FUTURE SCENARIOS FOR LAND USE AND COVERAGE IN THE MORRO DO CHAPÉU STATE PARK/BAHIA/BRASIL

Luana Daniella Silva Almeida1
Odaimys Socorro Ramos2
Deorgia Tayane Mendes de Souza3
Rodrigo Nogueira de Vasconcelos4

ABSTRACT

Objective: The present study area is a conservation unit that faces environmental conflicts associated with deforestation, hence the objective of this article is to evaluate changes in land use and land cover between the years 1985 and 2020, in the region currently covered by the Park State of Morro do Chapéu/BA and its surroundings, in addition to predicting future scenarios.

Method: Images from the Mapbiomas project from 1985 and 2020 were used, and from the neural network method, using the MOLUSCE plugin, it was possible to simulate a land use and land cover model for the year 2040.

Results and conclusion: The results showed little significant changes, practically imperceptible, with the most affected areas being those occupied by natural vegetation and agricultural classes.

Research implications: The Morro de Chapéu State Park is home to numerous floristic and faunal species, in addition to its physical, biological and environmental complexity, therefore predicting changes in the dynamics of land use and cover is the main factor for conserving this wealth.

Originality/value: This study contributes to the implementation of policies aimed at preserving this conservation unit and at the same time incorporates an unprecedented element with the simulations of future scenarios.

Keywords: Conservation Unit, Neural Networks, Molusc, Land Use and Land Cover.

CENÁRIOS FUTUROS PARA O USO E COBERTURA DA TERRA NO PARQUE ESTADUAL DO MORRO DO CHAPÉU/BAHIA/BRASIL

RESUMO

Objetivo: A presente área de estudo é uma unidade de conservação que enfrenta conflitos ambientais associados ao desmatamento, assim, o objetivo deste artigo é avaliar as mudanças do uso e cobertura da terra entre os anos de 1985 e 2020, na região atualmente abrangida pelo Parque Estadual do Morro do Chapéu/BA e seu entorno, além de prever cenários futuros.

Método: Foram utilizadas as imagens do projeto Mapbiomas de 1985 e 2020, e a partir do método de redes neurais, utilizando o plugin Molusce no ambiente QGIS, foi possível simular um modelo de uso e cobertura da terra para o ano de 2040.

1 Universidade Estadual de Feira de Santana, Feira de Santana, Bahia, Brazil. E-mail: geografaluanaalmeida@gmail.com Orcid: https://orcid.org/0000-0002-0221-9001
2 Universidade Estadual de Feira de Santana, Feira de Santana, Bahia, Brazil. E-mail: ody.socorro@gmail.com Orcid: https://orcid.org/0009-0001-9502-8844
3 Universidade Estadual de Feira de Santana, Feira de Santana, Bahia, Brazil. E-mail: dtmsouza@uefs.br Orcid: https://orcid.org/0000-0001-6791-3611
4 Universidade Estadual de Feira de Santana, Feira de Santana, Bahia, Brazil. E-mail: rnvuefpppgm@gmail.com Orcid: https://orcid.org/0000-0002-1368-6721
**Resultados e conclusão:** Os resultados mostraram mudanças pouco significativas, praticamente imperceptíveis, sendo as áreas mais afetadas as ocupadas pelas classes de vegetação natural e agropecuária.

**Implicações da pesquisa:** O parque estadual de Morro de Chapéu abriga inúmeras espécies florísticas e faunísticas, além de sua complexidade física, biológica e ambiental, por tanto prever mudanças na dinâmica de uso e cobertura da terra é o principal fator para conservar esta riqueza.

**Originalidade/valor:** Este estudo contribui para a implementação de políticas que visam a preservação desta unidade de conservação e ao mesmo tempo incorpora um elemento inédito com as simulações de cenários futuros.

**Palavras-chave:** Unidade de Conservação, Redes Neurais, Molusce, Uso e Cobertura da Terra.

RGSA adota a Licença de Atribuição CC BY do Creative Commons (https://creativecommons.org/licenses/by/4.0/).

**1 INTRODUCTION**

Over the last decades, terrestrial ecosystems have undergone major changes, the main transformative agent being changes in land use and coverage, which represent the clearest consequences of human intervention in the environment (Mustard et al., 2004), directly affecting essential parts of natural capital, such as vegetation, water resources, among others (Liping et al., 2018). In semi-arid regions, deforestation of natural forests for agricultural system deployment is the main cause of biodiversity loss and increased CO2 emissions (Fearnside, 2018; Duarte et al., 2020).

