GEOPROCESSING IN MODELING ECOLOGICAL CORRIDORS IN THE LAGOA SANTA KARST APA (MG)

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ABSTRACT: This study aimed to define which areas are most suitable for the establishment of ecological corridors for species found most relevant in a region of the Lagoa Santa Karst, State of Minas Gerais (Brazil), through a methodology that includes biotic and abiotic environment factors in modeling, with emphasis on the target species requirement in terms of habitat use. A model was generated for the specie *Callicebus personatus* (Sauá), connecting Poções and Cauaia forest fragments with 7.9km long, representing 2% of pixels classified as most suitable in the study area, in which 45.3 hectares should be reforested to increase the effectiveness of the corridor. The GIS proved effective as a tool for modeling corridors. Further studies are needed on the habitat use of species to provide data for studies of this nature, also including property and land value data.

1. INTRODUCTION

Environmental degradation nowadays makes necessary the adoption of conservation and recovery goals. The environmental issue is currently discussed in all areas of knowledge, leading many segments of society to join forces for the conservation of environment (Teixeira and Castro, 2003). However, these actions needs landscape-scale information for the short and long term consequences to be better understood. This way, landscape ecology presents itself as an important tool in planning, since it emphasizes large areas and the ecological effects of the spatial pattern of ecosystems (Sarcinelli, 2006).

In fragmented ecosystems, such as the Atlantic Forest and Cerrado, is important to understand how occurs the interaction between the different landscape units. Because for conservation of an ecosystem with this characteristic, the influence of one unit over other can be a determining factor for decision-making in planning and implementation of ecological corridors.

The fragmentation of natural systems and the changes in the land cover create areas of greater resistance and even barriers which restrict or prohibit the movement of animals. Consequently, the abundance and frequency of autochthonous species are changed because they have potential migration affected in a greater or lesser degree, depending on spatial arrangement of habitat patches, the characteristics of the matrix and migratory behavior of dispersing species (Korman, 2003).

Several ecological processes such as possibility of migration or extinction are attributes determined by the spatial configuration, expressed by the size of the landscape units and the degree of isolation or connectivity between these units. Thus, for every species, the attributes of each landscape unit will have different weights for the habitat suitability (Metzger, 2001). Some species are adapted to the environmental edge, otherwise others only reproduce in well protected forest cores.

Mech & Hallet (2001) found that the genetic similarity among populations of the rodent *Clethrionomys gapperi* was lower in those who were separated by a non-forest matrix. Increased in both populations embedded in major forest patches, suggesting that for specialists species such as *C. gapperi* the fragmentation can isolate populations of animals (and even plants) that becomes smaller and "stranded" in the fragments, tending to increase the inbreeding. Therefore, genetic diversity is reduced causing negative genetic effects, which usually lead to a weakening of the population as a function of inbreeding and the expression of deleterious genes (Arruda & Sá, 2004). Studies carried out in two nesting periods of bird *Piranga olivacea* showed that selection of local dominant males is related to the size of their habitat areas, as more fragmented and smaller ones were restricted to younger males with less territorial claim (Fraser and Stutchbury, 2004), confirming that the alteration of habitat patches may wield selective pressure on species.

Networks of wildlife corridors have been increasingly advocated as essential components of strategy for biodiversity conservation (Saunders & Hobbs, 1991), by favoring the movement of animals between the main fragments of the landscape, thus increasing the genic flow and dispersal of species. Even to have doubts about the positive outcome of the action of ecological corridors on biodiversity, despite the possible negative consequences caused by the facilitation of the spread of diseases, there is the conviction that the benefits justify the delineation and planning of wildlife corridors (Pereira *et. al,* 2007). Moreover, effectiveness of corridors is also challenged for two main reasons: the lack of efficient indicators to assess how functional they are and in which principles of design is based corridors. According Valeri & Senô (2004), the biggest problem is human perspective of their function, worrying about connecting patches and not necessarily presenting a greater connectivity to species. In landscape scale, a corridor must be established in regions where there's already a higher quality habitat for the species in question, as for geoprocessing techniques, our models must select the pixels classified as more appropriate in terms of habitat for them. Moreover, the selected species must have complementary needs, thus avoiding redundancy and covering the different landscape features that benefit a wider range of species (Majka *et al*, 2007).

