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Analysis of the landscape dynamics in the municipality of Rio Verde, Goiás, Brazil: a tool to choose priority areas for conservation

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Abstract
In a landscape, it is important to consider its dynamic to understand the causes of habitat loss and its relationship with other elements to propose priority areas for biodiversity conservation. In the present study, we considered the municipality of Rio Verde (GO) and analyzed its landscape in the years 1987 and 2016. This municipality has a primarily agricultural economy and, therefore, its natural habitats had been converted into anthropic landscapes. We conducted the initial analysis by interpreting the images of Landsat satellite for the years of 1987 and 2016, where we characterized: 1) increase in the agriculture areas; 2) reduction in the pasture areas; 3) reduction in the areas of savanna formation; 4) increase in the areas of forest formation; and 5) increase in the areas of Campestre formation. We observed that those areas of abandoned pasture or areas of savanna formation altered over the years were occupied by areas of Campestre formation. Based on landscape metrics obtained from Fragstats software, we observed that isolation was not altered among the analyzed class, except for urban areas and water. In 2016, the municipality of Rio Verde had only 198 fragments of native vegetation with more than 100 hectares. Therefore, we suggest such fragments are the most priority to conserve the local biodiversity.
Keywords: Fragmentation; Habitat loss; Fragstats; Insulation; Cerrado.

Introduction

The current historical period can already be seen as the sixth mass extinction of species, mainly due to changes in the evolution of land use and occupation without conservationist criteria (CEBALLOS et al., 2015). According to Santos and Câmara (2002), impacts on ecosystems occur as a function of land occupation growth, historically carried out through the use of archaic economic and social practices which were developed based on the

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idea of the inexhaustibility of natural resources, a process which has increased considerably over the last three decades.

In this context of deterioration, the Cerrado is also inserted, which was considered by Mittermeier et al. (2004) as one of the 34 biodiversity hotspots, because it presents a high index of endemic species submitted to a high level of environmental degradation. As a result of this high level of deterioration, this biome may be losing species still unknown to science (DINIZ-FILHO et al., 2005). Moreover, in the face of the sixth mass extinction, it may be that the opportunity to avoid the deterioration of biodiversity is passing rapidly, which will result in the loss of ecosystem services at different scales (CEBALLOS et al., 2015).

Beuche et al. (2015) concluded that by 2010, the natural coverage of remnants of Cerrado had already reduced to 47% in the Brazilian territory. As stated by Soares Filho et al. (2014), current Brazilian environmental policies will still allow additional deforestation in the Cerrado, which can worsen this scenario. Ceballos et al. (2015) have drawn attention to the urgency of intensifying conservation efforts in the current scheme. In this sense, from the environmental point of view, one of the actions to be performed is the mapping of fragile areas, which may be losing plant cover at faster rates than those required to maintain certain ecosystem services.

It is in this regard that research on landscape ecology has much to contribute towards biodiversity conservation and ecosystem services, as they present two main approaches. One is the geographical perspective which privileges the study of man's influence on the landscape and land use. The other is ecological which emphasizes the importance of the spatial context on ecological processes and also the established relations between environment and processes for biological conservation. Both benefit from the use of satellite imagery and Geographic Information Systems (GIS).

Advances in space technologies, data, and images obtained by orbital sensors and treated in GIS have become essential tools for mapping vegetation cover vegetal cover and, consequently, the remnants of the natural coverings, in this case, the Cerrado (MESQUITA JÚNIOR, 1998). These technologies enabled the improvement of methods to acquire ecological information of the vegetation and recognition of the distribution of its various morphotypes on a regional scale (MESQUITA JÚNIOR, 1998).

As stated by Rosa (1992), the development of GIS technology has permitted the integration and manipulation of diverse data and the construction of models that change in time and space. Such models allow characterizing the fragmentation of a landscape by providing quantitative values of spatial extent and distribution of the different types of fragments from which they are composed (VALENTE, 2001). The spatialization of these actions depends, however, on the prior understanding of the allocation and characteristics of their forest fragments, as well as on their interaction with other components of the landscape, that is, it relies on the understanding of the landscape structure.

