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ORIGINAL ARTICLE – Conservation of Nature

The Homogenization of two Different Natural Ecosystems by Conversion to Pasture in the Southern Espinhaço, Brazil

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Abstract

Fragmentation of natural areas alters the natural landscape, removing native vegetation and creating an anthropic matrix. In order to better understand the consequences of grazing in areas of campo rupestre and forest, the present study aimed to analyze changes in the vegetation of Cerrado and Atlantic Forest, in the Southern Espinhaço, between 1979 and 2015. The vegetation of the study area was identified as arboreal (forest), or herbaceous or shrubby (campo rupestre) by visual classification of a mosaic of aerial photographs from 1979 and the supervised classification of land use from a Landsat 8 image from 2015. Differences in vegetation were analyzed using a transition matrix based on the "Markov model", which indicated conversions of vegetation classes due to the misuse of land, mainly as pasture. The results indicate the conversion of arboreal vegetation area into areas of exotic herbaceous vegetation, and stability in the area of shrubby vegetation.

Keywords: Arboreal, herbaceous, landscape ecology, shrubby.

1. INTRODUCTION

One of the main causes of accelerated deforestation has been livestock activity, with the direct consequence of the conversion of native areas into pastures (Pendril et al., 2019). Fragmentation of the transition region between the vegetation of Atlantic Forest and Cerrado is the result of constant degradation of their natural ecosystems due to the misuse of land for agriculture and, mainly, for pasture (Salomão et al., 2018). This degradation alters more than just the biodiversity of the region because the region also encompasses an extensive drainage network, and thus serves an important role in regional nutrient recycling (Mingoti et al., 2016).

The removal of native forest alters the soil because the absence of vegetation can increase temperatures, cause erosion and modify the water balance (Mao et al., 2018). The creation of isolated fragments is due to the replacement of natural vegetation with different ecosystems, such as pastures and agricultural fields, thus immersing fragments in an anthropic matrix (Santos et al., 2019). Such landscape mosaics of tropical vegetation are subject to constant perturbation (Staal et al., 2018).

According to Nóbrega et al. (2017), the conversion of tropical savannas to pasture can also cause a regional decrease in mean monthly precipitation. Furthermore, even if there is no resulting change in mean precipitation, there will certainly be an increased frequency of the dry season. Changes in climate patterns due to pastures can make areas of vegetation transition increasingly susceptible to invasion by exotic plants (Garcia & Ballester, 2016).

Vegetation transformation in the municipality of Conceição do Mato Dentro, caused structural evolution of the communities of campo rupestre (Cerrado) and dense ombrophilous forest (Atlantic Forest), mainly due to the creation of pastures. This, in turn, has led to more and more changes to the optimal

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conditions of survival and reproduction for native species, and an increase in invasive species adapted to the new conditions (Salomão et al., 2019). In addition, this type of anthropism can result in other environmental impacts in the area, such as annual burning since fire is still used as a tool to expand agricultural areas (Resende et al., 2017).

To support this transformation in the Atlantic Forest-Cerrado transition, 35% of the open areas of Cerrado in Brazil had already been replaced by pastures by 2013 (see project TerraClass Cerrado - MMA, 2015). The concern with conserving the area is with the loss of biodiversity due to the alteration of the landscape by fragmentation, since this affects the biotic environment in the landscape and, consequently, the distribution of species (Resende et al., 2017). In this way, ecological conservation depends on native vegetation cover and how it is spatially distributed. Campo rupestre in the Southern Espinhaço have been subjected to degradation due to a variety of factors, but mainly the lack of ecological knowledge and poor management, which has resulted in the introduction of invasive exotic species (Fernandes, 2016).

Despite the high biodiversity and endemism of the study region, it has experienced intense habitat loss due to fragmentation caused by unregulated land use. Within this context, there is great concern about the campo rupestre, as it currently has one of the highest rates of land use conversion in Brazil (Garcia & Ballester, 2016). Furthermore, there have been no scientific studies in the area to inform local public policies regarding sustainable management of natural resources and restoration of impacted areas, and so monitoring of land use and occupation in the region is essential.

