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Forest fragmentation in the landscape in the Atlantic Forest Biome: A systematic review of the literature

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SUMMARY

Forest fragmentation is defined as the process by which a continuous area of habitat is reduced in size and divided between spaces. Therefore, due to the increase in these areas, this study aimed to conduct a systematic review of the literature on forest fragments in the Atlantic Forest biome in order to verify their main characteristics and landscape ecology. Publications in search platforms referring to the period from 2000 to 2020 were analyzed such as: SciELO, Google academic and CAPES journals portal. The search terms entered were: "Studies of forest fragments in the Atlantic Forest biome" and "Landscape ecology in forest fragments". A total of 15 articles were selected from among the works found, and 5 of these were chosen to be evaluated in the present study. Four of the five works were carried out in the state of Espírito Santo, close to basins and sub-basins, and only one work was carried out in a state park. Thus, the evaluated works with the theme, study of fragmentation and ecology of the landscape showed a high degree of fragmentation, meaning that they have fragments smaller than 5 hectares; in addition, all fragments have an irregular edge effect. Therefore, measures aimed at the conservation of biodiversity are needed in all places so that there is ecological restoration of the landscape and conservation of fauna and flora in the Atlantic Forest biome.

KEYWORDS: Landscape metrics. Future simulations. Geographic Information Systems.

1. INTRODUCTION

Forest fragmentation can be defined as the process by which a continuous area of habitat is reduced in size and divided between spaces separated by an environment or matrix of habitats different from the original (FORERO-MEDINA and VIEIRA, 2007). Due to the increase of these areas throughout the history of mankind, great debates have arisen regarding issues related to preservation and conservation, since fragmentation in its great majority is a phenomenon driven by the disordered activity of use and occupation of the territory, requiring interventions to change this current scenario (SANTOS et al., 2017).

Furthermore, the Atlantic Forest deserves to be highlighted when referring to fragmentation, as it is considered one of the most threatened forests on the planet (JUVANHOL et al., 2011). This biome previously occupied a large part of the Brazilian territory, however it is currently one of the most fragmented ecosystems when compared to tropical forests due to the various practices of land use. The biome is composed of very small landscapes with low diversity of habitats and isolated patches (RIBEIRO et al., 2009), therefore it constitutes one of the regions identified worldwide as a Hotspot, meaning that it is a priority area for conservation, of high biodiversity and threatened to the highest degree (BEZZERA et al., 2011). In view of this, there is a clear need for greater preservation of this ecosystem by developing studies to maintain the sustainability of forest remnants.

The effects caused by the intense deforestation activity result in a loss of green areas in a given location. In addition to the loss of habitat, fragmentation causes direct impacts by increasing the edge effects, loss of biodiversity, changes in ecological interactions and in species reproduction processes, isolation of plant formations, increased predation, competition and loss of micro-habitat (LINDENMAYER et al., 2008). Moreover, it is worth mentioning that the absence of all these factors directly causes an extinction of this biome and consequently the disappearance of rich fauna and flora diversity in Brazil.

In this context, studies are needed to elucidate the degree of effectiveness and vulnerability of these environments in order to gain more knowledge about the fragments. Therefore, the use of metrics and landscape ecology indexes aims to promote the use of these resources for maintaining biodiversity. Furthermore, the analysis enables assisting to define

management techniques to recover and/or conserve forest remnants (MORAES; MELLO; TOPPA, 2015). According to Metzger (1999), the landscape structure can be defined by metrics of area, shape and spatial arrangement of its interactive units (ecosystems, vegetation units or land use and occupation). In turn, this highlights the need for systematic literature review studies in order to obtain information on the location of the main fragments and consequently their respective results.

For greater understanding of the textual genre of the study, it is worth mentioning that there are different types of literature review studies; among these is the systematic review proposed by Pickering and Byrne (2014), which aims to standardize the search for all articles found to later perform a quantitative analysis. This type of review enables the researcher to identify the occurrence of the studies, their main results and their limitations, thus contributing to progress in research, in addition to being able to verify the possible methodological discrepancies (BORENSTEIN et al., 2009).