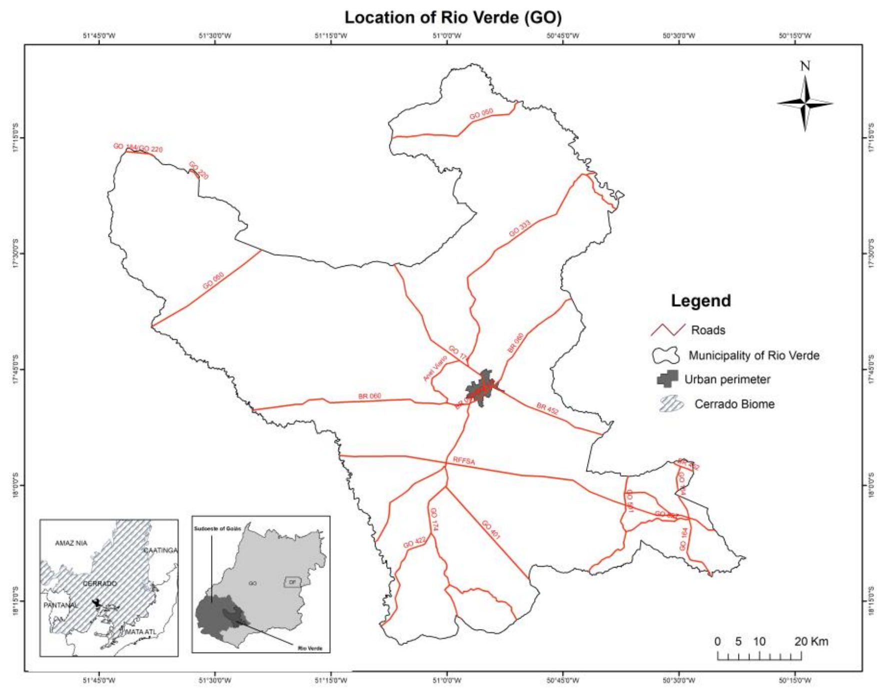
Thus, the study of vegetation fragmentation approaches the discipline called Landscape Ecology. This discipline deals with the relationship between spatial patterns and ecological processes, quantifying through "landscape metrics or landscape indexes" with precise spatial patterns (METZGER, 2003). Landscape Ecology or Geoecology has been promoting a change in the paradigms of analyses of the fragmentation and conservation of species and ecosystems, since it allows the integration of spatial heterogeneity and the concept of scale in the ecological analysis, making them more applicable to solve real environmental problems (METZGER, 2001).

In this context, the areas representing spatial transformations from economic policies are the focus of the investigations in landscape ecology, as they represent significant spatial changes of the natural elements of the landscape to the detriment of the anthropic ones. To better understand these processes and losses of ecosystem services, this research aimed to map the use of anthropic soil in the municipality of Rio Verde, located in the state of Goiás, Brazil, and the remnants of the Cerrado formations, comparing the last three decades. Also, we compared the landscape dynamics over these three decades with emphasis on landscape metrics which allow assigning environmental zoning basis, however, highlighting their fragilities and potentialities.

Material and methods

The study area is the municipality of Rio Verde, located in the Southwest microregion of the State of Goiás - Brazil, in the Cerrado Biome. Rio Verde extends over 8.415,40 km² and has an estimated population of 207 thousand inhabitants (IBGE, 2016) (Figure 1).

Figure 1. Location of Rio Verde, Goiás - Brazil.



Source: IBGE. Cartographic base. Authors organization, 2019.

Carneiro et al. (2011) found that in the past decade (from 2005 to 2008) the economic and agricultural dynamics of Rio Verde municipality maintained the vast changes in agricultural areas in the landscape, which interfered with the dynamics of native vegetation, especially between fragments of dense and sparse Cerrado, both of the savanna formation.