Therefore, the present study aimed to define which areas are most suitable for the establishment of ecological corridors for most relevant species found in a region of the Lagoa Santa Karst, State of Minas Gerais (Brazil). And intended also to verify the applicability of the tool Corridor Designer (Majka et al., 2007) in a tropical ecosystem. The modeling of ecological corridors in this work was based on the biophysical characteristics of landscape and the requirement of the species in relation to habitat use.

2. METHODS

2.1 Study area

The Lagoa Santa Karst APA is situated approximately 30 km north of Belo Horizonte, in Minas Gerais, an area of approximately 35,600 hectares (Fig. 1). The region has vegetation formations of cerrado and semideciduous forest. The cerrado is restricted to remnant spots in regeneration or in transition (forest-cerrado), featuring an ecotone region between the Cerrado and Atlantic Forest biomes (IBGE, 1993).

The average air temperature is about 23°C. The relative humidity ranges from 60% to 77% in dry and wet months, respectively, reaching 96% during the wettest months. The average rainfall is around 1,380 mm. The dry period extends for five months, from May to September, with less than 7% of annual rains, characterizing a typical tropical pluviometric regime, with a great concentration of rain in summer and dry in winter (Patrus, 1996).

For modeling of ecological corridors were selected core and buffer zones located north of the APA. According to the survey carried out by the biota agreement IBAMA / CPRM (1998), are located in this region the fragments with higher floristic diversity, species richness, area and degree of conservation, therefore, a priority for biodiversity conservation.

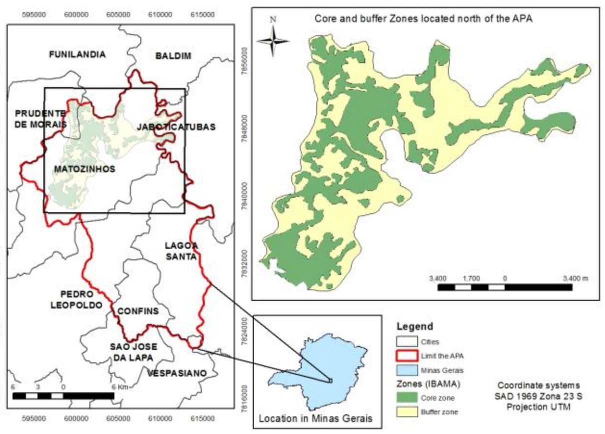

Figure 1. Location of the Lagoa Santa Karst APA.

2.2 Classification of land cover

The classification of land cover was delimited for the core and buffer zones located north of the APA. Samples were selected for training classes: forest (1), pasture (2), exposed soil (3), rocky outcrop (4), cerrado (5) and water bodies (6). The samples were digitized in shapefile and united in a single layer. The number of samples was determined by analysis of heterogeneity of class for each histogram, sampling a greater number of pixels in larger samples for most heterogeneous class.

The algorithm chosen for the classification was the Maximum Likelihood (*MaxVer*), the rejection fraction set to 0% (all pixels were classified) and the same priority for each class of coverage.

2.3 Digital elevation model (DEM)

The DEM was generated from the SRTM image (NASA) of the State of Minas Gerais, obtained for free. The SRTM was clipped with the perimeter of the APA and then interpolated to 20 meters through the following process: a) the original SRTM is converted into a shapefile of points (Spatial Analyst> Convert> Raster to features), in "Output Geometry Type" the format set was “point”, to generate a grid of points; b) the file containing the elevation points of each pixel of the original SRTM is interpolated by spline tool (Spatial Analyst> Interpolation> Spline) and in the "Output cell size" was set a pixel size of 20 meters.

2.4 Modeling of corridor

For area analysis and data entry into the modeling, we used the following databases: Ikonos image, MDE SRTM (NASA), digital vectorized roads, hydrography and city limits (IBGE) and the limit of the Lagoa Santa Karst APA (IBAMA) for the preparation of thematic maps. All data processing was performed in ArcGIS 9.3 environment

For the modeling of the corridor, initially was established the order of priority for the fragments so that the corridor may connect the fragments of greater richness and diversity of the landscape. Each corridor must be modeled individually for a single species, and only then, through a careful analysis, these are joined to form a general corridor that will support the other species. Were selected species that are more specialist, at risk of extinction and limited to dispersion, so that they create an “umbrella effect” whose will also ensure the preservation of other less demanding.

The target species were chosen based on the report of the biota of the APA-Lagoa Santa Karst (CPRM / IBAMA), through which were pre-selected species found in the fragments of interest that have the desirable characteristics to have this status. From this list, was started a survey to find data on use of habitat of those species to be subsequently added in the archives of reclassification, which will be the model parameters.