2. OBJECTIVES

This work aimed to study the forest fragments in the Atlantic Forest biome in order to verify their main characteristics, landscape ecology, development and degree of fragmentation through the accuracy of the results of the selected works in order to inform and collaborate for conservation and protection of this biome.

3. METHODOLOGY

Systematic reviews of the literature are important to establish and aggregate results of studies through research, evaluation and criticism, addressing all of these issues in just one document with the purpose of conceiving new knowledge (MORANDI, CAMARGO, 2015). The review of the present work has the study of forest fragmentation and landscape ecology in the Atlantic Forest biome as its main theme. The main focus upon which this work is focused is basically the following: What are the main methodologies and variables used to study forest fragments in the Atlantic Forest?

First, all articles published in scientific journals which presented correlation with the content covered and made available between 2000 and 2020 in search platforms such as SciELO, Google academic and the CAPES journals research portal, were used as data sources.

The article selection took place through more recent studies, aiming to identify the forest fragments with greater current degradation and which consequently fit better with the thematic of the work. The search terms entered were: “Studies of forest fragments in the Atlantic Forest biome” and “Landscape ecology in forest fragments”. All the scientific articles found were analyzed, not taking into account papers in the formats of theses, books or abstracts from congresses.

The works were selected according to several aspects such as the publication year, the means of dissemination, the places where the studies were conducted, the main tools used to carry out the work, in addition to obtaining knowledge on the vegetation type of forest fragments. Finally, the methodologies used were evaluated to detect the similarities or differences between them in order to select those which were closest to each other (INKOTTE et al., 2019).

4. RESULTS

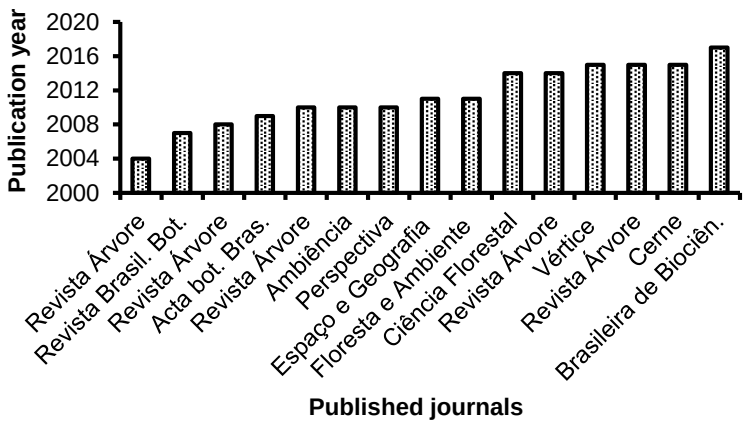
First, a total of 240 articles were found for the study on forest fragmentation considering the search “Study of forest fragments in the Atlantic Forest”. Next, 150 articles were found searching for the title “Landscape ecology in forest fragments”. After a thorough reading of their respective

abstracts, 15 scientific articles were chosen which fit the pre-established characteristics of the current study.

Of the total of 15 articles, 5 were published in the same journal, representing 33.33% and 10 were published in different journals, representing 66.67%, meaning that more than half of the works came from different scientific journals. However, among these 15 articles, 5 were chosen to be presented in the present work due to the methodology used and the publication year.

In evaluating the publication dates of the works, it is observed that the published works were found from 2004 to mid-2018, thus highlighting the occurrence of knowledge diffusion year after year in fragmented areas of the Atlantic Forest. Furthermore, the years 2010 and 2015 stood out for the publication of articles both with three publications, together representing 40% of the total years analyzed among the 15 pre-established articles (Figure 1).

Figure 1: Years of publications analyzed according to their respective journals.