To understand the dynamics of this problem, it is not enough to know the changes that have occurred in the past, and it is necessary to carry out prospective studies in the medium and long term, allowing for proper spatial planning (Henriquez, et al., 2006; Jat et al., 2008). The simulation of future scenarios makes possible a series of spatial analyzes, among which stand out: studies aimed at analyzing the evolution of forest cover and its replacement by agriculture, the evolution of urban areas as an element to be taken into consideration by planners in the construction of a more sustainable environment (Wang et al., 2018). Future models have become a powerful tool of spatial analysis and are considered by several authors as dynamic models, capable of predicting possible future behaviors, representing and estimating the magnitude of changes and their spatial patterns (Henriquez, et al., 2006; Houet et al., 2009).

In this research was used the method of Artificial Neural Networks (RNA) and aims to evaluate the dynamics of use and coverage of the land in the Morro do Chapéu State Park/BA and its surroundings, between the years 1985-2020, besides simulating and analyzing future scenarios for this region in a period of 20 years. The present area is a conservation unit that faces environmental conflicts such as: deforestation, burning, illegal removal of sand, land irregularity, predatory hunting and land invasion (INEMA, 2022). Therefore, proposing a model with future projection offers a vital element for decision makers to implement measures based on the protection of this region of immense natural wealth.

**2 THEORETICAL FRAME**

**2.1 Conservation Units**

Conservation Units (UC) are defined as "territorial areas and their environmental resources, including judicial waters, with relevant natural characteristics, legally established by
the Government, with conservation objectives and defined limits, under special administration regime, to which appropriate guarantees of protection of the law apply" (SNUC, 2000). In addition, the conservation units can be of federal, state and municipal origin, and separated into two categories: full protection, with the conservation of biodiversity as the main objective, and areas of sustainable use that allow various forms of use of natural resources with the protection of biodiversity as a secondary objective (MMA-SNUC, 2000). The Morro de Chapéu State Park is a full protection conservation unit where it is only admitted the indirect use of natural resources.

2.2 Neural Networks

Recent advances in neurophysiology have revealed various mechanisms about the way in which the flow and processing of information in the human brain occurs. Some of these mechanisms were mathematically modeled allowing the development of computational algorithms that simulate in a simplified way, the most basic of the brain structures: the neuron (Cerqueira et al., 2001).

The ability to implement computationally simplified versions of biological neurons has given rise to a subspecialty of artificial intelligence, known as neural networks. Defining this as "a set of mathematical methods and computational algorithms specially designed to simulate information processing and knowledge acquisition of the human brain" (Cerqueira et al., 2001). Operationally, a neural network is considered to be a processing box that can be trained so that, from an input data set, it can generate one or more outputs (Cerqueira et al., 2001).

RNAs can be divided into two categories: supervised and unsupervised. In the case of supervised models, they are trained from historical data, which is used in this article. However, in the unsupervised models, no training occurs; however, the software running researches and identifies patterns existing in a given data cluster and may return random results (Braga et al., 2007).

3 MATERIAL AND METHODS

3.1 Field of Study

The Morro de Chapéu State Park is located northwest of the municipality of Morro do Chapéu (figure 1), in the region of Piemonte da Chapada Diamantina, in the basin of the Paraguaçu River (INEMA, 2022). It extends through the Badeco, Estreito, Carinabas, Isabel Dias, Candial and Martinho Afonso mountain ranges. It was created on the basis of decree nº 23.862 of 12/10/73, which reserved the area, and decree nº 7.413 of 17/08/98 which recreated it with an area of 46.000 ha (Lobão & Vale, 2009). This region is inserted in an area of great scenic/tourist importance of the Chapada Diamantina and has as basic objectives to ensure the protection of numerous species of rare and endangered animals; preserve the characteristic vegetation of rupestral field and an ecotone cerrado/caatinga, as well as protect the existing archeological sites in the area (INEMA, 2022).
According to Lobão & Vale (2009), among the most important aspects that characterize this UC is its physical, biological and environmental complexity, whose mosaic is reflected in little known conditions related to the geographical location of the park, positioned at the northern end of a sedimentary plateau (Chapada Diamantina) limited by semi-arid depressions (Depression Sertaneja). The plateau is formed by rocks of the Morro do Chapéu and Caboclo formations, of pre-Cambrian origin, with predominance of sandstones, conglomerate sandstones, siltstones and claystones that reach altitudes higher than 1100 m.

