating a formal BZ, due to the consolidation of occupation inside. Where there is an opportunity to create a BZ, it is necessary to regulate land use, but this depends on the local culture, the legal system, and ultimately political will (Trzyna, 2017).

The BZ is the area surrounding a conservation unit, where human activities are subject to specific rules and restrictions, with the purpose of minimizing negative impacts on the unit. Therefore, its limit may be defined in the act of creating the unit or later (BRASIL, 2000).

This work aims to analyze the reduction of vegetation cover, between the years 2004 and 2018, in the BZ of PEPB, with the help of the Land Change Modeler (LCM) tool, of the GIS software IDRISI Selva edition 17.0 (education software license from the Teaching Laboratory in Geography - Institute of Geography - LABGEO-UERJ). According to Aryaguna and Saputra (2020), the LCM is a function of spatial modeling to predict land cover changes. LCM evaluates changes of the land use of two different periods, determines the changes, visualizes changes, and presents the results with various maps and graphs (Leta; Demissie;Tränckner, 2021). In addition to identifying how the land use legislation of the municipality of Rio de Janeiro contributed to promote residential occupation of this territory. The choice of the time interval refers to the real estate market. The year 2004 is prior to the real estate boom in the city of Rio de Janeiro and 2018 encompasses the period of decline of this market. Furthermore, according to the IPP (2018), there is the methodological compatibility employed in the extraction of the classes in both dates, enabling the comparative analysis. In the same period, the Urban Structure Plans (USP) for several areas of the City of Rio de Janeiro also emerged.

MATERIALS AND METHODS

Study area

Pedra Branca State Park (PEPB) is a fully protected CU, created in 1974 under state law 2.377. It is considered one of the largest natural parks in urban areas in the world, it covers an area of more than 12,500 hectares in the municipality of Rio de Janeiro. According to the IBGE (1992), PEPB is one of the most significant Atlantic Forest remnants, located in the western part of the city of Rio de Janeiro. PEPB's BZ was defined with an area of 8,810.7 hectares in the 2013 Management Plan (Figure 1).

Figure 1 - Pedra Branca State Park and Buffer Zone (RJ): study area, 2023
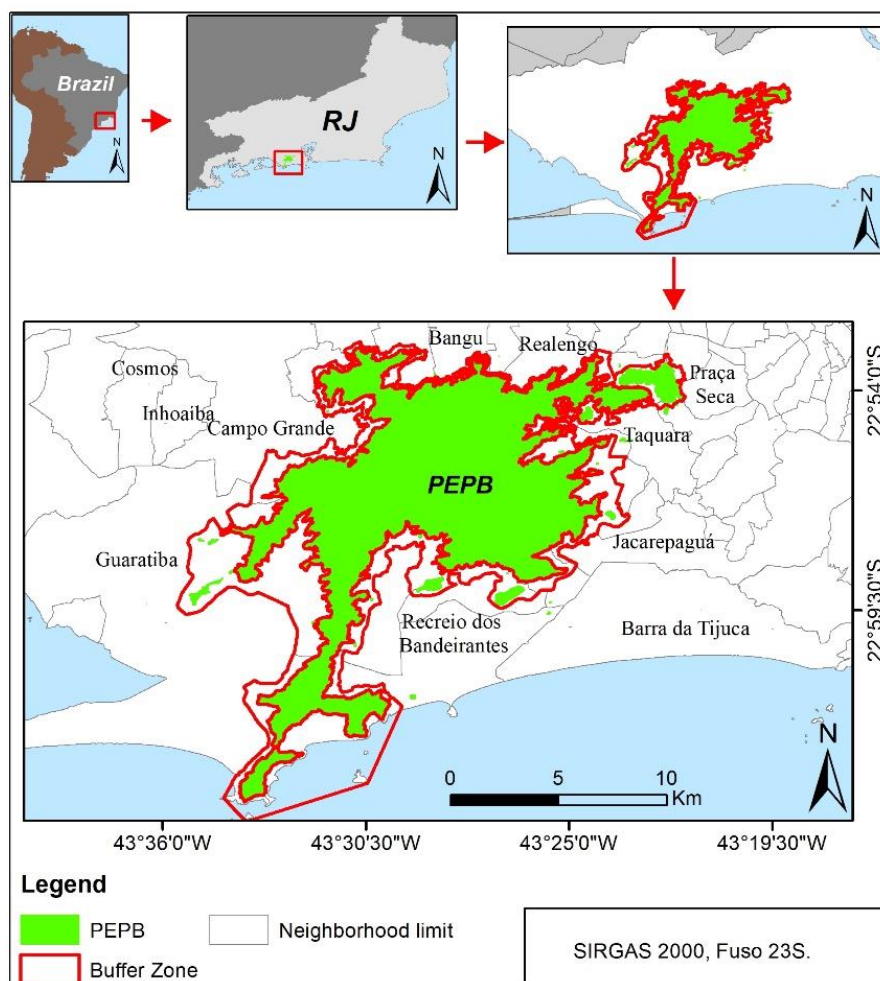
Sources: IBGE, 2010; IPP, 2018. Organization: the authors, 2023.

