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# Geoprocessing and Landscape Ecology for Assessment Fragmentation and Connectivity of the Habitats of the Microregion of Ceres, Goiás (Brazil)

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**SUMMARY**

This study aimed to map and evaluate the evolution of habitat fragmentation between 2009 and 2018, using the Microregion of Ceres (Goiás) as a sample reference, using principles of Landscape Ecology. The methodology comprised the mapping of the fragments in the two years analyzed, using the OLI/Landsat 8 sensor, using scenes 222/70 and 222/71. The SPRING 5.2 software was used, where the supervised classification was performed, applying the semi-automatic process. The computational algorithm applied to classify the scenes was Maxver, which classifies pixel by pixel and groups the information of each one into homogeneous regions. After extracting the fragments of native vegetation, the methodology proposed by Juvanhol et al. (2011), in which the fragments were grouped into classes: Very Small (MP) ≤5 hectares; Small (P) ≥5.01 and ≤10 hectares; Medium (M) ≥10.01 and ≤100 hectares and Large (G) ≥100.01 hectares. For the analysis based on metrics in Landscape Ecology, the ArcGis 9.2 Patch Analyst extension was used. The results showed the expansion of vegetation cover areas in the study area, concentrated on tops of hills, APP and legal reserves. However, they pointed out intense fragmentation of native vegetation, which hinders the performance of fragments as habitats. It is considered that, from the contemporary problem of degradation of natural environments to the detriment of economic development, studies like this are necessary in order to identify existing environmental problems and propose strategies to minimize and mitigate ecological imbalances.

**KEYWORDS:** Forest Fragments. Geoprocessing. Landscape Ecology.

## 1 INTRODUCTION

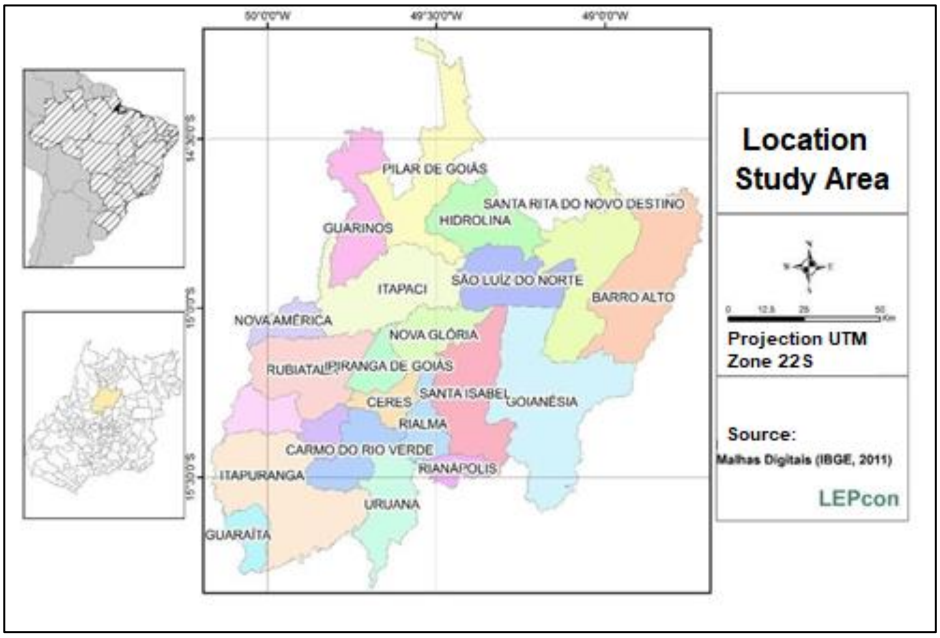
The analysis of geographical space allows us to understand the relationship between human action and nature, corroborating with this idea of dialectical unity, environmental issues gained relevance in discussions on spatial planning. In this perspective, Geography has established itself as a science responsible for integrating the parts of the physical environment (Lithosphere, Hydrosphere, Pedosphere, Biosphere) and, in addition, presenting the understanding of these interconnected parts and of the dynamic processes of interaction with man (BERTRAND, 1968).