The group of mountain ranges in the midst of depressions is a strategic and important element that houses springs and remnants of caatinga, cerrado, rupestrian and cactaceae, diverse endemic and a fauna rich in felines. In the areas of outcrops located in the center of the park, archeological sites and rock art abound. Furthermore, there is a fragmentation of the relief that provides microclimates and differentiated ecologies, especially contrasts of biomes and biological contacts (Cunegundes, 1989).

The northern portion shows a more continuous morphology, covered by caatinga, cerrado and seasonal forests, with strong fragments of pasture, deforestation and, secondarily, by subsistence farming. In the southwest, mountainous reliefs dissected by deep valleys draining into the basin of the river Jacaré are identified. To the southeast also extends an area of mountain ranges, developed on caboclos sediments, where cerrado and deciduous forests occur. In the central part of the park there is an important area that due to its different climatic conditions, make this site the most complex and ecologically diverse of the park (Cunegundes, 1989; Queiroz, 1985).
3.2 Changes in the Limit of the Morro do Chapéu State Park Area

The first delimitation of the Morro Chapéu State Park did not contemplate all the faunal, floristic and archeological wealth of the region. The UC was set up in a political context that overlapped environmental and social issues. The definition of the boundaries was done in a disjointed manner with the local population, without a prior public hearing for its creation, which generated ignorance by the population about its existence and importance (Carvalho et al., 2011).

In 2006, in order to correct these initial problems, studies were carried out to identify important points, taking into consideration the occurrence of deforestation, burning, degradation of springs, removal of soil, damage to rock paintings, poaching and biopiracy, and based on this a new polygon was delimited (Figure 2) (Carvalho et al., 2011). In addition, one of the problems that UC currently faces is the establishment of wind farms close to its limit, because although it is a potential generator of jobs, it is known that this situation affects conflicts of use, mainly in environmental terms (from the Lima et al. Annunciation, 2013).

![Figure 2: Changes in UC polygonal.](source)

Source: prepared by the authors (2023), IBGE data (2021)

3.3 Modeling Space Dynamics

Modeling of spatial dynamics was developed according to Figure 3, which summarizes the procedures performed encompassing the preparation of input data, modeling (definition of parameters, simulation tests and validation), as well as obtaining the prognostic scenario of land use and occupation.
To evaluate the dynamics of land use and coverage, the historical series of Mapbiomas, version 7 was used as reference, being used as training data the images of 1985 and 2020, and for validation the year 2021. Later, the images were reclassified into larger classes, to obtain a better result during modeling. At the same time, the following variables were chosen by adopting a statistical classifier that uses Euclidean distance: native vegetation, cattle raising, unvegetated area, urban area, body of water, wind farm and roads.

According to Gauch (1982), the Euclidean distance classification method is a supervised classification procedure that uses this distance to associate a pixel with a given class. The lower the value between two communities, the closer they are in terms of quantitative parameters per class, so the shorter the Euclidean distance, the greater the efficiency of the procedure. It is considered one of the most widely used measures of dissimilarity between communities in practice.

Besides these variables, other physical and environmental indicators were considered, such as: distance to the roads, distance to the wind farm, altimetry and slope, the latter two being generated from SRTM images (Shuttle Radar Topography Mission), obtained on the site of the American Geological Survey (USGS Earth Explorer).

### 3.4 Simulation with Neural Networks

After the database preparation stage, these served as input to the RNA model in the QGIS software version 2.8.9 through the Molusce plugin. By means of Pearson's method it was possible to verify the correlation between the variables for the calculation of the changes in the use and cover of the land. The Markov chain transition matrices were used in the calculation of the probability of change from one class to another.