The suitability habitat model was generated using the factors land cover, elevation, distance of the road and position topographical, on the weights 70, 15, 10 and 5% respectively. The parameters used in modeling are listed in Table 1.

Factor	Weight	Class	Suitability
Land cover	0,7	Forest	100%
		Pasture	5%
		Exposed soil	0%
		Rocky outcrop	0%
		Cerrado	25%
		Water bodies	50%
Elevation	0,15	0 to 300m	10%
		300 to 900m	100%
		900 to 1000m	10%
Road distance	0,1	0 to 100m	10%
		100 to 500m	60%
		500 to 3500m	100%
Topographic position	0,05	1 – valley bottom	40%
		2 – gentle slope	100%
		3 – steep slope	80%

		4 – hilltop	60%

Table 1.Parameters used in modeling.

For processing the database on the model was chosen geometric mean. It has been shown more realistic, according to the latest news on ecological limiting factors called the Leibig's Law of the Minimums, similar to the limiting reagent in chemical balances. In this case, the lack of some factor in the landscape can not be rewarded by another, even in abundance.

3. RESULTS AND DISCUSSION

Among the pre-selected species, we chose *Callicebus personatus* (Sauá) as target, once that it was the only who had sufficient information about habitat use to be used in modeling and had the desirable characteristics to be classified as a target. Other species present, as *Panthera onca* (onça pintada), *Puma concolor* (suçuarana) and *Lycalopex vetulus* (raposa-do-campo) were not selected, although there was information available habitat use, they are generalists. In this case, the implementation of a corridor for these species would not favor most of the fauna. The species of birds and snakes envolved present a dearth of information on habitat use in the literature.

A land cover map (Figure 2) was generated with a raster of consistency of the classifier, which analysis showed that the algorithm found most difficult to distinguish heterogeneous classes, such as "forest", "exposed soil" and "cerrado". These errors occur due to high resolution image, which consequently generates classes with great diversity resulting in too much noise in the classification that was fixed by the filter "Focal Statistics". It was considered the circular neighborhood and statistical Majority, which returns for each pixel the most common value in the neighborhood. Were tested 6-12 pixel radius and the best result was obtained using the filter circular radius of 12 pixels. The overall classification accuracy and Kappa index were 83.96% and 48.46% respectively. The total and relative areas of each cover class are listed in Table 2.

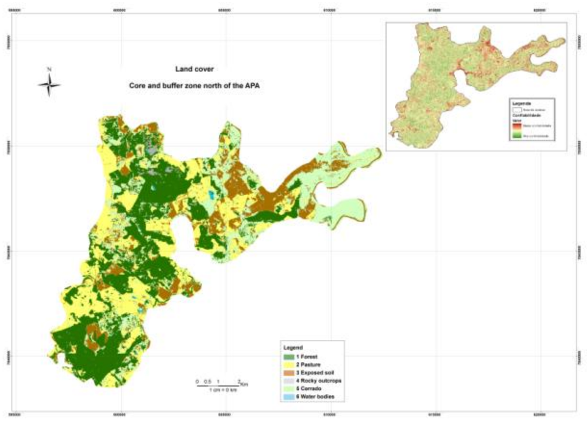

Figure 2. Map of land cover

Land cover	Area	% of total area
Forest	2788,6	35,51
Pasture	2130,3	27,13
Cerrado	1722,7	21,94
Exposed soil	1144,6	14,58
Rocky outcrops	41,1	0,52
Water bodies	25,5	0,32
TOTAL	7852,8	100

Table 2. Total and relative surface of classes in analysis area

The hydrography was not included due to the peculiarity of the landscape covered, where the bodies are mostly water ponds, not featuring a continuous distribution along the ground. From an ecological perspective, riparian areas have been considered extremely important corridors for movement of wildlife across the landscape, as well as the dispersion of plants, offering favorable conditions for flora and fauna, serving them for protection and cover and producing the food they need (Jacob, 2003). Thus, it is undeniable the importance of considering these areas in the modeling in regions where the drainage network constitutes a stream, forming a potential corridor.

The DEM generated by the interpolation indicated altitudes ranging from 100 to 450 meters in the APA (Figure 3).