Thus, to carry out the mapping of the advance of the anthropic use of the soil and the dynamics of the natural habitats, we selected the years of 1987 and 2016. For this analysis, the Landsat TM satellite images with spatial resolution of 30m, bands associated to the RGB channels, with exact composition with 0.45-0.90 µm spectral response were used, discriminated in the following spectral intervals (blue - 0.45 -0.52 µm, green - 0.52-0.60, red - 0.63-0.69 and the next IV - 0.76-0.90). The images were obtained between July and October from the National Institute of Space Research (INPE) to allow a better interpretation through the spectral response, due to the seasonality of the vegetation, which allows identifying accurately the phytophysiognomies that considerably lose their leaves in this period.

The images were classified in the ArcGis software through pixel classification, which initially analyzes classes of reflectance subdivided into water, urban area, pasture, agricultural are, and Cerrado vegetation. The main categories of native vegetation were divided into forest formation, savanna, and grasslands (RIBEIRO; WALTER, 2008). Field validation was necessary to confirm the classes generated through *in situ* samples and to continue the analysis of the landscape metrics.

Besides, we used the Fragstats software to analyze the "landscape metrics or landscape indexes" of the remnants, as proposed by McGarigal and Marks (1995). Fragstats is a free space statistics software designed to quantify the composition, configuration, and connectivity of spatial objects within a raster image. It accepts a graded image, performs image searches to search for contiguous fragments of each type, and then calculates a comprehensive set of landscape values and indexes based on the fragments found (HESSBURG et al., 1999). The use of this software for analysis of landscape metrics has already been used in studies in the state of Goiás (CARVALHO et al., 2009; CARNEIRO, et al., 2011; SIQUEIRA et al., 2017, among others).

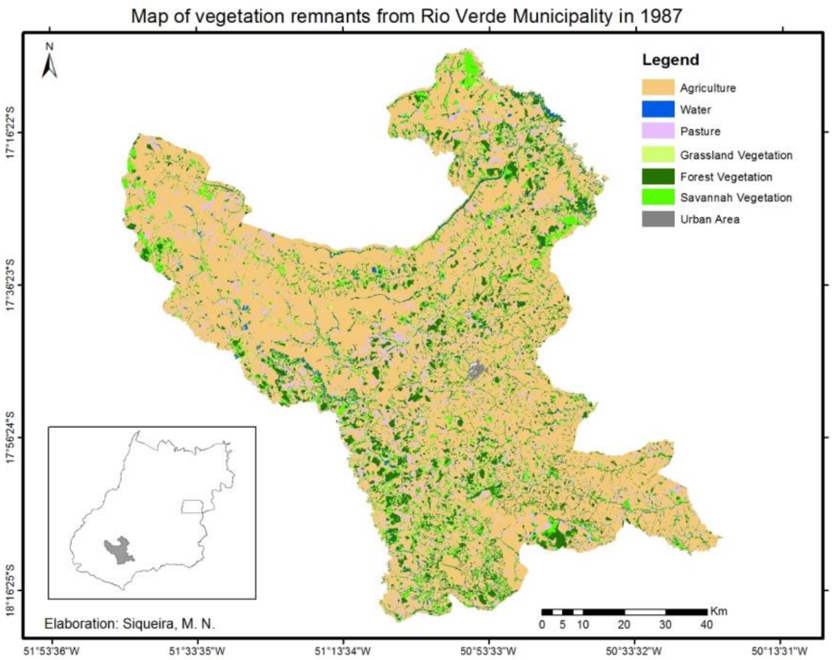
Among the methodologies proposed in landscape ecology, we adopted the Metrics of Fragmentation (degree of rupture of an initially continuous unit), Isolation Metrics (measure the isolation of a single fragment and the average isolation for all areas), as well as the Connectivity Metrics (landscape ability to facilitate biological flows) (METZGER, 2003).

Results and discussion

When interpreting the satellite images of Rio Verde for the years 1987 and 2016, it was possible to perceive a significant advance of the agricultural activities on pasture areas, but mainly on the native vegetation (Figures 2 and 3). The Pasture not only lost space to agricultural activities but it also migrated to more concentrated areas in the southwest portion of the municipality.