Data Set

For the creation of the PEPB BZ database in GIS, the spatial files in vector format and shapefile extension (.shp) of the land use of the years 2004 and 2018 (Figure 2) were used, among others, made available by Institute Pereira Passos (IPP, 2004; 2018), Rio de Janeiro City Hall.

Figure 2 - PEPB BZ land use map: years 2004 and 2018
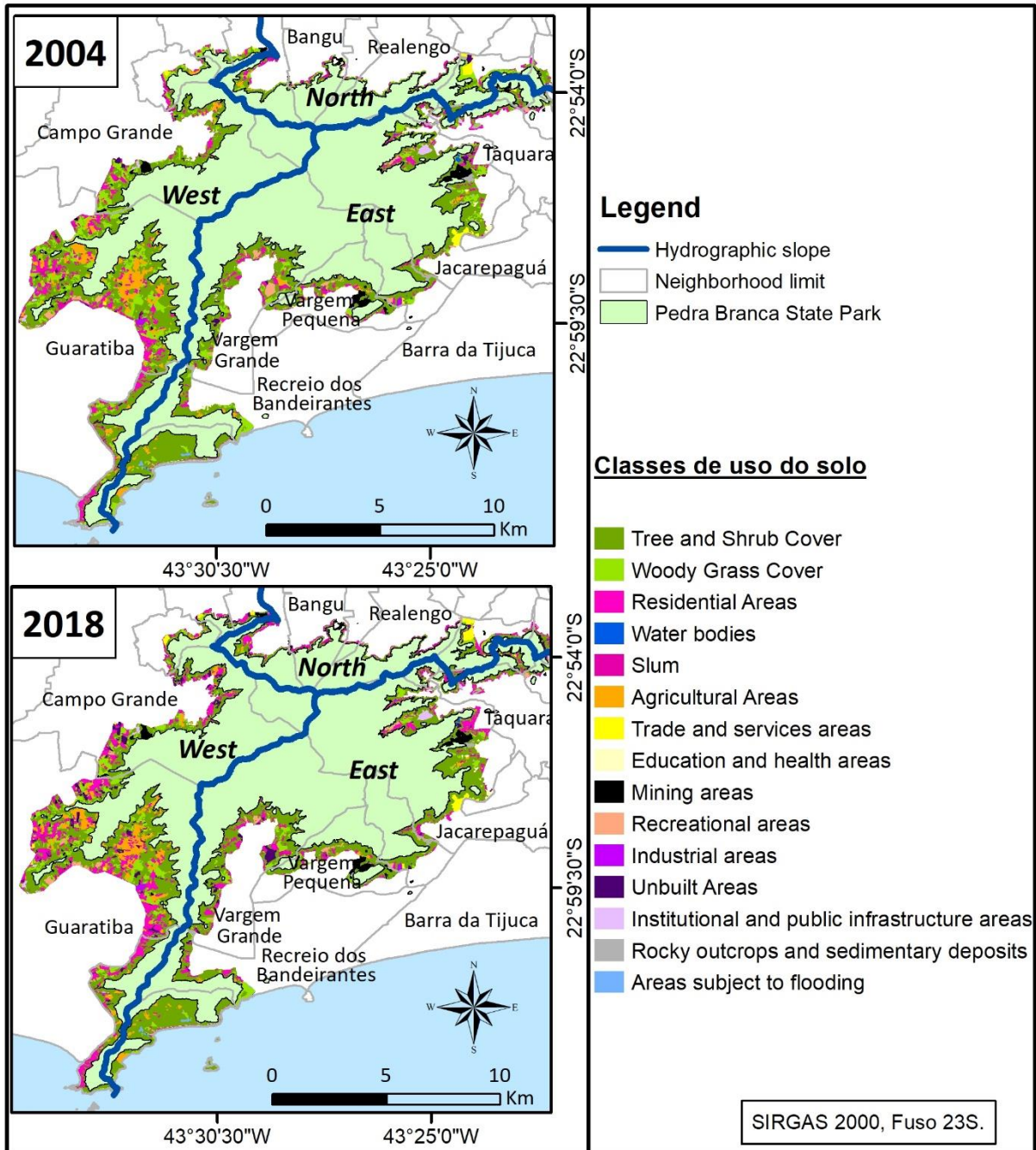
Sources: IBGE, 1992; IPP, 2004; 2018. Organization: the authors, 2023.

The land use mapping performed by IPP (2004) consists of the classification of urban and non-urban morphologies of the city of Rio de Janeiro through visual interpretation of digital orthophotos (Fusco; Costa; Gahyva, 2012). The shape file metadata informs that the work performed by IPP (2018) consisted of the vectorization of land use and land cover of vegetation classifications of the city of Rio de Janeiro. This was carried out from the interpretation of orthophotos at a scale of 1:10,000 for the respective

years, together with experiences accumulated in field surveys (Pereira et al., 2021). The vector files (shapefiles) were treated in ArcGIS 10.5 software, then land use maps were prepared for the year 2004 and 2018, in the PEPB BZ, so that the values and legends were identical.