In view of the present concern, this study aimed to quantify conversion of forest and campo rupestre due to changes in land use and occupation by analyzing vegetation classifications from satellite images and assessing the effects associated with these losses.

2. MATERIALS AND METHODS

2.1. Description of the study area

The studied area is located within the transition between the Cerrado and Atlantic Forest biomes in the municipality of Conceição do Mato Dentro, state of Minas Gerais, Brazil. The area encompasses 12,359 hectares and, according to the classification of K**ö**ppen – Geiger (1929), the climate of the region is tropical altitude, which is represented by elevations above 500 m, mild temperatures between 18ºC and 26ºC, a thermal amplitude between 7ºC and 9ºC and elevations varying between 679 and 1472 meters a.s.l.

In the region of transition, areas of dense ombrophilous forest at higher elevations are composed of arboreal vegetation, while those of campo rupestre are composed of herbaceous vegetation dominated mainly by native and exotic grasses and a composite shrub vegetation of scattered twisted trees and shrubs. Areas of dense ombrophilous forest and campo rupestre in Conceição do Mato Dentro have been converted to pasture by the introduction of invasive exotic grasses such as *Braquiaria decumbes* (Salomão et al., 2018). This fact is worrisome since the region has a history of accentuated fragmentation, which when added to the conversion of dense ombrophilous forest and campo rupestre to pasture, further favors the loss of biodiversity (Salomão et al., 2019).

2.2. Image processing and classification

To analyzing the transition probability for areas according to vegetation class, vegetation coverage for the years 1979 and 2015 was mapped. The year 1979 was the first year for remote sensing of the non-fragmented area. The thematic classes used were establish from field work carried out in the study area, which aimed to capture the type of vegetation, soil conservation status and anthropic use.

The arboreal vegetation class was comprised of dense ombrophilous forest at elevation areas that had not been anthropized by pasture and agriculture. The campo rupestre was classified as shrubby, being composed of medium-sized vegetation in areas of higher elevations with the presence of agricultural crops, and herbaceous, being covered by creeping native and exotic vegetation and characterized by the occurrence of *Brachiaria decumbens* in pasture areas. The vegetation classification was first performed visually in the field in July 2015.

2.2.1. Mosaic of aerial photographs (flights of December, 1979)

A mosaic is a set of aerial photographs registered and united by adjustments and overlaps (Cunha et al., 2006). The mosaic of the present study (Fig.1) was created from 17 aerial photographs of the study area, which were located in a photograph from the municipality of Presidente Kubitschek (sheet 2460). The photos were provided by Companhia de Pesquisa de Recursos Minerais (CPRM) and transferred to Casa da Glória do Instituto de Geociências da Universidade Federal de Minas Gerais (IGC-UFMG). After georeferencing, the photographs were combined in a mosaic using the mosaiking tool of Envi 4.5 software.

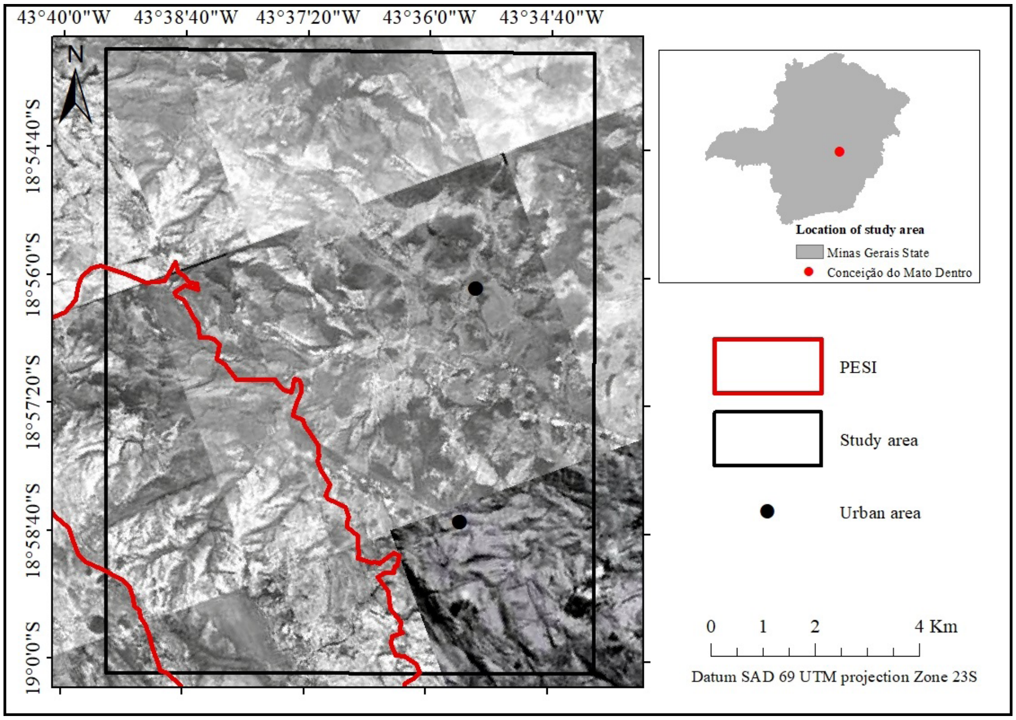
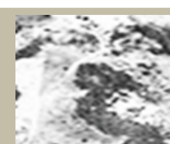
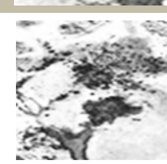
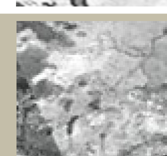