In this process of production of nature, the environment has been directly affected by the consequences of the socioeconomic dynamics of land use, causing ecological imbalances in the ecosystem, in which the remaining areas of native vegetation have increasingly suffered with the pressure of economic activities, and with to other degradation processes also too.

The contemporary environmental issue is about the degradation of native environments to the detriment of economic development; therefore, studies are needed in order to identify existing environmental problems and propose strategies to minimize and mitigate ecological imbalances. Therefore, the objective was to map and evaluate the evolution of the fragmentation of habitats in the Center of Goiás between 2009 and 2018, having as a sampling reference the forest fragments of the Microregion of Ceres (Goiás), using the principles of Landscape Ecology.

The Microregion of Ceres (figure 1) is one of the eighteen microregions of the state of Goiás in Brazil. It is located in the mesoregion of Centro-Goiano, and had, in 2020, a total population of 231,239 inhabitants (IBGE, 2020). It has an approximate area of 13,163 km² (IBGE, 2020), which corresponds to 3.87% of the total area of the state of Goiás. It is formed by 22 municipalities, namely: Barro Alto, Carmo de Rio Verde, Ceres, Goianésia, Guaraíta, Guarinos, Hidrolina, Ipiranga de Goiás, Itapaci, Itapuranga, Morro Agudo de Goiás, Nova América, Nova Glória, Pilar de Goiás, Rialma, Rianápolis, Rubiataba, Santa Isabel, Santa Rita do Novo Destino, São Luiz do Norte, São Patrício and Uruana.

**Figure 1: Location of the Microregion of Ceres, Goiás**




Source: Authors, 2021.

The study area is located in the Cerrado Biome, characterized by a specific climatic dynamic (two defined seasons), with rainy summer and dry winter. It has an average annual rainfall of 1,500 mm per year, with a thermal average of 18°C in winter and 22°C in summer. Shows contrast in hypsometry between 300 and 1600 meters. Most of this biome is located in the Brazilian Central Plateau, being the second largest in the country. The Cerrado has different landscapes such as: forest formations (Ciliar Forest, Gallery Forest, Dry Forest and Cerradão). Savânicas - Cerrado in the strict sense, Cerrado Park, Palmeiral and Vereda – a type of wetland, humid ecosystems) and natural grasses (Campo Sujo, Campo Limpo and Campo Rupestre) (RIBEIRO; WALTER, 2008).

## 2 LANDSCAPE ECOLOGY: INITIAL REFLECTIONS

The Brazilian Savanna has a considerable richness of biological diversity, with about 200 species of mammals, 800 of birds, 180 of reptiles, 150 of amphibians and 1,200 of fish. It is the second largest biome in extension in South America, while it is the one with the lowest percentage of areas with strict protection, being only 8.21% of the area of 2,036,448 km² is legally protected (ICMBIO, 2007).

According to the Ministry of Environment of Brazil (MMA, 2020), the Brazilian savannah holds 5% of the planet's biodiversity, but it is the most threatened biome in the country. It is estimated that 47.84% of the Cerrado area has already been deforested by 2008. This process occurs due to its characteristics that are favorable to agriculture and livestock, and the growing demand for charcoal for the steel industry (expansion of forestry). Thus, the Cerrado landscape presents fragmented habitats, which is a problem for the conservation of the biome's biodiversity.

This form of appropriation and organization of space has been most responsible for the degradation of ecosystems, such as the geographic isolation of habitats, for example, in which biodiversity is threatened, as there is difficulty in exchanging genes and competing for food in forest fragments (patches). Metzeger (1999) points out that the process of fragmentation of natural habitats is the result of human actions, because they alter the continuity of the landscape, causing changes in the structure and composition of native vegetation areas and, consequently, loss of biodiversity.

For Pirovani (2010), fragmentation is characterized by the rupture of a continuous unit, leaving smaller elements that present ecological dynamics and processes that are distinct from the original unit. Each patch constitutes an ecotype of the landscape. For the author, it is necessary to study the dynamics and ecological functioning of these fragments, based on Landscape Ecology and metric parameters for investigating the ecological quality of native vegetation habitats.