Following the methodology (Figure 3) proposed by Pereira et al. (2021) the distribution maps of the land use classes referring to the years 2004 and 2018 were exported to the IDRISI software, aiming to identify the classes that presented themselves more dynamic in the study area. The background areas in both maps were specified as 0 and are identical, otherwise they cannot be compared. The spatial parameters, rows and columns in the generated raster file, were calibrated to be equal in both maps, thus allowing the comparison of areas where the land use class decreased or increased. For this, the LCM tool was used, through which it was possible to generate the graph of losses and gains - a quantitative evaluation that shows, in a bar graph, how much each class has lost and gained in area (Pereira et al., 2021). According to Assalve and Fuzzo (2021), the LCM is important for environmental studies, as it allows us to analyze the changes that have occurred in a landscape. It is a popular tool for analyzing and forecasting land use change in order to assess its influence on biodiversity (Haj; Ouadif and Akhssas, 2023).

To compare changes in land use, in the LCM Project Parameters option was added to the 2004 map in the previous land cover image and the 2018 map in the subsequent land cover image. It was then possible to create a graph with the land use classes that contributed most to the variation in residential areas through the Change Analysis option where the Residential Areas class was selected in the Contributors to net change. Then to generate the Persistence Map, the tree and shrub cover class was selected in the map's Gains/Losses option by selecting the Persistence option, making it possible to identify where in the study area the vegetation underwent the least change over the period analyzed. LCM Change Analysis presents a set of tools for the rapid assessment of changes in land use, making it possible to generate assessments of gains and losses, persistence and specific transitions, in both map and graph form (Eastman, 2012).The entire procedure was repeated with only with the area of the PEPB buffer zone in the Campo Grande, Region to generate the contribution graph of change the class land use tree and shrub cover, to see which use class has grown the most over the vegetation in this area.

Also, the IDRISI area calculation tool was used to measure how many hectares each class of land use and occupation lost in the analyzed period, to generate the table with losses and gains between the years 2004 and 2018. Finally, the land use legislation of the municipality of Rio de Janeiro was analyzed. This made it possible to identify the type of use allowed by public administrators in the vicinity of the PEPB BZ that contributed to promote residential occupation in this territory.

Figure 3 - Flowchart of the GIS methodology
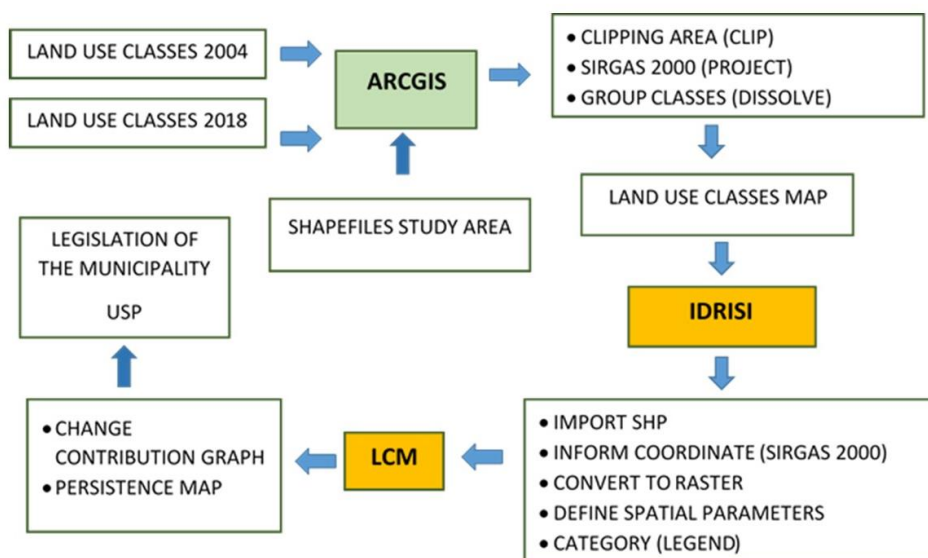
Source: Adapted from the methodology proposed by Pereira et al., 2021. Organization: the authors, 2023.

RESULTS AND DISCUSSIONS

Conservation unit buffer zone in an urban area

Since the end of the nineteenth century, the creation of CU has established itself in the world and in Brazil as the main strategy for the protection of nature (Drumont; Franco; Oliveira, 2010). According to Drumont, Franco and Oliveira (2010), the most recognized founding milestone of the modern protected areas policy was the creation, in the United States of America, of Yellowstone National Park, in 1872, which influenced the environmental public policies of countries like Brazil. The incorporation of the American model of National Parks in Brazilian is seen as a great victory of the rising Brazilian environmental movement (Leite, 2015).

 According to Costa et al. (2007), Brazil has sought to regulate the creation of parks, biosphere reserves and forests since 1965, through the Forest Code (Law No. 4771). Nevertheless, only in 2000, through Law No. 9985, the country established the SNUC. To minimize or even avoid negative impacts on the CUs, BZs were defined (Ganem, 2015). As important as managing conservation units themselves, is to seek to establish criteria for use and occupation and monitor the buffer zones. This will help prevent encroachment on the boundaries of protected areas (Ribeiro; Freitas; Costa, 2010).