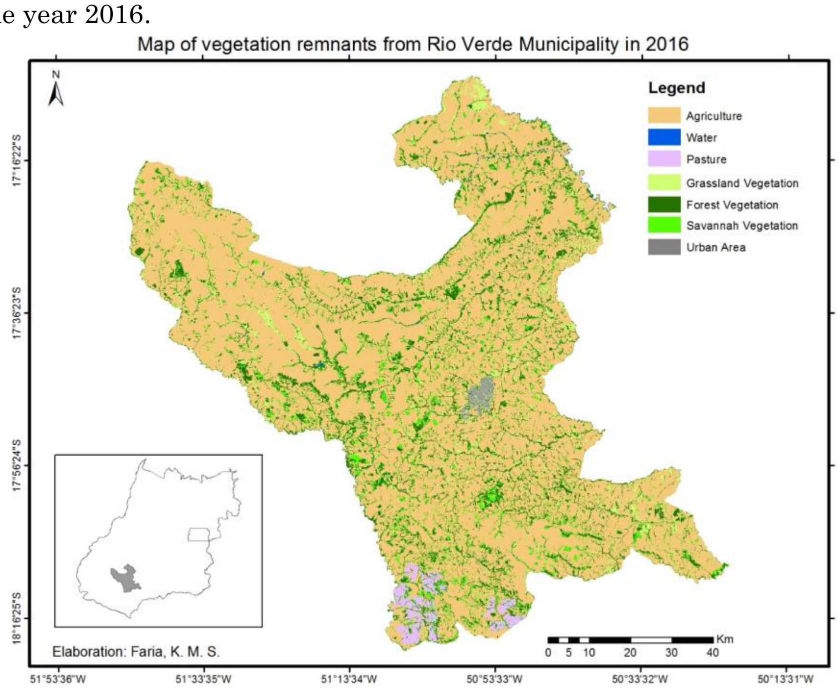
The analysis of the landscape metrics in the Fragstats software was carried out at a training level, not a phytophysiognomy, in which it is possible to corroborate from Table 1 what the maps indicate in relation to the increase in Agriculture activity in the last 30 years, a representation of 66.98% of the territory of Rio Verde in 1987, to 74.59% in the year 2016.

Figure 2. Map of remnants of vegetation and anthropic soil use in the municipality of Rio Verde, in the year 1987.



Source: Landsat Images. Elaboration: Siqueira (2016).

Figure 3. Map of remnants of vegetation and anthropic soil use in the municipality of Rio Verde, in the year 2016.



Source: Landsat Images. Elaborated by Faria (2016).

Table 1. Analysis of landscape metrics relating to classes for the years 1987 and 2016 in the city of Rio Verde, Goias – Brasil.

Metric/ year	Formation	CA	PLAND	NP	TE	TCA	EMN_MN	COHE-SION
1987	Agriculture	561,093.12	66.98	34,323	67,580,940	334,692.09	71.74	99.97
	Water	14,682.87	1.75	25,974	9,235,320	2,.418.39	126.58	81.61
	Pasture	75,158.73	8.97	85,964	40,717,830	2,752.56	86.02	89.32
	Grasslands	21,941.82	2.62	53,839	16,387,140	1,401.84	100.39	74.92
	Forestry	93,306.42	11.14	38,213	29,986,170	36,291.51	97.90	93.76
	Savannah	70,264.17	8.39	82,944	38,347,020	11,036.43	83.37	89.79
	Urban	1,205.37	0.14	40	111,240	664.74	436.70	98.86
2016	Agriculture	627,619.77	74.59	14,421	34,850,400	557,891.82	79.97	99.97
	Water	876.51	0.10	48	275,850	319.32	1,751.18	96.61
	Pasture	12,519.63	1.49	315	1,251,630	8,425.44	90.82	98.90
	Grasslands	49,591.35	5.89	68,732	27,032,340	7,896.24	94.23	88.56
	Forestry	95,946.93	11.40	42,528	37,292,370	35,268.03	84.78	95.50
	Savannah	51,243.03	6.09	50,803	27,080,070	15,251.94	92.35	87.50
	Urban	3,606.12	0.43	157	622,920	2,023.02	75.32	99.29

Legend: Class area in hectare (CA), percentage of the class area (PLAND), number of class fragments (NP), total perimeter of edge in meters (TE), total central area in hectares (TCA), Euclidean distance nearest neighbor class (EMN_MN), and connectivity between class fragments (COHESION).
Source: elaborated by the authors (2016).