The study of fragments based on the thresholds of Landscape Ecology is essential to understand the ecological functioning on a regional scale. Any change in a fragment, in relation to size and shape, can reduce the population of the species, interfere with the vital flows of this system, compromising the natural biodiversity in these places. For Primack and Rodrigues (2001), when natural vegetation is destroyed or degraded, fragments of habitats are generally abandoned by species, which migrate to other larger fragments, running risks in this process.

In the subdivision of Landscape Ecology, there are indexes that make it possible to understand and assess the ecological functioning of the fragments: size, central area, shape, diversity, etc. All these features are directly correlated and will influence the edge effect. This directly influences the ecosystem and natural biodiversity, since the edges are the places of interaction with the matrix, which limit distinct biotic units (HILTY et al., 2006).

## 3. METHODOLOGY

Initially, the mapping of native vegetation fragments of the Microregion of Ceres was carried out, based on the years 2008 and 2019. The sensor used in this process was the OLI/Landsat 8, which has a spatial resolution of 30 meters. The scenes used are described in table 1. For the extraction of information, the SPRING 5.2 software was used, where the supervised classification was performed, applying the semi-automatic process, that is, grouping of similar pixels, through the segmentation process (area of pixel 15 and similarity 18). This step was characterized by the recognition of homogeneous target patterns, distinguishing the areas that present different spectral behavior on the surface, with the efficiency of the algorithm and the ability to recognize the user's features.

**Table 1: Identification of scenes used for mapping**

| Orbit/Point | Date | Date |
|---|---|---|
| 222/70 | 11/09/2009 | 04/09/2018 |
| 222/71 | 08/10/2009 | 11/09/2018 |
| 222/70 | 11/09/2009 | 04/09/2018 |

Source: Landsat 8, 2009 and 2018.

The computational algorithm applied to classify the scenes of the OLI/Landsat 8 sensor was Maxver, which classifies pixel by pixel and groups the information of each one into homogeneous regions. This classification associates each pixel to the class with greater probability of generating another one, with its characteristics (JENSEN, 1996). The performance and acceptance threshold of the mapping are described in table 2.

**Table 2: Average of the results of the semi-automatic classification of forest fragments of native vegetation**

| Semi-automatic classification of forest fragments | |
|---|---|
| Average performance 91.00% | Acceptance threshold 95% |
| Average Abstention 9.00% | Maxver classifier |
| Confusion 0,00% | |

Source: Authors, 2020.

After extracting the fragments of native vegetation, the methodology proposed by Juvanhol et al. (2011), in which the fragments were grouped into classes: Very Small (MP) ≤5 hectares; Small (P) ≥5.01 and ≤10 hectares; Medium (M) ≥10.01 and ≤100 hectares and Large (G) ≥100.01 hectares. It was based on literature on habitat fragmentation, which indicates that larger native vegetation fragments, or patches that are close together and with more rounded shapes, are ecologically better than smaller ones that are more distant and irregularly shaped.

For the analysis based on metrics in Landscape Ecology, the ArcGis 9.2 Patch Analyst extension was used. The indices were calculated according to equations 1 to 6.

Equation 1, which describes the relationship between perimeter and area of the native vegetation fragment, where L= Perimeter and S= Area.

$$\frac{L}{S} \tag{1}$$

Equation 2, which deals with the correlation between perimeter and area, is described in equation 2, Where L= Perimeter, S= Area and the constant (=282).

$$\frac{282\ x\ L}{\sqrt{S}} \tag{2}$$

Equation 3, which indicates the density of fragments of native vegetation in the mosaic of landscape, where Ni is the number of patches in the study area and Li is the perimeter.

$$\frac{Ni}{A} \tag{3}$$

Equation 4, which corresponds to the Hulshoff index (1995), in which if Li indicates high values, it indicates the presence of many fragments with small areas, Si is the total area of the fragments and Ni is the number of patches.