The concern with protected areas surroundings is something that has been drawing attention from groups around the world. This can be seen in the publication of Trzyna (2017), entitled "Urban Protected Areas - profiles and guidelines for best practices", which establishes general guidelines, offers examples of problems, opportunities, and solutions for these areas in an urban environment. An example of a protected area that is concerned with occupancy in its surroundings is the Calanques National Park in Marseille, France, where the BZ between the park core and urban parts is very narrow and, in some places, non-existent. Among the conflicts in the surroundings, Cadoret and Daumalin (2017) cite the real estate development in the former military complex of Mont-Rose, where the various pacts between political and economic actors have been denounced by residents, associations and opposition parties.

Another example is Bukhansan National Park in Seoul, South Korea where urban development, including high-rise apartment buildings, has reached the edge of the Park. As a result, Park managers and Seoul urban planners promote "ecological urban planning" in the buffer zone (Trzyna, 2017). Also in South Korea, Mudeungsan National Park in Gwangju, the city government has banned the advance of urbanization with planning and regulation of land use in the buffer zone. Taken together, these measures not only protect the Park, but also work to constrain urban sprawl (Trzyna, 2017).

Residential occupations are the most worrying pressure in Conservation Units within urban areas in Brazil, especially without domestic animals raising policies. According to Loss (2013) it is estimated that 1.4 to 3.7 billion wild birds are killed annually in the United States by domestic animals. In Australia, many urban environment protected areas suffer severe damage from domestic and street cats (Dickman, 1996). Residence proximity to CU can generate several negative impacts, such as deforestation and domestic animals attacking wildlife. The Domestic dogs may be considered a potential threat to the integrity of protected areas in Brazil (Lessa et al., 2016).

The PEPB is an example of a CU that suffers from urban pressure throughout its surroundings, where residences advance into the interior of this unit (Figure 4), also brings impacts to wildlife. Nevertheless, even with the urban pressure around PEPB, wild animals have been sighted by researchers who estimate that it is due to the low visitation during the Covid-19 pandemic period. Hunting for food, such as urban garbage and poultry farming, are constant for mammals, even large felines such as cougars that are sighted at the limits of CUs and increasingly closer to urban settlements (Menegassi, 2021).

Figure 4 - Residences on the edge of the PEPB: Rio Grande, Taquara neighborhood, 2018

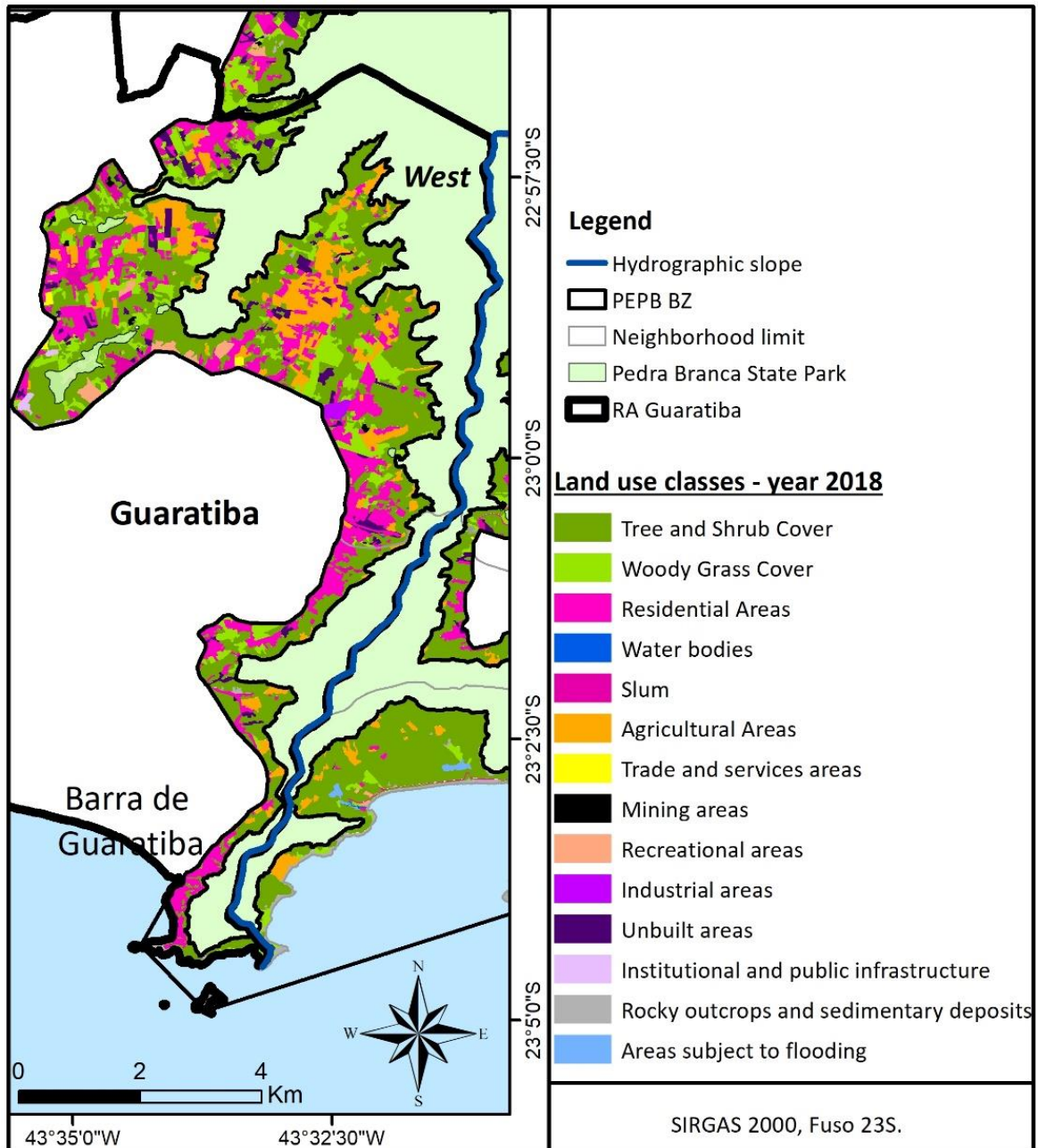Source: The authors, 2018.