The model was trained from less to more, as can be seen in Table 1, that is, starting with relatively small values of samples and interactions, and gradually increasing until reaching a Kappa value of 0.93 and a relatively small margin of error. In neural network classification, the number of interactions is important and should be large enough to train the network (Braga, et al., 2000).
The following stage refers to the use of modeling based on cellular automata, capable of forecasting future scenarios based on pre-inserted data. In other words, the time series represented by the images of maps classified for use and coverage and the other variables of each period are modeled by rates calculated from the transition probabilities of the cells.

Based on this model (which operates the same algorithm used in the generation of the transition matrix), cellular automata modeling generates two new products: a safety analysis and a simulation map that corresponds to a future scenario.

The RNA algorithm was chosen because of the ease of application and observation of better statistical indices in the generation of the final products, both of the transition matrices and map of changes, and of the modeling and forecasting of prognostic scenarios of use and coverage.

The scenario simulation was carried out for the years 2021 and 2040. For the 2021 forecast it was possible to apply the validation tool, comparing it with the map obtained from the time series for 2021. As there are no reference maps for validating the scenario generated for 2040, the forecast usage and coverage map was compared with another product, but only by means of tabulated data of percentage of area of the typologies analyzed.

After training the RNA algorithm using 20000 samples and 1000 interactions, it was possible to model the future scenario for the year 2021. For the validation of this proposed model we obtained the results of the Kappa index in the "Validation" tab of the Molusce plugin comparing with the 2021 image of the maps.

In general, the indices indicate that the result was satisfactory between the two compared images. The simulated classification for the year 2021 presented a mapping equivalent to the actual classification for the year 2020 with hit numbers of 98.99% (% of correctness-accuracy values), against 1.01% of simulated classes in non-conformity (commission errors).

The other indices jointly provided significant statistics. The value of 0.97 (overall - general Kappa) is considered extremely high, since the maximum value for this index is 1, which represents the total accuracy of the number of pixels correctly classified between the reference map and the simulation map.

The Kappa Histogram (Histogram) statistics is an estimate of the frequency of simulation distribution and the Kappa Location¹ (locality) which tests at different locations of the image to perfectly specify the locations between the reference maps and the simulation map were 0.99 and 0.98, respectively, considered quite acceptable for simulation of land use and coverage, so simulation for 2040 was possible.
4 RESULTS AND DISCUSSION

4.1 Dynamics of Land Use and Coverage

Based on the analyzes carried out, it was identified that the area of the UC and its surroundings presented significant changes in the period 1985-2020. It was observed that the class with the highest density within the UC is the natural vegetation, but this same class underwent the greatest modifications, being affected by a process of reduction of its area. In 1985 it had 159,178.5 ha, and in 2020 it occupied 148,901.94 ha, totaling 10,275.56 ha of reduction. It showed a trend that was marked by several moments: a) from 1985 to 1987 its decline process was slower than that of 1988 to 1995, where it manifested a strong reduction process (Figure 4); b) from 1996 to 2013 it was characterized by several oscillations; c) and from 2013 to 2020 it continued its reduction process, but at a slower pace than in previous years. According to the data obtained in the Molusce plugin, the total loss of this class in relation to 1985 represents 5.75%.

![Dinâmica de uso e cobertura da terra (1985-2021)](image)

**Figure 4:** Dynamics of land use and coverage (1985-2021).

**Source:** prepared by the authors (2023)

On the other hand, the farming class in 1985 was 32,209.2 ha and in 2020 reached 41,407.56 ha, showing an increase of 9,198.36 ha. In general, this class maintained an increasing trend practically throughout the period with slight oscillations, representing an approximate increase of 4.33% of the total area analyzed.

In the case of the urban class, in 1985 it occupied 34.56 ha and in 2020 it reached 242.64 ha. The behavior of this class was growing throughout the period of analysis, increasing its area 7 times more than in 1985. Although this increase is relatively important, it represents only 1.25%.

The non-vegetated class also showed changes, but to a lesser extent compared to the previous classes. In the year 1985 the non-vegetated areas comprised 3,014.01 ha and in the year 2020 reached 3,947.76 ha, showing a growth of 933.75 ha, which represents an increase of approximately 0.19%.
At first glance, it can be said that the water class has seen the least change in terms of dimensions. However, when analyzing the data in detail, one can observe how it has been oscillating, marked mainly by a strong reduction process. In 1985 it was 64.62 ha and in 2020 it was only 1.08 ha. Its highest value was in 1992 where it reached 106.92 ha and until 2003 had a very unstable behavior characterized by continuous increases and decreases. Since 2007, there has been a constant process of reducing the areas occupied by rivers, lakes, reservoirs, etc., reaching 2021 with a loss so marked that it can be said that to date the region had lost practically all of its area occupied by bodies of water.