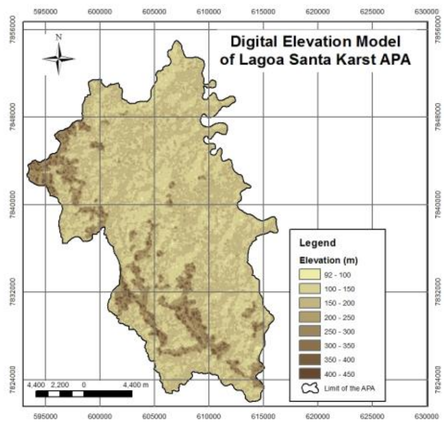

Figure 3. Digital Elevation Model of Lagoa Santa Karst APA

The corridor model created between the fragments “Lagoa Cauaia” and “Poções” had as start and end points polygons created on those center areas. The models were generated covering from 0.1 to 10% of the pixels classified as most suitable in the area of analysis.

Analyzing each fraction individually (Figure4), it is noted that the model which includes 0.1% of most suitable pixels of the landscape has tracks with a width of a single pixel (20 meters), which is undesirable, since a corridor with such dimension would be totally affected by edge effects. On the other hand, the model of major fraction (10%) presents a corridor of large area in excess. In this case, the implementation would be hampered because it would involve a lot of properties and a high maintenance cost. Furthermore, the corridor area overcomes the area of the two connected fragments.

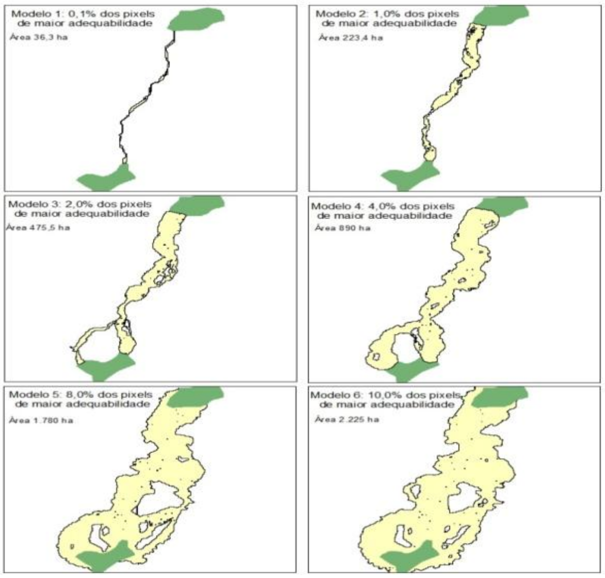

Figure 4. Corridor models generated for *C. personatus*, ranging from 0.1% to 10% of the pixels most suitable in the area.

Considering the balance between functionality for the target species and the cost of conservation for the corridor, the model chosen was the one who selected 2% of pixels classified as most suitable.

The total area of the corridor was 4.76 km^2. The distance between the points of beginning and end of the hall, into a single segment, was 7.93 km. The length of largest area between patches without forest cover was 1.51 km, which is the longest distance that animals would have to cross in the least suitable environment in the corridor (Figure 5).

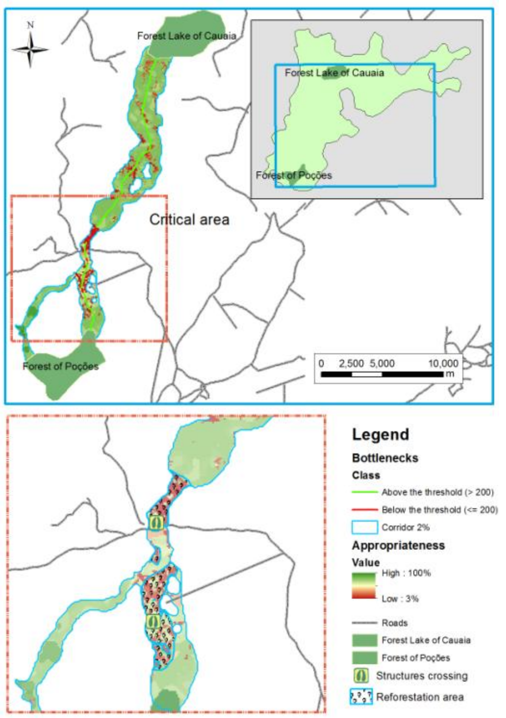

Figure 5. General analysis of corridor

The narrowest portion of the model has 121.65 meters width and the wider has 773.22 meters. For analysis of distribution and abundance of the "bottlenecks" that may restrict or forbid the passage of animals, it was determined a lower limit of 200 meters. Of the total length of 7933.06 meters of the corridor, 91.10% is above the limit set 200 meters wide (Figure 6).