PEPB BZ in Rio de Janeiro city

The Pedra Branca State Park (PEPB) was created in the 1970s, through state law no. 2.377, which established that all areas in the Pedra Branca Massif and its foothills above 100 meters height, are part of this integral protection Conservation Unit.

The PEPB BZ has the function of protecting the Park from impacts arising from activities developed in its surroundings. According to INEA (2013) to define PEPB BZ, it initially used as reference a 3 km buffer from the limit of the Park. Based on this area stretches were included and excluded, following criteria such as: inclusion of the Guaratiba aquifer, wetlands of ecological importance to the CU and preserved natural areas; as well as the exclusion of consolidated urban areas. PEPB's BZ is inserted in six Administrative Regions (AR's) under the management of the Rio de Janeiro City Hall: Bangu, Realengo, Campo Grande, Guaratiba, Barra da Tijuca and Jacarepaguá. The Bangu and Realengo area are the narrowest within the BZ, with less than 0,5 km width. Guaratiba and Barra da Tijuca have stretches with more than 1,5 km.

Analyzing the 2018 land use map it is seen that residential areas advance from the edge of the BZ towards the southernmost part of the western slope of the PEPB, especially in the Guaratiba AR, but there are still significant areas of family farming or class of agricultural areas (Figure 5).

The more dynamic land use classes, considering the total area of the BZ are: residential areas, tree and shrub cover, woody grass cover, agricultural areas and unbuilt areas. Between the years 2004 and 2018 the class Tree and Shrub Cover lost more than 238 ha, while Residential Areas gained more than 349 ha (Table 1).

Figure 5 - Land Use: West part of PEPB BZ, 2018

Source: The Authors, 2023

Table 1 - PEPB BZ Land use classes: Gains/Losses, between the years 2004 and 2018

| Classes | Year | | Gains/Losses (Ha) |
| | 2004 | 2018 | |
	Ha		
Tree and Shrub Cover	4.367,34	4.128,43	-238,91
Woody Grass Cover	1.088,46	807,98	-280,48
Agricultural Areas	791,13	402,15	-388,98
Unbuilt Areas	74,99	255,45	180,46
Residential Areas	791,13	1.140,55	349,42

Source: The authors on IDRISI Selva. Based on Land use data (IPP, 2004; IPP, 2018).

Agricultural areas lost more than 388 ha, between the years 2004 and 2018, as seen in Table 1. In the neighborhoods of Grumari, Guaratiba, Barra de Guaratiba and Campo Grande (western slope), there is the highest concentration of agricultural crops, of which banana, persimmon, cassava and ornamental plants stand out (INEA, 2013).

According to Costa (2006), it is on the northern slope of the PEPB (mainly with the neighborhoods of Realengo, Bangu, Jardim Sulacap), where the BZ is smaller, that the human occupation pressure occurs in a more expressive way. In the residential area change contribution graph (Figure 6), the Woody Grass Cover, Tree and Shrub Cover, and Agricultural Areas classes are the largest contributors to the growth of residences within the PEPB BZ.