Pasture reduced from 8.97% to 1.49%, and especially small portions of pasture in wetlands near the waterways were abandoned, and agricultural activities replaced regeneration of grass formations. This reduction of pasture areas corresponds to the agricultural matrix of the municipality based on the production of commodities.

The savanna formations that reduced from 8.39% to 6.09% also gave rise to Grasslands formations, which to a lesser extent were also replaced by agricultural areas. In this way, the increase of the Grasslands areas can be observed by the loss of pasture areas and savanna areas. For example, in 2016, it possible that some environments of Park Cerrado (savanna area) have become more open due to anthropization process and, consequently, were classified as grassland formations. Forest formation showed the smallest change, with an increase of less than 0.3%. A similar increase to forest formation occurred for the urban area class.

Park Cerrado or Murundus, which is very peculiar and sensitive phytophysiognomy, since mixes savanna and grassland formation (Ribeiro and Walter, 2008), lost area in the extreme northeast of the municipality. These authors classify and characterize the vegetation of the Cerrado and emphasize that the Cerrado biome is composed of phytophysiognomies arranged in three types of formations (forest, savannas, and pastures). The actual savanna formations are grouped into Cerrado *sensu stricto* (thin, typical, dense and rocky cerrado), and in the paths, Park Cerrado and Palm Groves. The authors point out that the Park Cerrado is a savanna formation composed of trees grouped and concentrated in small elevations of the terrain, presenting heights of 3.0 to 6.0 meters, tree cover of 5 to 20%, under gleysolos or plintossolos. These small elevations of the terrain are sometimes imperceptible, but others, known as murundus, are more visible.

Fragments of Park Cerrado, are therefore priority areas for conservation in the State of Goiás, because they constitute reserve areas for biodiversity, and have become legally protected as Areas of Permanent Preservation since 2007 (GOIÁS, 2007). The environmental legislation from Goias state (GOIÁS, 2007; 2013) defines Park Savana as a phytophysiognomy of the Cerrado biome, which consists basically of a humid field, on steeply sloping ground, with rounded or clean islands of grassland or cerrado with a diameter of about 1 (one) to 10 (ten) meters, per centimeters in height. Additionally, this phytophysiognomy is usually located upstream of the spring and along the water source.

According to the regulations that protect the environment of Park Savana, any suppression of vegetation or even the use of areas located near murundu fields, drainage, cultivation, grazing, and other activities must maintain a minimum radius of 50 meters wide around these areas, in addition to passing through environmental impact assessment and environmental licensing (GOIÁS, 2007).

Even with the gain of forest and pasture areas and the reduction of savanna formations, the final balance of native vegetation in 2016 was 23.38%, higher than the 22.15% that covered the municipality in 1986. Carneiro et al. (2011) also observed a dynamics of increase of some typologies of vegetation in the municipality of Rio Verde, when analyzing the landscape dynamics between the years 2005 and 2008, highlighting that the native vegetation balance in the municipality was about 22% in the year 2008.