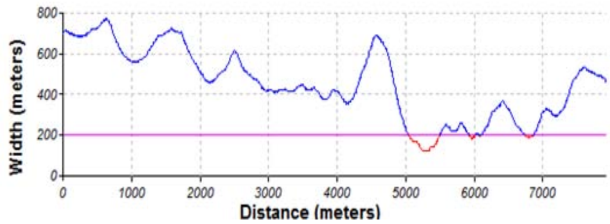

Figure 6. Graphic analysis of corridor “bottlenecks” along the length.

Concerning the quality of habitat within the corridor, based on the adequability model, were arbitrarily defined four classes of quality, considering the minimum value of 3% and maximum 100% of this model: a) 3-27% areas of non-habitat; b) 27-52% strongly avoided; c) 52 to 76% occasionally visited to good; d) 76-100% ideal habitat. The distribution of the number of pixels in each classes are represented in Figure 7.

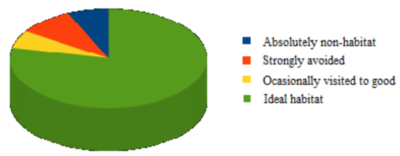

Figure 7. Distribution of number of pixels at each suitability class

Observing the graph it can be noticed that the model selected most of the pixels classified as high suitability. However, this information is not sufficient to evaluate possible efficiency of the model. To this end, we must analyze this information visually. By overlaying the information on the total area of the corridor, the suitability inside of it, the presence of bottlenecks and the presence of roads in the area a new map was generated (Figure 8).

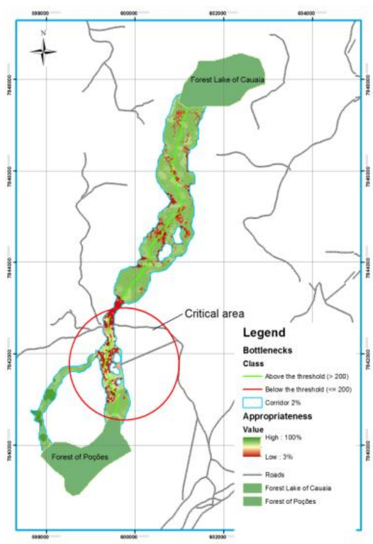

Figure 8. Analysis of the corridor including different factors. the critical area is highlighted.

In this map was found that the pixels of lower suitability of the corridor are concentrated just at the narrowest segment of the model and where two roads intersect. Thus, in the implementation of this model it would be necessary to adopt measures to mitigate these risks through the restoration of natural vegetation, building structures crossing the roads and an environmental education program that involves local people. The road structures are the main source of disturbance in natural territory, according Byron et al (2000).

5. CONCLUSION

Geoprocessing techniques have proved an efficient tool for modeling the ecological corridor, making possible the simultaneous spatial analysis of various factors that influence the efficiency of the corridor for biodiversity conservation. The spatial models present advantages for the ability to generate alternative scenarios with territorial representation and simplicity in the interpretation of results (Botequilha and Ahern, 2002)

The thematic maps that describe the suitability along the length of the corridor allows a better understanding of the internal environment and this can assist in conservation strategies of fauna corridors. The difference of this methodology, is to select the most appropriate according to the requirement of the species.

Soil cover is generally greater weight factor for any species. This way, the classification accuracy determines quality of the generated model. Using high resolution images as used in this work can lead to problems due to the large presence of noise generated in the classification, which can affect the results of the modeling, and should be minimized through a suitable filter.

Although in this study the analysis area enclosed is relatively small, this same methodology can be used at larger scales, according to the needs of selected species. The scale is of great importance when relationships between living organisms are taken into account. Results show that the territorial connectivity is dependent to some extent the effects of territorial range of use of the organism in question. When the species in question makes a quite limited use of land and confined to small spaces, the territorial configuration is very limited in connectivity and demographic dispersion (Rantalainen et al, 2004). Similarly, species with high mobility between areas far removed are not much dependent on the individual configuration of the spots. Conversely, the species needs are defined on a scale beyond and below which have capacities demographic dispersion (Keitt et al, 1997)

Other factors may be included in the model, according to local circumstances and requirements of the species involved.

Further studies are needed on the behavior and habitat use of species that have the potential to be chosen as target species, allowing the addition of different animal groups in shaping the ecological corridor, thus increasing its effectiveness.

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