Figure 1 - Residential area change contribution graph between the years 2004 and 2018 in the PEPB BZ
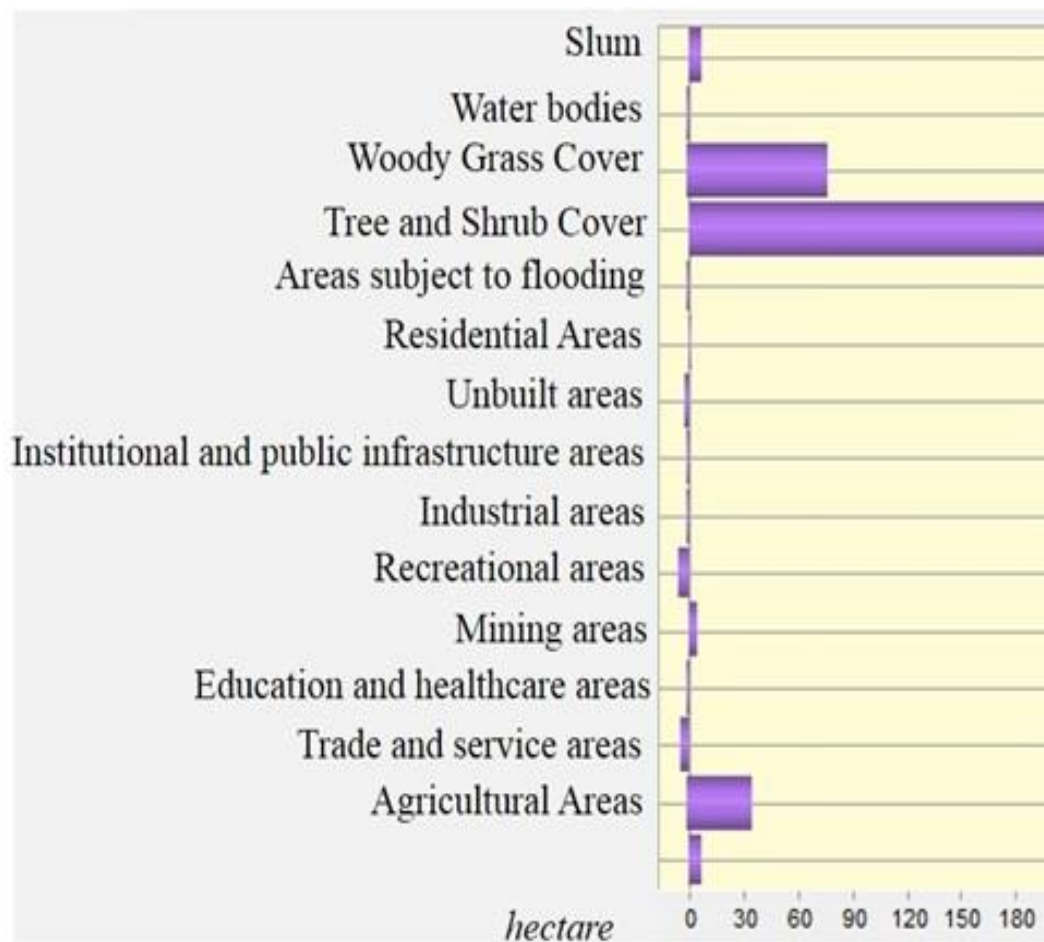

Source: Elaborated in IDRISI Selva with data from IPP, 2004 and IPP, 2018. Source: The Authors, 2022.

The unbuilt areas grew over 180 ha, enabling a more detailed analysis of the city's development since these areas, according to SMU (2017), represents a transition period for effectively structured urban areas, due to land preparation and implementation of construction sites for future residential areas. According to the PEPB Management Plan (2013) for the PEPB BZ, 182 environmental licenses have been issued since the year 2002, with the vast majority of municipal licenses issued with validity as of 2008, referring to the license for "Residential construction" (INEA, 2013). Despite this, the areas with vegetation cover in the PEPB's BZ are significant, especially on the eastern slope (Figure 7).

Figure 7 - Tree and shrub cover persistence map in the East part of PEPB BZ, 2004-2018
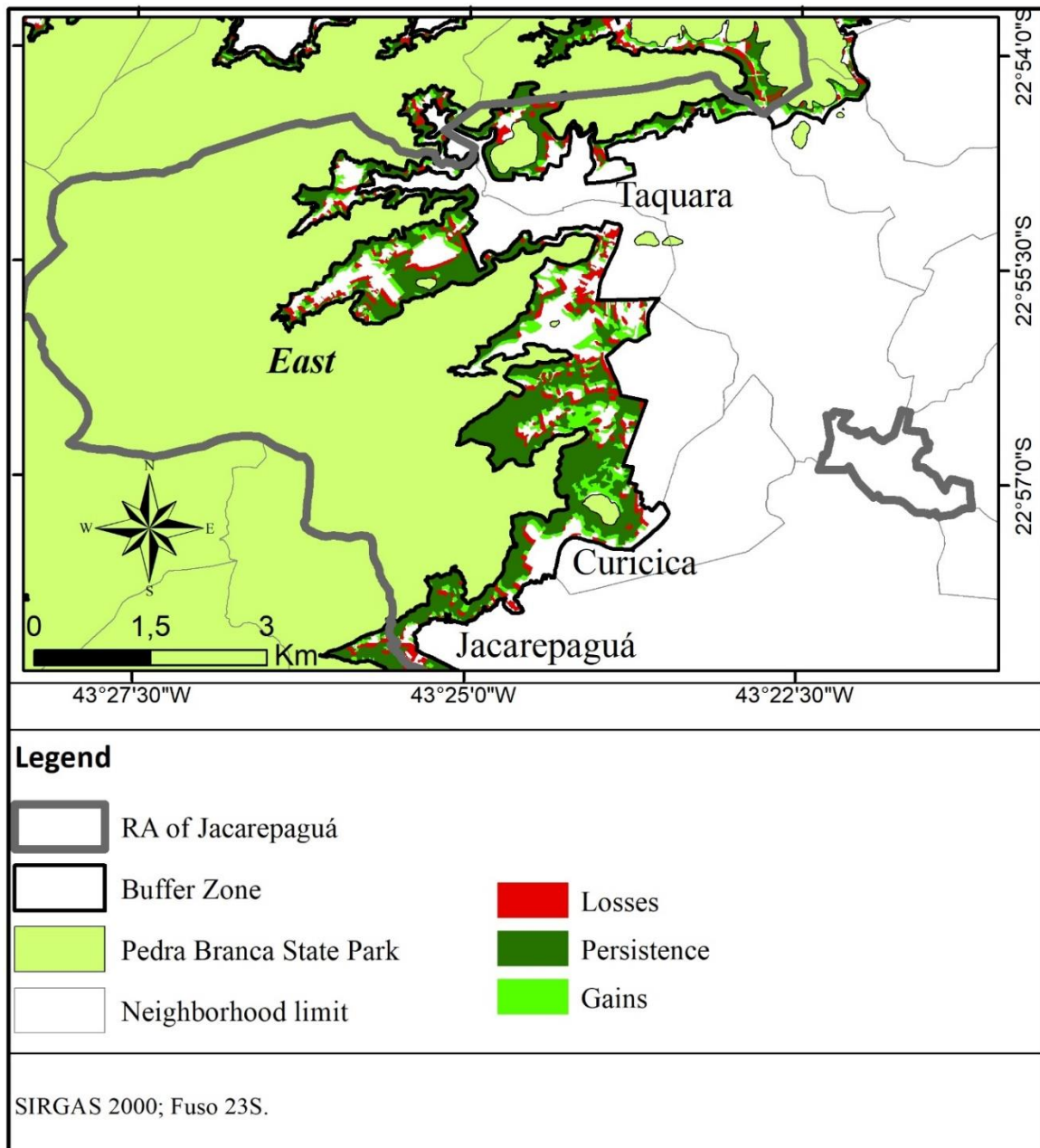
Source: The Authors, 2023.

