

Multivariate statistic applied to the study of the landscape ecology in the Atlantic Forest

Landscape ecology studies assisting planning and spatial planning, so it is important to know the behavior of the Atlantic Forest under the effects of rural and urban use, especially in fragments existing in a small municipality. When associated with multivariate statistics analyses, these data and information enable the diagnosis of the status quo of vegetation fragments. The research aimed to analyze the ecology of the Atlantic Forest landscape, in a small municipality, applying multivariate statistical techniques. The photo interpretation and calculation of the measurements of the passage were performed, and in the second moment, the proximity matrix was calculated, and finally, the cluster analysis was performed. The results allowed separating the Atlantic Forest fragments observed in four clusters with characteristics of ordinary size, in addition to significant internal similarity and great external dissimilarity concerning the ecology parameters of the analyzed landscape. Conclude that applying the cluster analysis technique will assist better management of the preservation and conservation of forest fragments, providing public policies and better management of areas, directing actions to the most threatened fragments.

Keywords: Ecology; Quadratic Euclidean Distance; Ward Method; Clustering.

Estatística multivariada aplicada ao estudo da ecologia da paisagem na Mata Atlântica

Os estudos de ecologia da paisagem auxiliam no planejamento e ordenamento do território, por isso é importante o planejamento e ordenamento do território, por isso é importante conhecer o comportamento da Mata Atlântica sob os efeitos do uso rural e urbano, principalmente em fragmentos existentes em um município de pequeno porte. Quando associados a análises estatísticas multivariadas, esses dados e informações permitem o diagnóstico do status quo dos fragmentos de vegetação. A pesquisa teve como objetivo analisar a ecologia da paisagem da Mata Atlântica, em um município de pequeno porte, aplicando técnicas estatísticas multivariadas. Foi realizada a fotointerpretação e cálculo das medidas da passagem, e no segundo momento foi calculada a matriz de proximidade e por fim foi realizada a análise de agrupamento. Os resultados permitiram separar os fragmentos de Mata Atlântica observados em quatro aglomerados com características de tamanho normal, além de significativa similaridade interna e grande dissimilaridade externa quanto aos parâmetros ecológicos da paisagem analisada. Conclui-se que a aplicação da técnica de análise de cluster auxiliará uma melhor gestão da preservação e conservação dos fragmentos florestais, proporcionando políticas públicas e melhor gestão das áreas, direcionando ações para os fragmentos mais ameaçados.


Palavras-Chave: Ecologia; Distância Euclidiana Quadrática; Método Ward; Agrupamento.

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INTRODUCTION

According to the history of deforestation of the Atlantic Forest, due to anthropic causes, it stands out as one of the most predatory in history at the global level. This deforestation dates to Colonial Brazil, but in the 20th century it reached alarming levels, with among its main causes obtaining timber products (MARTINS et al., 2004). One of Brazil's goals in the Sustainable Development Goals focus on ensuring the conservation, recovery, and sustainable use of terrestrial ecosystems and their services, especially forests, swamps, mountains, and arid lands agreements. However, public managers and other actors have failed to conserve these areas, especially in the Atlantic Forest that has strong anthropic dynamics causing fragmentation.

The fragmentation of remnants has direct effects on the ecological relations of plants and animals. The impacts of rural and urban activities promote the reduction of gene flow, reproductive isolation and, consequently, lead to a loss of genetic diversity. It is essential to know the behavior of the Atlantic Forest under the effects of rural and urban use, especially in fragments existing in a small municipality, and its implications for developing the state of Pernambuco (DANTAS et al., 2017).

The small and medium-sized municipalities in Brazil have been the scene of intense land use and occupation transformations, especially in the last four decades, due to urban expansion and the development of rural activities, even more intense in small cities. These municipalities have stood out as an object of study regarding the pattern of landscape structure, since public policies, economy, ways of life, environmental policies, among other aspects, reverberate in spatial configuration and signal possibilities and points of future conflicts.

Analyzing natural spaces, such as Atlantic Forest fragments, in a small municipality, environmental tensioners and negative environmental impact levels can be identified, supporting mitigation and remediation actions and public policies that promote sustainable development, guaranteeing the maintenance of the environment (COSTA, 2020). It should also be considered that small municipalities, such as São Vicente Férrer, in Pernambuco State, have fragments of Atlantic Forest that, without monitoring and studies on their status of environmental fragility, can be suppressed from the landscape, with high costs to environmental and ecosystem services, with losses in quality of life and regional economy. Based on theoretical assumptions of Landscape Ecology, which led this study, changes in land use alter the size and shape of the fragments of the remaining vegetation of the Atlantic Forest and the distance between them (MARTINS et al., 2004).