Figure 1. Mosaic of aerial photographs of the study area including part of Parque Estadual Serra do Intendente (PESI).

The visual classification of the vegetation of the mosaic was based on the key of vegetation for fragments proposed by Panizza & Fonseca (2000) and resulted in the three classes of vegetation: arboreal, shrubby and, herbaceous. The parameters evaluated were color intensity (tonality), saturation, texture and appearance. According to the interpretation key for panchromatic images (black and white) proposed by Messias (2012), areas colored white and represented by smooth texture and irregular shape are classified as "bare rock" (Table 1).

Table 1. Visual classification of the vegetation of the study area

Classes	Tonality	Saturation	Texture	Appearance (irregular)
Arboreal	Very dark gray	High	Fine	
Shrubby	Dark gray	Medium	Fine	
Herbaceous	Light gray	Low	Fine	
Bare rock	Very light gray	-	-	

To analyze the vegetation for 2015, a Landsat 8 satellite image from 18 July, 2015, was used to produce a map of land use and occupation. All satellite images show systematic distortions during the acquisition process, and so geometric correction (registration) was necessary (Espirito-Santo & Shimabukuro, 2005). To register the image, the 2010 Geocover image of the state of Minas Gerais was used as a spatial reference. This process was done with corresponding control points of the two images using the registration tool of Envi 4.5 software.

2.2.2. Supervised classification of Landsat 8

According to Rudorff et al. (2007), supervised classification of images is the most widely used method for quantitative analysis of data and is based on the use of algorithms to determine the pixels that represent values for a certain class. This method requires prior knowledge of the number of classes of land use and coverage contained in the image. Supervised classification for land use and occupation of the study area (Fig. 2) was developed based on previous knowledge of sampling points obtained during fieldwork conducted in July 2015, which determined a class of arboreal vegetation for areas of forest, and a class of shrubby and, herbaceous vegetation for areas of campo rupestre. The herbaceous vegetation comprises pasture areas and may be exotic or native.

The points sampled in the field were inserted and analyzed within the accuracy indexes global accuracy and *Kappa* described by Bolfe et al. (2004); according to the author, the accuracy values for the indexes should be above 85%. Kappa tests are used to measure the accuracy of image classifications because the test is able to account for all elements in a confusion matrix (Hua 2017). These values were obtained using the software Envi 4.5 from the confusion matrix generated with the post classification option for the comparison between the regions of interest of the classified image and the classification observed in the field. The accuracy (global 94%, Kappa 86%), indicated that the classification was satisfactory and better than would be obtained from a random classification.