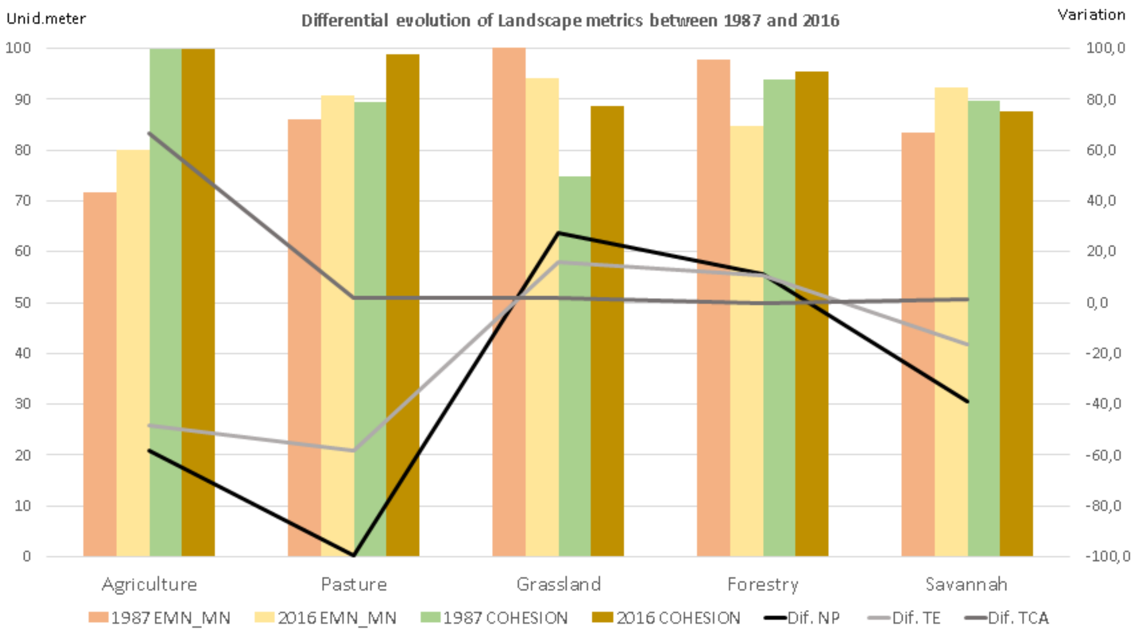
Thus, it is possible to observe that eight years after the analysis of Carneiro et al. (2011), the municipality of Rio Verde still obtained a small gain of native vegetation cover, especially in areas of the southeastern portion of the municipality, in Areas of Permanent Preservation. This fact may be a response to the obligation of the Rural Environmental Registry (CAR, in Portuguese), which according to Brazil (2012), is the national electronic public registry, mandatory for all rural properties, with the purpose of integrating the information environmental aspects of rural properties and possessions, composing a database for control, monitoring, environmental, economic and anti-deforestation planning. Thus, many owners are isolating legally protected areas to avoid environmental liabilities.

Rio Verde presented in 2016 anthropic activities covering 76.5% of its territory. Ponciano et al. (2015) found that for the municipality of Mineiros, also located in the Southwest of Goiás, the anthropic activities covered only 58.7% of the municipality and that native vegetation still comprised about 41.2% of that area in the year 2012. However, this difference may be associated with the soils and type of relief that predominate in these municipalities, since Ponciano et al. (2015) pointed out that the highest percentage of native vegetation remaining is under Permanent Preservation

Areas of drainage or slope or escarpment. As for Rio Verde, Carneiro et al. (2011) emphasize the predominance of flat topography, and Santos (2006) highlights the predominance of latosols.

We observed that the number of fragments (NP) between the analyzed years reduced by about 58% for the agriculture class (Figure 3). This reduction happened because the size of continuous agricultural areas increased. Agricultural fragments and the area of the class increased by 66.7% and almost 12%, respectively. The border area reduced by almost 50%. The nearest neighbor Euclidean distance for the agriculture class is the lowest in relation to the other classes (79.97 meters in 2016), remaining almost unchanged between the years analyzed (an increase of about 9 meters), as well as the high connectivity which remained unchanged.

Figure 3. Differential evolution of Landscape metrics between 1987 and 2016 (Agriculture/ Pasture/Grassland/ Forestry/ Savannah)



Source: Data extracted from the metrics of NP, EMN, COHESION, NP, TE, and TCA and organized by the authors (2018).

The pasture had the most substantial loss in area (about 83%), accompanied by a significant loss in the number of fragments, which reduced by about 99% (Table 1). Despite the loss in area and quantity, pasture fragments become larger (206% increase of the central area of these fragments), with a drastic reduction of the border area (97% reduction). The fragments of this class showed an increase of only four meters in the Euclidean distance of the nearest neighbor and had greater connectivity.