The transition matrix shows how the classes were redistributed over time (table 2). It is observed that 86.21% of the natural vegetation was conserved and its reduction was a result of changes in use. On the other hand, 13.42% of its areas were destined to agricultural activity, which explains the increase of this activity during the study period.

Table 2: Transition matrix of land use and cover classes from 1985 to 2020

<table>
<thead>
<tr>
<th>Class</th>
<th>Natural Vegetation</th>
<th>Crop and livestock</th>
<th>Urban</th>
<th>Not Vegetated</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Vegetation</td>
<td>86.21%</td>
<td>13.42%</td>
<td>0.42%</td>
<td>0.02%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Crop and livestock</td>
<td>14.68%</td>
<td>79.96%</td>
<td>4.71%</td>
<td>0.64%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Urban</td>
<td>9.11%</td>
<td>7.93%</td>
<td>82.71%</td>
<td>0.19%</td>
<td>0.04%</td>
</tr>
<tr>
<td>Not Vegetated</td>
<td>0.00%</td>
<td>0.04%</td>
<td>0.08%</td>
<td>99.88%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Water</td>
<td>74.25%</td>
<td>17.65%</td>
<td>1.21%</td>
<td>0.16%</td>
<td>6.72%</td>
</tr>
</tbody>
</table>

Source: elaborated by the authors (2023) from the Molusce plugin, data Mapbiomas (2023)

In the farming class, 79.96% of the total hectares that comprised in 1985 remained, while 14.68% became natural vegetation and 4.71% in urban areas. However, the increasing behavior of changes that it maintained throughout the period, was expanding through areas occupied by natural vegetation, water and urban areas. This means that it lost dimensions in the same classes that it later occupied.

It was found that the urban class was one of the classes that underwent the most changes. By 2020, this class had retained 82.7% of its initial area, with 27.3% being redistributed among the other classes, with 9.11% for natural vegetation, 7.93% for farming and relatively low percentages in the other classes. However, its growing trend over time has been appropriating spaces occupied by other classes mainly in agriculture and livestock.

The non-vegetated class was the most conserved, with 99.88% of its area, that is, almost all the area was maintained during the study period, with very insignificant percentages that were occupied by urban areas and farming.

On the other hand, the water class presented alarming figures, with the very low level of persistence of only 6.72%. Most of its area was intended for natural vegetation and farming, followed by urban and non-vegetated areas. Another problem that he presented associated with the drastic loss of his area, over the 35 years, is linked to the non-gain of space in any of the other classes, only with 0.04% in the urban class, which compared with the 93.27% that went on to make up part of other classes, is an extremely low percentage and responds to its exponential reduction during the study period.
4.2 Land Use and Occupation Scenario for 2040

To simulate the use and occupation of the land for 2040, it was necessary to create a polygon that covers the area of the UC and its surroundings 15 km away. The transition matrix of land use and coverage between 2020-2040 is presented in Table 3 that shows the percentages of persistence on the diagonals and the percentage of change on the lines.

**Table 3:** Transition matrix for land use and cover classes between 2020 and 2040

<table>
<thead>
<tr>
<th>Classes</th>
<th>Natural Vegetation</th>
<th>Crop and livestock</th>
<th>Urban</th>
<th>Not vegetated</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Vegetation</td>
<td>0.99</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Crop and livestock</td>
<td>0.00</td>
<td>0.98</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Urban</td>
<td>0.02</td>
<td>0.01</td>
<td>0.96</td>
<td>0.00</td>
<td>0</td>
</tr>
<tr>
<td>Not vegetated</td>
<td>0.00</td>
<td>0.64</td>
<td>0.00</td>
<td>0.34</td>
<td>0</td>
</tr>
<tr>
<td>Water</td>
<td>0.05</td>
<td>0.27</td>
<td>0</td>
<td>0</td>
<td>0.67</td>
</tr>
</tbody>
</table>

*Source:* elaborated by the authors (2023) from the Molusce plugin

The calculation of the change quantity for 2040 shows that for a period of 20 years, the trend of the coverage classes is greater for persistence than for change. This can be observed by means of diagonal values in bold, which highlight the persistence of the categories. For most classes of coverage, the persistence value was greater than 95% probability.