### The USP as a facilitator of residential occupation in PEPB BZ

The Master Plan of the municipality of Rio de Janeiro defines the Urban Structure Plan (USP) as one of the urban planning instruments. This establishes the guidelines for local development and, updates and improves the urban legislation for a neighborhood or a set of neighborhoods (RIO DE JANEIRO (RJ), 2011).

In late 2009, new laws for specific neighborhoods or regions of the city were approved, motivated by the city's choice to host the 2014 FIFA World Cup and the 2016 Olympic Games (Cardeman, 2014). USP's were prepared for several neighborhoods in the West Zone of the city, with urbanistic parameters more attractive to the real estate market. Due to land saturation for building in the South Zone, this region began to be the object of interest by the sector (Cardeman, 2014). In this context we can highlight the Supplementary Law No. 72 of 27/07/2004, which established the USP of the Administrative Region of Campo Grande which includes the neighborhoods of Campo Grande, Santíssimo, Senador

Vasconcelos, Cosmos and Inhoaíba. In addition, the Complementary Law No. 104 of 11/27/2009, known as USP of Vargens, which encompasses the districts of Vargem Grande, Vargem Pequena, Camorim and part of the districts of Recreio dos Bandeirantes, Barra da Tijuca and Jacarepaguá, in the XXIV and XVI Administrative Regions, which also integrate the BZ.

According to Pereira et al. (2021) in the Campo Grande AR the vegetation at the edge of the PEPB almost disappears to give way to residential, unbuilt and agricultural areas. In the contribution of tree cover change graph, it is possible to see this (Figure 8).