$$\frac{1}{Ni}\sum\frac{Li}{Si} \tag{4}$$

The average patch size (MPS) is estimated by equation 5, where ni is the number of patches and aij is the area of each patch.

$$\frac{\sum_{j=1}^{n} aij}{ni} \qquad (5)$$

Equation 6 indicates the area of the largest fragment of the matrix (Largest Patch Size - LPS), where A is the landscape area

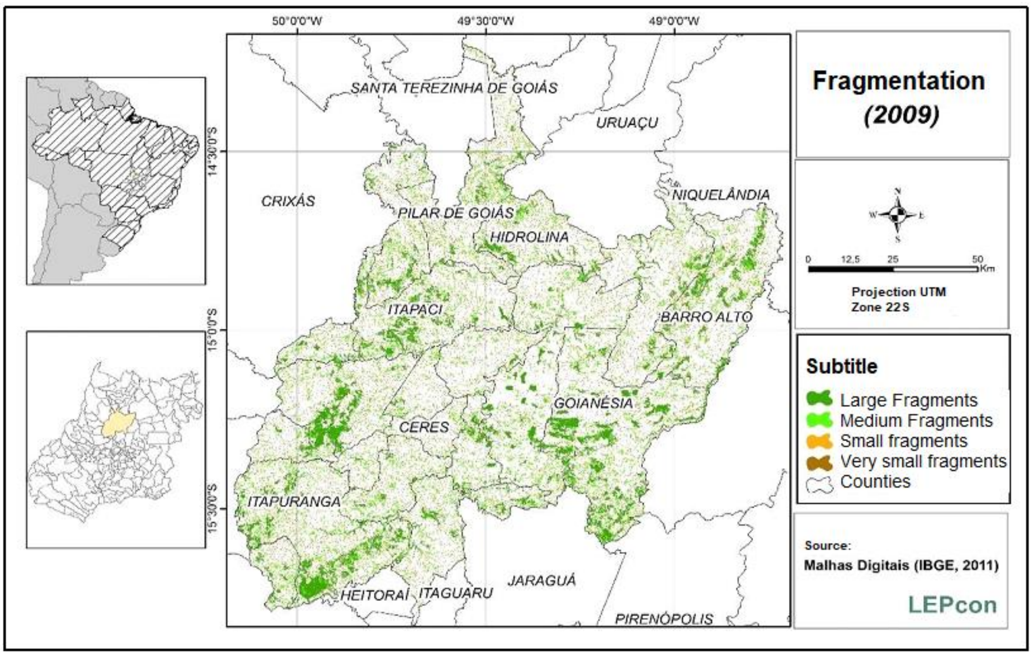
$$\frac{Max\ (aij)}{A} 100 \qquad (6)$$

After generating the results of the equations, the data were exported to spreadsheets in Excel 2020 format for analysis. Mapping results were exported in jpeg format. Graphs were also produced to assist in the analysis, which are presented below.