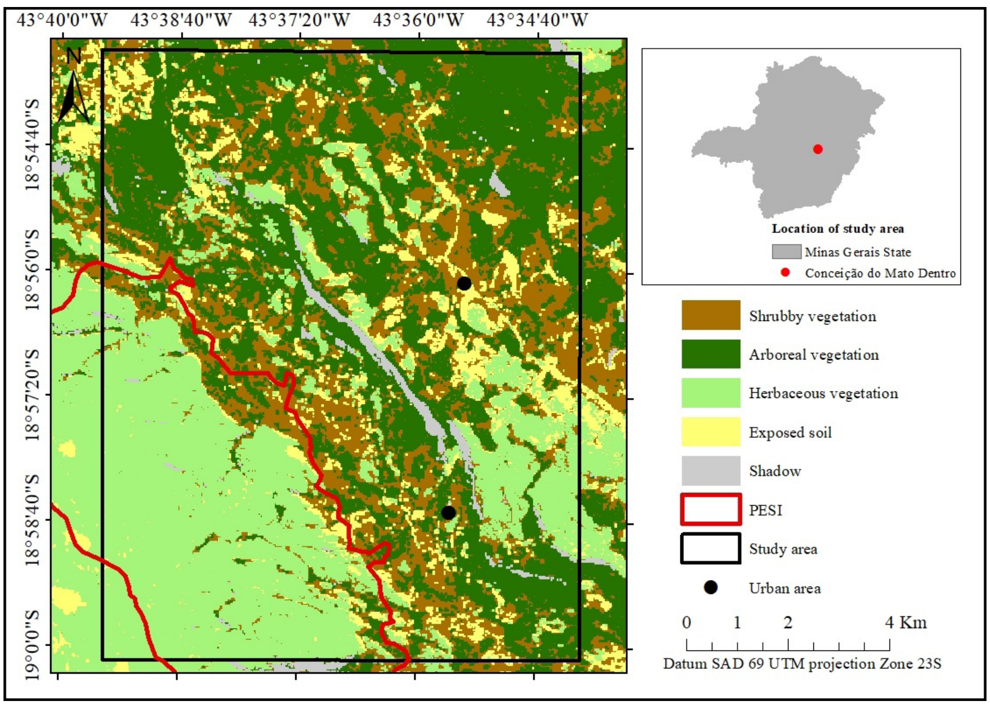


Figure 2. Land use and occupation in the study area for 2015, which includes part of Parque Estadual Serra do Intendente (PESI) and the urban area.

3. DETECTION OF CHANGE AND THE TRANSITION MATRIX

The transition matrix permitted the analysis of the processes behind the probable patterns of vegetation change through pixel-to-pixel comparison of losses and gains of the area of vegetation classes (Romero-Ruiz et al., 2012) as a function of land use and occupation differences between the mosaic of aerial photographs (1979) and the satellite image (2015). Areas of the vegetation classes were calculated using the software Envi 4.5.

The Markov Model consists of making a transition matrix whose purpose is to describe changes in populations or communities (Gotteli, 2009). According to Nappo (2005), the only requirement of this model is that populations can be separated into groups of states and that there is the possibility of transition from one state to another over a given time.

Changes in land use and coverage, simulated from Markov Chains, are based on probability theories and given by the equation 1 (Ruhoff et al., 2010):

$\text{II}^{(t+1)} = pn \, \text{II} \, t$

Where $\text{II}^{(t)}$ corresponds to the state of the system at time *t*, *t* +1 corresponds to the state of the system after that instant *(t)* and *P n* are the possible states that are represented in matrices of transition possibilities. These transition matrices represent the possibility of a given state *i* remaining the same or changing to state *j* during the time instant $t \geq (t+1)$.

The transition matrix for three classes (arboreal, shrubby and herbaceous), showed the proportion of the total landscape area lost, represented by the rows (1979), and the total area gained, represented by the columns (2015). The notation Aij (where i ≠ j) indicates the proportion of the landscape that went through a transition from class i to class j between the years 1979 and 2015; the main diagonal elements, with the notation Ajj, indicate the proportion of classes that exhibited persistence of class j; the proportion of the Ai+ landscape that is occupied by class i in 1979 (Coelho et al., 2014), is given by equation 2:

$$Ai{+}=\sum_{i=1}^{n} Aij$$

where: n is the total number of classes.

The proportion of A+j landscape that is occupied by class j in 2015, is given by equation 3:

$$A{+}j=\sum_{i=1}^{n} Aij$$

Finally, the probabilities of each state of the matrix were arranged in a vector π called the State Probability Vector. The classes that had a probability of change below 3% were considered insignificant and, therefore, were not analyzed.