In native vegetation, the grassland formation, which clearly gained anthropic savanna formations and abandoned pasture areas, showed an increase of about 27.6% in relation to the number of fragments (Table 2), together with a 126% increase in its area, plus a 4.6 fold increase in the central area of these fragments and also with an increase in the area of border at almost 65%. There was also a reduction of the nearest neighbor Euclidean distance in six meters and an increase in connectivity, although the connectivity in the year 2016 is still considered low among these remnants (88.56). The lowest dynamics occurred in the forest formation, in which the metrics presented a few variations. Despite a reduction in forest area of 2640.51 ha, its dynamics concerning landscape metrics were little impacted, with a loss of only 2.8% in its total area. Thus, even with little lost area, it was enough to cause a more significant fragmentation of this class, increasing by 11.3% the number of fragments. The greater fragmentation led to a loss in the central area of 2.8%, which caused the increase in edge area by 24.3%. Despite the increase in fragmentation, remnants of forest formation became closer by about 13 meters in relation to the nearest neighbor Euclidean distance, and connectivity also increased from 93.76 to 95.50.

The Savannah formation underwent major changes over the years analyzed, as it lost about 27% of its area. At the same time, about 38.7% of fragments were extinguished for this formation, leaving larger fragments, which can be explained by the increase of the central area by about 38%, with the consequent reduction of border area by almost 30%. The distance of the fragments of this class increased by about nine meters at the nearest Euclidean distance, and consequently, the connectivity reduced from 89.79 to 87.50. However, urban areas do not significantly affected landscape analysis, as does the water class, given the low representativeness in the municipality of Rio Verde, although there are four urban districts besides the urban area.

Table 2. Analysis of the landscape metrics related to the size of the spots (fragments) of each class for the years of 1987 and 2016 in the municipality of Rio Verde, Goiás

Land use	Size	NP 1987	NP 2016
Agriculture	< 1.0 ha	31,423	12,743
	1.01 - 10 ha	2,445	1,415
	10.01 - 50 ha	344	182
	50.01 - 100 ha	53	30
	> 100 ha	58	51
Pasture	< 1.0 ha	77,218	238
	1.01 - 10 ha	7,523	47
	10.01 - 50 ha	1,054	12
	50.01 - 100 ha	122	0
	> 100 ha	47	18
Grasslands	< 1.0 ha	50,311	62,789
	1.01 - 10 ha	3,371	5,325
	10.01 - 50 ha	147	527
	50.01 - 100 ha	8	59
	> 100 ha	2	32
Forestry	< 1.0 ha	34,975	30,424
	1.01 - 10 ha	7,093	6,256
	10.01 - 50 ha	1,150	1,227
	50.01 - 100 ha	184	175
	> 100 ha	126	131
Savannah	< 1.0 ha	74,394	42,995
	1.01 - 10 ha	7,680	6,964
	10.01 - 50 ha	734	768
	50.01 - 100 ha	83	61
	> 100 ha	53	15

Source: elaborated by the authors (2016).

Landscape analysis of spot size dynamics makes it possible to understand trends in the fragmentation or fusing of patches over the years

(Table 2). For the fragments of Agriculture, the reduction of fragmentation is outstanding, since there is a drastic reduction especially of the fragments smaller than 10 ha (reduction of about 58%). However, although the larger fragments also showed some reduction, the concentration of arable land in areas larger than 10 ha is evident, corroborating with the analysis of the landscape by class.

In the same context, concerning the dynamics of the size of the spots, the pasture was the class that reduced its fragmentation the most, since several spots smaller than 10 ha disappeared over the analyzed years (99.6% of the spots). On the other hand, the grassland formation, as opposed to the pasture, showed a considerable increase of the fragmentation, and the spots smaller than 10 ha increased by 26.8% and those bigger than 10 ha but smaller than 50 ha, considerably increased by 258.5%. Forest and savanna formations reduced fragmentation, especially fragments smaller than 10 ha, since they reduced 12.8% for forest formations and 39.1% for savanna formations.

Carvalho et al. (2009) reported for the state of Goiás that the landscape dominated by the crops show greater fragmentation of the Cerrado concerning landscapes dominated by pastures. The dynamics of the landscape in Rio Verde, corroborates this trend of increasing fragmentation of natural remnants of Cerrado, in a landscape whose percentage of agriculture changed between 66.98% and 74.59% between 1987 and 2016.