## 4 MULTITEMPORAL MAPPING OF NATIVE VEGETABLE COVERAGE IN THE MICROREGION OF CERES (2009 – 2018)

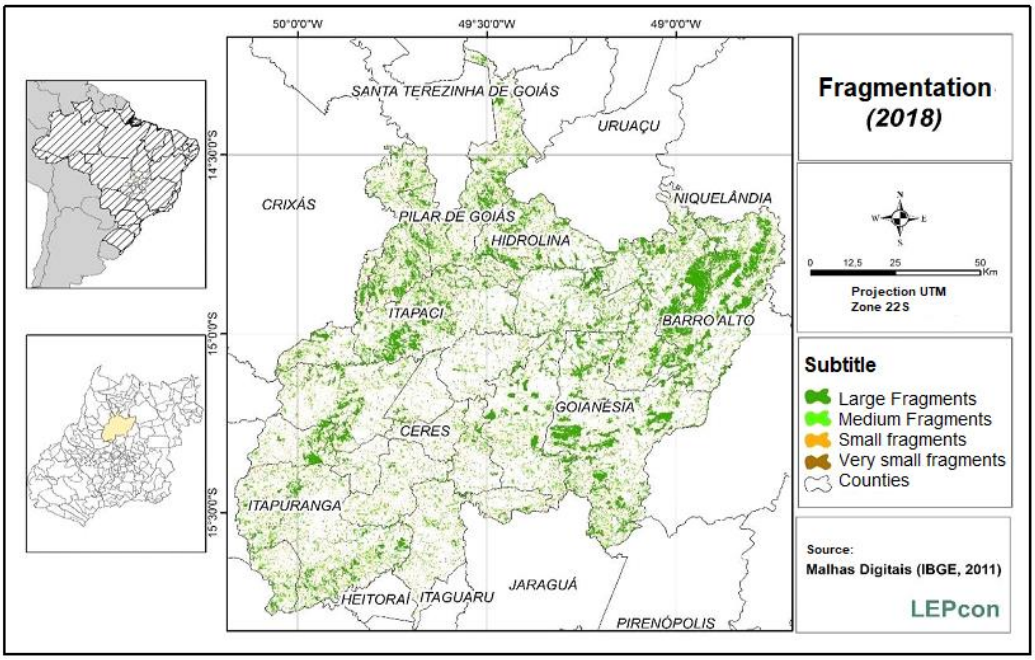
The mapping of the native vegetation cover of the Microregion of Ceres (figures 2 and 3) for the years 2009 and 2018 indicated that there was an increase in vegetation cover in the region. This result, in fact, contradicted the logic of the national scenario, in which the percentages of deforestation increased, especially in the current arc of deforestation, which has occurred in the portion of Brazilian territory that covers the states of Mato Grosso, Pará Sul do Amazonas and Acre.

**Figure 2: Native Vegetation in the Microregion of Ceres in 2009**



Source: IBGE, 2020.

**Figure 3 - Native Vegetation in the Microregion of Ceres in 2018**

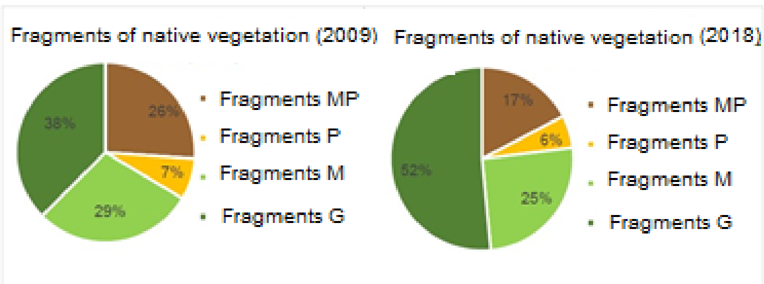



Source: IBGE, 2020.

Despite the increase observed, considering the reality of the micro-region, it was observed that the areas of natural vegetation are mostly restricted to areas already intended for this purpose, such as hilltops with inappropriate relief for some activities, Permanent Preservation Areas (APP's), and legal reservations. The northwest region of the Microregion stands out, such as the Barro Alto municipalities, where the greatest increase in native vegetation was observed, which in percentage numbers was equal to 5%.

Despite the increase in vegetation cover, habitat fragmentation is still a serious ecological problem for the Microregion of Ceres. The numbers show that fragmentation is present at different levels, with both large and very small patches, the latter not fulfilling the function of habitat, due to the limited supply of resources for the maintenance of the animals' lives. Figures 4 and 5 show the fragmentation of natural areas in the Microregion of Ceres.

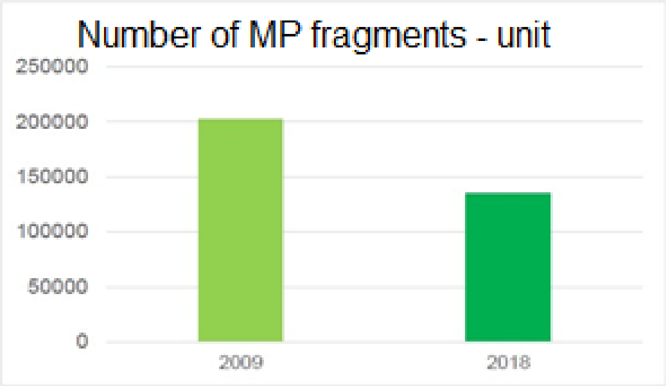
**Figures 4 and 5: Category of native vegetation fragments in the study area (2009 – 2018)**




Source: Authors, 2020.