3.1. Edge metrics

To calculate the edge effect, we used the landscape metrics of *total edge* (TE) and mean of *area-perimeter ratio* (PARA_MN) by vegetation class of 1979 and 2015 using the software Fragstats 4.2. Classes that had lower mean *area-perimeter ratio* and higher *total edge* had higher edge effect. An edge of 100 meters was considered for the calculation of the metrics.

4. RESULTS

4.1. Change in areas of classes from 1979 to 2015

From 1975 to 2015 the area of arboreal vegetation suffered a retraction, as indicated by the negative value, whereas the areas of the shrubby and herbaceous classes underwent expansions, as represented by positive values (Table 2).

Table 2. Areas for vegetation classes in the study area for 1979 and 2015.

Vegetation Classes							
Area(ha)	Arboreal	Shrubby	Herbaceous	Exposed rock	Exposed soil	Total area	Vegetated area
1979	6,573	3,033	505	2,248	-	12,359	10,111
2015	4,045	3,932	3,259	-	1,123	12,359	11,326
1979-2015	- 2,528	+ 899	+ 2,754	-2,248	+1,123	4,776	+ 1,125

Table 3. Matrix of transition probabilities among vegetation classes of the study area for the years 1979 and 2015.

		2015			
		Arboreal	Shrubby	Herbaceous	Total
1979	Arboreal	0.73	0.03	0.24	1
	Shrubby	0.03	0.77	0.20	1
	Herbaceous	0.20	0.17	0.63	1
Total		0.96	0.97	1.07	**3**

The values of Table 3 were arranged in vector π (stwate probability vector):

$$\pi = \begin{pmatrix} 0.73 & 0.03 & 0.24 \\ 0.03 & 0.77 & 0.20 \\ 0.20 & 0.17 & 0.63 \end{pmatrix}$$

4.2. Border effect

For 1979, the mean *perimeter-area ratio* varied little among classes, therefore only *total edge* was considered. For 2015, the mean *perimeter-area ratio* (PARA_MN) also varied little among classes, and so only *total edge* was also considered. Because arboreal vegetation had the highest *total edge* it had the greatest edge effect, while herbaceous vegetation had the lowest *total edge* and thus the least edge effect (Table 4).

Table 4. Mean *area-perimeter ratio* (PARA_MN) and *total edge* (TE) for the vegetation classes of the study area for the years 1979 and 2015.

CLASS	PARA_MN		TE	
	1979	2015	1979	2015
Arboreal vegetation	1116:0577	1049:4862	3,929	781,975
Shrubby vegetation	1108:6412	1060:5243	1,862	140,094
Herbaceous vegetation	1030:6903	1035:4481	180	10,998

5. DISCUSSION

5.1. Transitions in the dense ombrophilous forest

The transition of areas from 1979 to 2015 revealed an accelerated reduction of vegetation cover with the substitution of native vegetation by pasture and agriculture. During the period from 1979 to 2015, the arboreal class experienced the greatest reduction in area with a loss of 2,528 hectares (Table 2) in the study region.

The gross loss of area for the arboreal class was due to the ease of deforestation in flat areas for the establishment of pasture and agriculture, which confirms that accessibility is one of the main factors behind deforestation (Pleniz 2016). According to Filho & Moura (2016), declivity is one of the most widely considered parameters in methodologies for land use suitability classification in Brazil and is directly related to livestock and agricultural practices, which explains the conservation of the humid ombrophilous forest in the steepest areas of the study area.

Extensive areas of native forest undergoing rapid changes result in a "fish bone" type of pattern (Maurano et al., 2019), which may have favored changes in the composition of arboreal vegetation in flat areas mainly due to agriculture and livestock. This pattern has a significant effect on ecological relationships since the isolation of an area reduces gene flow, promoting low genetic diversity, and affects the local microclimate, the hydrological cycle, maintenance of natural resources, the protection of slopes and oxygen production and CO2 capture, among other effects (Dantas et al., 2017).