For the landscape of Rio Verde, the large number of patches of native vegetation of less than 10 ha is a worrying situation, since there may be a reduction in the quality of these habitats for the local biodiversity. Although Fahrig (2003) warns that only the loss of habitat is insufficient to affirm that there will be a consequence to biodiversity, the author points out that the loss of habitat coupled with the fragmentation of the landscape brings severe consequences to biodiversity. In this context, Scariot et al. (2005) complement that the negative alterations to the biodiversity due to the fragmentation are more significant when there are changes in the isolation of the spots, besides change in the form, the size of the stain, in the surrounding matrix of the fragment and also the edge effect. The authors point out that these changes increase the occurrence of natural and anthropogenic disturbances within the fragment, affecting biodiversity and consequently ecosystem services.

Considering that Carvalho et al. (2009) point out that the areas cultivated with agriculture generate a more harmful landscape structure for biodiversity conservation in the Cerrado biome, it is urgent to think of a biodiversity conservation program for the municipality of Rio Verde. This is because only 15 fragments of the savanna formation present areas larger than 100 ha, and for the forest formation there are 131 fragments, and for the grassland formation, 32 fragments exist. Of the latter, the coves mentioned above (Park Cerrado), located in the extreme northeast of the municipality, were the most mentioned, and they had more arboreal vegetation in 1987 when they were classified as savanna. However, in 2016 its changes have already led to the predominance of grassland formations, in addition to those remnants also having lost habitat area.

Several authors investigate the sustainability of fragments for certain groups of animals and plants (SIQUEIRA et al., 2017; SILVA; ROCHA, 2015; SCHMIDT et al. 2012). The fact is that if the vegetation does not present sustainability, it will end up affecting the communities of animals and the functional diversity of diverse groups of living beings. In this context, Siqueira et al. (2017) found that fragments of Thick Cerrado (a savanna phytophysiognomy) do not present negative effects of loss of woody plant diversity when extensive areas lose habitat and remain with an area greater than 50 ha. Together with this scenario, in a large study carried out in the Atlantic Forest, Magioli et al. (2015) found a relationship between functional diversity and habitat spot size, with habitats smaller than 60 ha presenting the lowest values of functional diversity for medium and large mammals. Cullen et al. (2005) also suggested that for large mammals, the average area of habitat to affect populations minimally would be 100 ha.

In this perspective of understanding the quantity, location, and patterns of patches of sustainable habitats in the municipality of Rio Verde, there is a concern with the maintenance of ecosystem services for the municipality, since Carvalho et al. (2009) have already warned that agricultural matrices are more detrimental to biodiversity. This is also the reality of the municipality of Rio Verde. Therefore, a determining factor in a fragmented landscape is the quality of the habitat, involving the availability of resources necessary to maintain the standards of the communities present on the site. Given that the agricultural matrix of Rio Verde represents 74.59% of the municipality, it is possible that many of the fragments smaller than 10 ha are affected by the edge effect. It comes from a matrix that uses fertilization processes, exotic cultivated species and aggressive inputs for biodiversity such as agricultural pesticides. Therefore, the spatial analysis of the Rio Verde landscape needs to be complemented by more in-depth ecological studies to point out possible threats to biodiversity, but also to confirm possible priority areas for biodiversity conservation. It is also worth noting that up to now the municipality of Rio Verde does not present any Protected Area in its territory to expand these ecosystem services, which are of high environmental and economic importance.

Conclusions

The analysis of the landscape dynamics in Rio Verde between 1987 and 2016 revealed patterns of loss of natural habitats in area and quality since savanna formations gave way to agricultural activities or were anthropized to the point of becoming open formations and grasslands. The agricultural activity that predominates in the municipality led to the migration of the pastures to its southwest portion, in addition to bringing a worrisome warning, given that the literature indicates that agricultural matrices bring more negative impacts to biodiversity.

The remnants of native vegetation are currently under pressure of agricultural activities and are losing area, in addition to generating more fragmented vegetation. It is necessary to think about the conservation of significant areas that allow the maintenance of ecosystem services. For this, the larger areas must be taken into account, with sufficient natural resources to maintain biodiversity and functional diversity in these environments. Mapping and landscape dynamics over the last three decades is only an initial step in understanding the location of large remnants of natural habitats that are potential for conservation.

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