Despite the increase in forest area in some areas, there was an increase in deforestation in units of very small fragments, which presented a reduction of about 9%, as shown in Figure 6. Ecologically, this implies that the number of temporary shelters for wildlife has declined in the fragmented landscape mosaic, which certainly contributes to the process of geographic isolation.

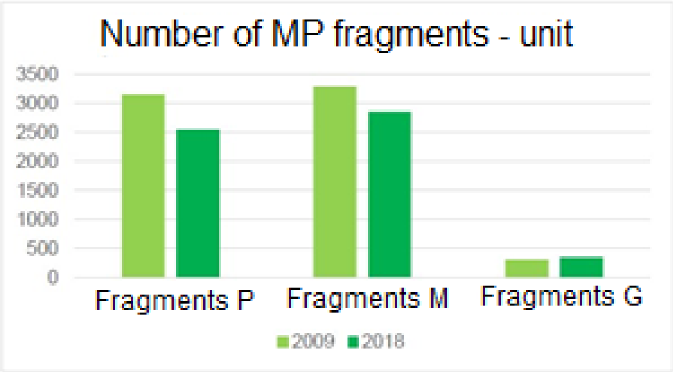
**Figure 6: Expansion of the fragmentation process (2009 – 2018)**




Source: Authors, 2020.

The figure 7 shows the comparison between the categories of fragments MP, P, M and G.

**Figure 7: Comparison between the categories of fragments (2009 – 2018)**




Source: Authors, 2020.

In 2018, the categories MP, P and M also showed a reduction compared to 2009. It is noteworthy that the maintenance of these smaller fragments spread across the landscape mosaic is an important factor in reducing the degree of threat to the isolation of species, since this isolation is configured as a threat of extinction due to competition for resources and a decrease in the rate of recolonization in a fragmented habitat. This finding is based on the percolation theory, which has as a basic rule the premise that an organism needs to find at least one resource when moving through the matrix (FARINACI, 2008). Regarding category G, attention was drawn to the increase in these fragments between the years analyzed, which occurred due to the junction of medium fragments with areas of APP. The quantity increased from 319 to 356 units.

**5 THE FRAGMENTED LANDSCAPE IN THE MICROREGION OF CERES**

The habitat fragmentation process can be attributed to several causes, which can be divided into anthropogenic and natural ones. The latter may be associated with climatic fluctuations, soil differentiation, appearance of topographical barriers, sedimentation of rivers and seas and temporary or permanent processes of flooding. It is important to note that these processes occur over a relatively large geological period, which minimizes their negative effects on life, as it allows part of the species to adapt to changes in the environment. Furthermore, when observing its implications along a geological scale, positive results can be highlighted, such as genetic differentiation and the formation of new species, being, therefore, extremely relevant in the formation of biodiversity (RIBEIRO; RIVAS; SANTOS, 2012).

In relation to anthropogenic causes, it is observed that they are the ones with the greatest proportion and impact, causing the formation of patches (patches) and global changes in habitats, considered the causes of mass extinction events (MELLO, 2014). The anthropogenic factors of relevance to environmental degradation are observed in agricultural exploitation, wood extraction, hunting, fires, urbanization, leisure and in the implementation of transport, sanitation and energy infrastructure (RIBEIRO; RIVAS; SANTOS, 2012).

According to Rodrigues and Nascimento (2006), the fragmentation of habitats caused by human activities generates effects that are concentrated in the edge area. Burning or application of chemicals, and/or deeper effects can reach the center of the fragments. Other negative impacts are hunting, logging and even acid rain, which can also reach the interior of a fragment.