A reduction in the *area-perimeter ratio* and an increase in *total edge* of the arboreal class (Table 4) were observed from 1975 to 2015, which caused an effective increase in the edge effect for those areas. The size of the edge area of fragments is directly related to the surrounding environment, such that the type of matrix near fragments can make the edge effect more or less intense. (Costa et al., 2019).

Fragments with lower area/perimeter ratios, due to greater edge effect, are subject to changes to the microclimate within fragments, such as increased internal temperature and occupation by invasive species. (Fernandes & Fernades 2017). Thus, for this study, we can conclude that the edge effect for the arboreal class from 1979 to 2015 was certainly a result of forest fragmentation for the establishment of pasture and agriculture, and is related to the potential conversion of 24% of its area into the herbaceous class.

Forest fragmentation is a serious phenomenon in the process of expansion of the agropastoral frontier in Brazil as it causes the isolation of different sized forest stretches among disturbed areas, leaving the periphery of fragments more exposed to insolation and modification of the wind regime (Silva et al., 2012). These changes were analyzed in the arboreal class since the expansion of livestock production was mainly due to the emergence of grasses with high adaptability to the climate and low-fertility soil (Lima & Gama, 2018).

The species *Brachiaria decumbes*, is found in high frequency in the study area because it is perfectly adapted to the meager environmental conditions and provides high productivity, and thus is becoming the main plant introduced into pasture areas (Sá Souza et al., 2018). This study demonstrates that the edges of forest fragments represent suitable areas for the development of herbaceous species, which successfully inhabit this ecotonal environment (Muller et al., 2009).

5.2. Transitions in the campo rupestre

The high potential for natural regeneration of shrub species of the campo rupestre in areas of pasture (Viani et al., 2010) explains the 77% probability of shrub vegetation remaining from 1979 to 2015 (Table 3).

The large pastures and agricultural areas presently found in the campo rupestre are evidence of great environmental impacts (Fernandes et al., 2016), however, the natural restoration of campo rupestre can occur in pasture areas when they are abandoned due to low productivity (Silva et al., 2017). According to Luz et al. (2018), the natural restoration of vegetation occurs more easily in anthropized environments when the areas possess high potential for regeneration. However, the presence of exposed soil in many of the abandoned pasture areas of the study area indicates that the capacity for natural regeneration has been lost.

Pasture generally reduces the carbon and nitrogen concentration of the soil, since these elements are very vulnerable to cultivation because they are concentrated in the topsoil (Cavagnaro et al., 2016), and thus regeneration capacity is easily lost. However, some authors such as Silva et al. (2019) have reported that pasture establishment can not only recover soil carbon content but, in some cases, it can increase it.

The changes that occurred with the herbaceous class were represented by a 63% probability of persistence and 20% and 17% probability of conversion to arboreal and shrubby classes, respectively. The probability of persistence for this class is associated with the continuous use of areas for grazing.

Exotic species of the genus *Brachiaria* introduced for foraging were responsible for maintaining the exotic herbaceous class. In abandoned pastures these species indicated a potential for interference in regeneration and possess characteristics that favor the low growth of native herbaceous plants in open areas, such as tolerance for nutrient poor soils and vegetative propagation, resulting in greater competitive ability and, consequently, biomass accumulation (Calil et al., 2016).

The occurrence of abandoned pastures may also favor the conversion of 17% of the herbaceous area to shrub as represented in Table 3. Native herbaceous vegetation acts in the reconstitution of the original shrub vegetation by helping to protect the land from erosion; maintaining the necessary temperature, luminosity and humidity; and facilitating the attraction of animals by restoring animal-plant interactions. (Reis et al., 2003).

Changes in the composition of vegetation of natural ecosystems associated with pasture and agricultural practices can have serious consequences, not only with regard to biodiversity, but also regarding the deterioration of the soil and the consequent variation in the local climate (Longo et al., 2000). Lack of management and an increase in abandoned pastures can lead to total degradation of the soil and other natural resources, with irrecoverable losses for all of society (Peron & Evangelista, 2004). Thus, in order to analyze transitions among vegetation classes of the Cerrado and Atlantic Forest biomes, this study constitutes a relevant resource for predicting damage to the environment, and can serve to facilitate local ecosystem maintenance.

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