In evaluating the five works mentioned above, four of them were carried out in the state of Espírito Santo, highlighting the occurrence of fragments found in this region and consequently the importance of further studies to analyze the current state of these areas. In addition, four studies were carried out close to basins and sub-basins, and only one study was carried out in a state park (Table 1).

Table 1. Main characteristics of the fragments and tools used in the analyzed works

References	Location	Area	Patch %	Scale	Software	Software extension
Bezerra et al. (2011)	Córrego Horizonte hydrographic sub-basin, Horizonte, Alegre, ES	250.32 ha	19.01 %	1:1500	ArcGis 9.3.	Patch Analyst
Juvanhol et al. (2011)	Forno Grande State Park, Espiríto Santo, ES	21.749.80 ha	42.60 %	1:1.500	ArcGIS 9.3	Patch Analyst
Pirovani et al. (2014)	Itapemirim River Basin, Espiríto Santo, ES	28.267.18 ha	17 %	1:1.500	ArcGIS 9.3	Patch Analyst
Jesus et al. (2015)	Poxim River Basin, Sergipe, SE	9.412 ha	8.05 to 36.32 %	1:100.000	ArcGis 9.3	Patch Analyst 5.0.
Silva et al. (2015)	Rio da Prata sub-basin, Aracruz and Ibiraçu, ES	1.355.32 ha	40.69 %	1:5.000	ArcGis 10.2	V-LATE 2.0 beta

Through the results of the works, it is noted that the total fragment area as well as the patch percentage and the extent of the software differed between the authors, however the same software for analyzing the area was used in all the works performed. This software is considered the basis for mapping forest fragments to obtain the number of fragments and their size by means of their extension, which creates a vector file for each forest fragment (SILVA et al., 2015).

Based on the results related to landscape metrics (Table 2), it can be concluded that almost all the fragments analyzed in the area had a relatively small size (<5 hectares). The degree of fragment degradation can be assessed through the mean patch size (MPS) and the number of patches (NUMP). Through the data below, it is evident that Pirovani et al. (2014) presented the highest number of analyzed patches; this is mainly due to the area, because in this case large fragments were considered as those with an area greater than 50 hectares, thus interfering in the discrepancy between the results established by the other authors.

Table 2. Results of the landscape ecology indexes of forest fragments.

Indices	Units	References				
		Bezerra et al. (2011)	Juvanhol et al. (2011)	Pirovani et al. (2014)	Jesus et al. (2015)	Silva et al. (2015)
MPS	Hectare	27.80	10.54	8.61	67229.00	281.77
NUMP	Hectare	9.00	2652.00	3285.00	140.00	164.00
PSSD	Hectare	39.91	200.40	37.35	10.65	37.19
PScoV	Percentage	143.49	1900.51	433.85	109.40	13.20
TE	Kilometers or meters	27690.00	3743922.00	6093977.15	112.00	214.20
MSI	Adimensional	1.82	1.71	2.07	2.70	1.77
Analyzed area	Hectare	> 100 ha	> 100 ha	> 50 ha	> 100 ha	> 100 ha

In which: MPS (Mean patch size); NUMP (Number of patches); PSSD (Standard deviation of patch size); PScoV (Coefficient of variation of patch size); TE (Total edges); MSI (Mean shape index).

It can be noted that the largest standard deviation was found in Juvanhol et al. (2011), which had the largest number of patches found after Pirovani et al. (2014) considering an area above 100 hectares. The values found by Juvanhol et al. (2011) are considered high values, and may indicate that there is great variation in the fragment sizes in the area, meaning patches with area values much above or below the average value. This is mainly due to the value obtained with the mean size of medium and large fragments (MPS) of 220.4 hectares and standard deviation of the patch size (PSSD) of 111.6 hectares.

According to Pereira et al. (2001), the mean size of the fragments should be analyzed by examining the standard deviation; if the standard deviation is very high, it is possible that there are large fragments, even with a relatively low mean size. Thus, the highest coefficient of variation was found by Juvanhol et al. (2011) due to the amount of large fragments found in the area in relation to the other studies analyzed.