The highest probability of change involves the conversion of unvegetated areas to agriculture (64%). According to the simulation, there is still the possibility of areas with the presence of water being transformed into areas of farming class (27%), which leaves the farming class the greatest threat to the UC. The other transitions between classes are not very representative for this period, being below 1%.

We can observe more specifically how the classes of land use and coverage of the simulation performed behave, comparing Figure 4 with Table 4, as follows:
Figure 5: 2020 and 2040 Land Use and Cover Maps
Source: drafted by the authors (2023)

<table>
<thead>
<tr>
<th>Class</th>
<th>Total area (2020/ha)</th>
<th>Total area (2040/ha)</th>
<th>Area Variation (ha)</th>
<th>% occupied (2020)</th>
<th>% busy (2040)</th>
<th>% Variance Busy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Vegetation</td>
<td>187 777.24</td>
<td>187 697.79</td>
<td>-81.45</td>
<td>65.82</td>
<td>65.79</td>
<td>-0.03</td>
</tr>
<tr>
<td>Crop and livestock</td>
<td>88 130.34</td>
<td>88 810.56</td>
<td>680.22</td>
<td>30.89</td>
<td>31.13</td>
<td>0.24</td>
</tr>
<tr>
<td>Urban</td>
<td>8 507.88</td>
<td>8 465.67</td>
<td>-42.21</td>
<td>2.98</td>
<td>2.96</td>
<td>-0.01</td>
</tr>
<tr>
<td>Not Vegetated</td>
<td>842.31</td>
<td>293.13</td>
<td>-549.18</td>
<td>0.30</td>
<td>0.10</td>
<td>-0.20</td>
</tr>
<tr>
<td>Water</td>
<td>26.28</td>
<td>18.90</td>
<td>-7.38</td>
<td>0.001</td>
<td>0.006</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Source: Molusce (2023)

Comparing Figure 5 with Table 4 we have:
- Decrease in the natural vegetation class from 187,777.24 ha (65.82%/2020) to 187,697.79 ha (65.79%/2040);
- Increase in the farming class from 88,130.34 ha (30.89%/2020) to 88,810.56 (31.13%/2040);
- Decrease of the urban class from 8,507.88 ha (2.98%/2020) to 8,465.67 (2.96%/2040);
- Decrease of the non-vegetated class from 842.31 ha (0.30%/2020) to 293.13 ha (0.10%/2040);
- Decrease in the water class from 26.28 ha (0.001%/2020) to 18.90 (0.006%/2040).
• In relation to the location of the main changes, it is noted that, according to the simulation maps, the farming class is the only one that will increase, and may indicate a trend, mainly to the southeast of the area modeled.
• As can be seen from both the maps in Figure 5 and Table 4, the natural vegetation cover will be reduced slightly.

5 FINAL CONSIDERATIONS

The analysis of changes in the use and coverage of the land in the Morro do Chapéu State Park and surrounding area, in the period from 1985 to 2020, allowed to conclude that the most significant changes occurred in the classes of natural vegetation and farming.

Modeling proved effective in the light of the indexes achieved, which demonstrates that the table of variables chosen and the application of the Molusce plugin in QGIS met the expectations of this process.

The mapping for the year 2040 indicated a small reduction in areas of natural vegetation, but all the other classes diminish and only the farming class increases the size of its area. It can be said that this a priori simulation seems to be positive, since the scenario of 2020 and 2040 appear to be very similar, as if there were no significant changes, indicating a certain stability in the area and probable compliance with the goal of the UC, but one needs to be alert to the advance of farming, since it is an activity that has propagated deforestation for its expansion.

In this way, the simulation foreseen in this work constitutes an important planning instrument for the management of protected areas, to the extent that the revision of management programs can be established, also encompassing their buffer zone, in the elaboration of studies of environmental impacts, in the revisions of municipal administrations in their master plans, among others.

As recommendations for future studies and better detailing of the research, we indicate testing other combinations of variables, carrying out simulations for more distant periods, inserting a set of supervised samples and thus verifying the variation of the classes of use and cover of the land.

REFERENCES