In the Brazilian savanna, much of what is left of the natural vegetation is found as forest fragments. The formation of these fragments can be linked to several processes. The formation of clearings (drilling), construction of roads or land dividing fences (dissection), fragmentation, reduction and loss of habitat still stands out within the fragmentation (MELLO, 2014).

During perforation, a part of the vegetation is removed from the interior of the forest, thus forming clearings, which generate consequences of fragmentation from the inside out. In the dissection, the vegetation is divided by some type of anthropic construction, such as roads, walls and fences, causing the formation of two distinct fragments. Fragmentation is seen as the division of an environment, forming fragments of coverage granted to each other. In the reduction process, an already fragmented environment is reduced by anthropic action or even by the effects of the formation of borders.

Analyzing all these processes, it is clear that there is an order, in which they usually occur, starting with perforation and dissection and culminating in fragmentation, which results in the reduction and loss of habitats. Thus, the formation of forest fragments goes through a series of historical processes and disturbances that successively and jointly lead to the loss of vegetation and biodiversity as a whole (MELLO, 2014).

All these processes mentioned above tend to cause, as seen, the formation of patches or even total loss of habitats, causing a reduction in the size of populations, interruption or reduction of migration and immigration (MELLO, 2014), in addition to various disturbances , which together cause changes in the micro-habitats of the edges of the fragments, which can cause, for example, the population of exotic species and pest attacks, which directly influence the quality or even continuation of life of native species, and hinders the regeneration of the environment (SAMPAIO, 2011).

After mapping the microregion's native vegetation, landscape metrics were extracted to assess the region's fragmentation process. Of the total fragments of native vegetation (FVN) mapped with base 2018, most (134,489 units) were included in the class of very small fragments. These fragments are sensitive to the process of changing the landscape by human activity. It is known that the ideal for the conservation of biodiversity is the maintenance of fragments with larger areas, depending on the quantity and quality of resources for the biota, but the SLOSS (Several Small Patches) effect also presents functionality in the landscape. These areas are considered a temporary shelter for fauna (trampoline phenomenon) and avoid their geographic isolation (FORMAN, 2006).

The metrics referring to the edge of the fragments are important for decision making, regarding strategies to reduce the influence of externalities from the matrix (exotic species, different temperature and humidity, etc.). Fragment edge density (ED) is the ratio of the perimeter of edges to the area of the fragment and reveals the relationship between the shape and size of the fragment, indicating that large fragments of the microregion of Ceres had greater potential for biodiversity conservation (JUVANHOL; FIEDLER, 2001). Edge metrics (ET) revealed that the sum of the perimeters of all very small fragments had the highest edge value among all categories (very small, small, medium and large), this is due to the number of units of this category. The data showed that the fragments are dispersed in the landscape without adequate planning regarding their shape, presenting irregular shapes.

The indicator that evaluates the shape of the fragment (MSI) points out the geometry of the fragments that can be classified as regular or irregular. The very small and small fragments had more regular shapes, unlike the medium and large fragments. Regarding the distance from the circular figure to the medium and large fragments, it can be said that they are connected with the APP's, and how they follow the drainage outline, therefore irregular and elongated shapes. It is noteworthy that the concern with the shape of the fragments is essential to ensure the quality of habitats, and therefore the conservation of biodiversity.

## 6 EDGE EFFECT: REFLECTIONS ON THE CONSEQUENCES OF HABITAT FRAGMENTATION

The anthropic fragmentation of habitats mainly affects the balance of natural environments, which can compromise the presence of some species or even the reduction of their populations. This happens, for example, due to the obstruction of migration and dispersal of species, which ultimately results in loss of biodiversity (BARROS, 2006). Regarding the shape and size of the fragment, the reduction of the cohesive environment to smaller remnants makes them more sensitive to external conditions, resulting in what is called the edge effect (BATISTA et al., 2013). This effect is associated with the area of natural vegetation that is in contact with an anthropized environment, generating changes from the outside to the inside, influenced by the open area (SANTIAGO, 2008).