Figure 8 - Tree Cover Change Contribution Graph, on Campo Grande AR, Rio de Janeiro, between 2004 and 2018 LCM
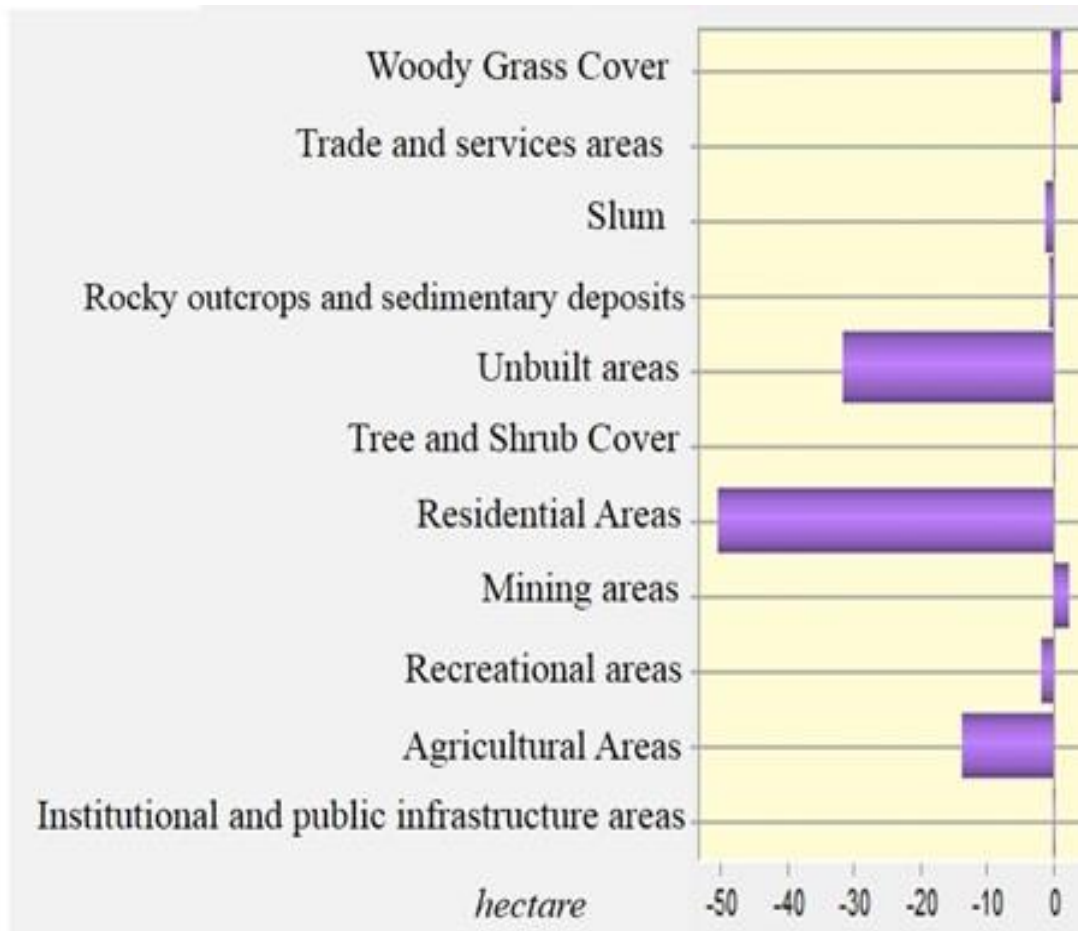
Source: elaborated in IDRISI Selva with data from IPP, 2004 and IPP, 2018. Source: The Authors, 2022.

This may have been motivated by the Campo Grande USP (western part of the PEPB) because it enabled an attractive territorial planning for the growing real estate market in the city. The main contribution was with the works of the Federal Program "Minha Casa Minha Vida" (PMCMV), which began in 2009 and started to significantly increase the residential area in the neighborhood (Pereira et al, 2021). In its zoning, it establishes that the Environmental Zone 2, an area located in the PEPB's BZ, previously designated for agricultural use, will now receive buildings in Residential Grouping 1 - consisting of single-family or two-family buildings.

Another area that also underwent changes over the last 10 to 20 years was the neighborhoods on the eastern side of the PEPB that made up the Vargens USP. The plan had the role of stimulating occupation in the Barra da Tijuca AR, an area of great environmental fragility, which is why it was so criticized and its revision was proposed. Today the Supplementary Law Project 140/2015 is still being discussed in the Rio de Janeiro City Council, which proposes a series of changes to the Vargens USP. However,

both legislations continue to allow the construction of residences in the PEPB's BZ insert of this USP area (Figure 9).

Figure 9 - Residences in insert the PEPB's BZ, Road Mucuiba in Vargem Grande neighborhood, 2018

Source: The Authors, 2018.

In the Guaratiba AR area (western side of the PEPB) the current land use legislation is the Decree No. 322 of 1976, which allows buildings with up to three floors on the edge of the PEPB (Figure 10). The Guaratiba USP, presented by the Municipal Secretary of Urbanism in 2013, and again in September 2019, proposes the creation of an Environmental Conservation Zone at the edge of the Park. Nevertheless, it does not cover the entire BZ, which is considered a Residential Zone in this proposal.

Figure 10 - Buildings on the edge of the PEPB, Guaratiba neighborhood, 2018

Source: The authors, 2018.

According to Costa et al., (2007) the tendency is always to have pressures from outside to inside the CU, particularly from the population, to move into new areas. Therefore, analyzing the changes in use and vegetation cover in the PEPB's BZ is important to draw the attention of the public authorities to review their legislation and seek ways to contain the advance of residential areas towards the Park.

FINAL CONSIDERATIONS

The use of the Land Change Modeler (LCM) tool allowed the proposed analyses to be carried out, facilitating the interpretation of the change in land use and vegetation cover in the study area. This enabled to visualize the trend of residential development over areas with vegetation cover in the park's Buffer Zone.

The comparative procedure, between the years 2004 and 2018, made it possible to observe the growth of the residential land use class and the reduction of areas with vegetation cover. With this method it was possible to realize how the current land use legislation should protect the CU, but instead, it motivates the growth of residential areas around the Park. Therefore, creating means to contain the residential expansion in the PEPB's BZ is to reduce the risk of invasive, exotic and domestic species and halt the advance of urbanization towards the Park, preserving this territory with significant biodiversity for future generations.

The laws are not the ultimate solution to urban conflicts, but they demonstrate how the government manages and preserves the environment in protected areas in Brazil. Urban legislation, in most cases, legitimizes pressure from the real estate market to the detriment of legal efforts to preserve the environment. And the Buffer Zone of the Pedra Branca State Park is an example of that, despite it appears in the Master Plan, but is ignored in the USP's, which recognize the Environmental Conservation Zone and allow residential construction there, contributing to the loss of vegetation cover.

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