The basic concept of the mean shape index (MSI) is that the patches are more circular in shape when closer to one, and the larger it is, the greater the irregularity. The author who showed a more regular shape was Juvanhol et al. (2011), while the most irregular shape was Jesus et al. (2015) with a value of 2.70; this same author also had the highest mean patch size index (MPS), with a much higher value than the other authors. However, all fragments showed effects considered irregular,

meaning greater than one, confirming the degradation present in the analyzed sites. The size and shape of the fragments are directly related to the edge; after all, the smaller the fragment or the more elongated, the more intense the edge effect will be (PRIMACK and RODRIGUES, 2001).

However, it is common to find a greater quantity of small forest fragments in Atlantic Forest landscapes, and one of the main problems is exactly the edge effect (TABANEZ and VIANA, 2000). The relationship between the number of fragments and the area they occupy most of the time is divergent, meaning that the large fragments have a smaller percentage in number; however, they represent a larger area of the forest remnants. Likewise, small fragments have a larger number of units, but the sum of their areas represents a smaller percentage of the total area of mapped forest fragments and are more related to the edge effect (JESUS et al., 2019).

In addition, it is important to address that the edge effect not only favors developing species of the extremities, but often predators, parasites and generalist species which tend to exclude, through competition or predation, the species from within (METZGER, 2009). However, in analyzing the fragmentation origin in different studies, it is evident that only two among the five authors presented the fragmentation origin, with these being Bezerra et al. (2011) and Silva et al. (2015). The causes were through the disordered occupation of land/coffee cultivation and through anthropic action, respectively. Therefore, it was essential to highlight the cause of fragmentation in order for there to be more information for readers, since it can foster techniques related to preserving the area in order to minimize the unfavorable effects on the regions.

The vegetation type of forest fragments (Table 3) is another important element for analysis, especially when it comes to a biome which is threatened with extinction to the highest degree, such as the Atlantic Forest.

Table 3. Vegetation type of forest fragments of the analyzed works.

References	Vegetation
Bezerra et al. (2011)	Seasonal Semi-deciduous Forest.
Juvanhol et al. (2011)	Dense Montana and Altomontana Rainforest, with transition to the Seasonal Semi-deciduous Forest
Pirovani et al. (2014)	-
Jesus et al. (2015)	Restinga, mangroves and fragments of humid tropical forest
Silva et al. (2015)	Remnant of the Atlantic Forest

In which: - the vegetation type was not specified.

However, not all authors presented the vegetation type; this may have occurred due to the extension of the analyzed areas, but the information would be extremely relevant and would contribute to situating the main vegetation of the location. Furthermore, having knowledge of the physiognomy, the forest distribution situation and the remaining fragments is essential to analyze, maintain and guarantee biodiversity and the conservation of water resources (PEREIRA et al., 2017). Another important topic which deserved to be highlighted is the soil type in the region, for which it is necessary to have knowledge in order to select the species which can adapt well to the place if you choose to revitalize the area.

Therefore, it is worth emphasizing the importance of methods which aim to contain the extension of these environments such as ecological corridors, which aim to mitigate the effects of ecosystem fragmentation by promoting the connection between different areas (MMA, 2020). However, no author mentioned the importance of this resource to contain the advances in their

respective areas; after all, the results presented in the works did not show satisfactory rates. In fact, it is eminent that this technique plays a fundamental role in minimizing the damage caused by interrupting a green area, which would add to the well-being of present and future generations.

5. CONCLUSION

The works evaluated with the study theme of landscape fragmentation and ecology showed a high fragmentation degree, meaning that they have fragments smaller than 5 hectares; in addition, all fragments have an irregular edge effect. Therefore, measures aimed at the conservation of biodiversity in all places are necessary so that ecological restoration of the landscape and conservation of fauna and flora in an area representative of the Atlantic Forest biome can be performed.

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