Naturally, the borders existing in a non-fragmented habitat are composed of different biological communities that interact, which generates positive consequences for the maintenance of the landscape's biodiversity. However, the edges formed by anthropic action are commonly surrounded by agricultural and pastoral areas, logging and/or deforestation, fires, housing construction and other various human interventions, which destabilize the ecosystem on the edge of the fragment, causing the so-called edge effect (RIBEIRO; RIVAS; SANTOS, 2012).

The edge effect is constituted by different types of consequences, imposed directly on the edge soon after the formation of the fragmented environment. The abiotic effects occur due to changes in the microclimatic conditions of the fragment's edges. The microclimate of a given environment refers to the natural environmental characteristics that are favorable to life there, referring, therefore, to solar incidence, average air and soil temperature, average air and soil humidity, soil pH and currents of air. Thus, with the formation of a vegetation patch, its edges start to have all these characteristics modified in relation to the center of the fragment, causing numerous later changes, such as biotic effects (BLUMENFELD, 2008).

The edges of the fragments also start to suffer an increase in solar incidence, especially at dawn and dusk, when sunlight directly reaches the edge environment. This fact causes several biological changes, including abnormalities in the germination and development process of plants. Furthermore, the increase in luminosity triggers an increase in temperature in the environment, affecting the humidity of the air and the soil (BARROS, 2006). In the microregion fragments of Ceres, it was observed the exacerbated growth of plants known as lianas, shrubby vegetables that have small diameter and height, as a consequence of greater luminosity.

On the other hand, with the change in the flow of air currents, the circulation of moisture resulting from the transpiration of plants between the center and the end of the fragment is compromised, causing the heterogeneity of the distribution of this abiotic factor in all parts of the forest environment. In addition, the wind coming from the external environment tends to increase the temperature and decrease the humidity inside the fragment, adding to the increase caused by solar radiation. Finally, intense air currents can influence the structural wear of the outermost vegetation of the fragment, with a high occurrence of breaking branches and trunks, or even the fall of entire trees uprooted (BARROS, 2006).

In the study of the edge effect, several factors must be considered, among which the size and shape of the fragments stand out, these having to do with the degree of exposure of the fragments to the matrix and the consequent magnitude of the alterations. Thus, the smaller the size and the more sinuous or irregular the shape of the fragment, the greater the contact area and, therefore, the greater the edge effect (RIBEIRO; RIVAS; SANTOS, 2012). In addition, the fragment isolation grate must also be considered as seen in insular biogeography (MELLO, 2014).

addition to the direct effects on biological communities, the formation of borders produces indirect effects, causing a series of behavioral changes that generate, therefore, several other changes, since in community interspecific relationships are unfeasibly important to maintain life. Thus, among the indirect biotic effects occurring at the edges, the increase in the herbivory index stands out (RIBEIRO; RIVAS; SANTOS, 2012), causing great physical wear of leaves, fruits and seeds on vegetables, resulting in changing processes as pollination and seed dispersal, linked to the wear and tear of the responsible agents' behavior, these being mainly insects, mammals and birds.

## 7 CONSIDERATIONS

It is considered that the study presented here has its importance, as it enables knowledge of the Cerrado landscape in its functional and ecological aspects. In summary, different from expectations and according to the work methodology, the native vegetation in the micro-region of Ceres increased between 2008 and 2018, due to the conservation of part of the APP and Legal Reserves areas. The hypotheses raised for this increase are limited to the application of the Forest Code, which requires the protection of the banks of water courses and establishes the maintenance of 20% of the soil covered by natural vegetation in the region.

Although the verified increase in vegetation is positive, it is important to emphasize that the fragmentation of habitats is still a worrying fact in the micro-region analyzed, as it causes serious ecological problems involving flora and fauna, especially in the dispersion of seeds and in the formation of blocking environments for some native species. With the studies carried out, it was possible to detect factors that indicate the presence of fragments with long areas separating them, that is, without any connectivity.

Thus, this study is also presented as a possibility for other areas of research, according to the objectives, such as monitoring wild fauna that have their behavior altered by any change in their habitat. Finally, it is considered necessary more environmental policies aimed at areas of the micro-region where the fragments are more spread out, making it impossible to connect the habitats.

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