It is worth noting that studies of landscape patterns, the interaction between spots in the landscape, and the way patterns of landscape composition change with place where it is located, together provide theoretical and empirical support to the global understanding of the landscape, aiding planning, and spatial planning (CASEMIRO, 2009).

Such data and information, when associated with multivariate statistics analyses, enable the diagnosis of the status quo of vegetation fragments, which is quantification and determination of the biological condition of vegetation (related to the level of environmental fragility of the vegetation fragment).

From this perspective, the study aimed to analyze the ecology of the Atlantic Forest landscape, in a small municipality, through multivariate statistical techniques.

REVIEW OF THE LITERATURE

According to Landscape ecology

According to Costa (2020), the study of spatial arrangements of the landscape is a reflection generated by the influence of historical and modern changes in the natural and anthropic spheres. According to Odum and Barrett (2008), landscapes can be classified according to the degree of anthropic intervention. Thus, it is considered a 'natural landscape' that has had no interference, human origin, and 'modified landscape' is where there was human influence or intervention, and the 'cultural landscape' is where continuous human interference and the environment are combined. The 'cultural landscape' can also be considered a rural landscape, characterized by agropastoral or urban activities constituted by human agglomeration.

Costa (2020), studying a landscape, states that, whether natural, modified, or cultural, we must take into account the multiple scales of landscape elements, which are characterized as 'spots' or 'fragments', varying in type, heterogeneity, size, shape, and location, among other characteristics. The landscape is a matrix composed of ecosystems, containing a dominant ecosystem and spots or fragments of other secondary ecosystems, organized in variable patterns, connected, or isolated.

The connections between the fragments are ecological corridors, as they function as a means of passage between one fragment and another (CASEMIRO, 2009). Studies conducted by Fahrig (2020) show that the biological and physical effects of ecosystem fragmentation are severe; in this perspective, it is important to analyze the landscape ecology of Atlantic Forest fragments.

The characterization, description, and quantification of the landscape structure have helped to identify spatial and ecological characteristics, which have been taken as an object of study by the areas of Ecology, Geography, and Biology, to diagnose the degree of shredding and isolation of forest fragments (LANG et al., 2009). The study of landscape ecology aims at measuring and quantifying landscapes under certain structural and spatial aspects, and circumstances, with their respective parameter values, called landscape structure measurements or landscape metrics (CASEMIRO, 2009).

The landscape metrics has allowed performing evaluations at different spatial and time scales, contributing significantly to a better understanding of the patterns and processes involved in the maintenance of ecosystems, and to establish strategies aimed at biodiversity conservation, especially in the Atlantic Forest where there are strong anthropic interactions with preserved fragments (RUDOLPHO et al., 2013).

Multivariate Statistics

The techniques of multivariate statistics allow performing in a single analysis that previously required

multiple analyses using univariate techniques. The multivariate statistic corresponds to all statistical methods and techniques that simultaneously analyze multiple measurements and parameters about each individual or object under investigation. However, some multivariate techniques are uniquely designed to deal with multivariate issues, i.e., multivariate analyses, such as canonical variables, factor analysis, factor analysis, and discriminant analysis.

Currently, multivariate analytical methodologies are being widely applied in the most diverse research areas and have also been reaching the industry. The success of these techniques has allowed a strong integration of multivariate techniques in their 'analysis tools'. With the increasing use of techniques, publications dealing with the theoretical and mathematical aspects of these tools in the most diverse areas of science have increased. However, few publications approach this tool in a comprehensive language for researchers who are not experts in mathematics or statistics.

Publications that discuss the practical applications of multivariate statistics, offering a conceptual discussion of statistical methods, are even rarer than those that bring conceptual questions. In some areas of science, such as administration, genetic and behavioral improvement, multivariate statistical analysis is more widespread and widely used. However, in other areas such as the ecology of the landscape, which is the target of this study, there are not many scientific studies that address the application of multivariate statistical methodologies. Consequently, there are not many 'computational statistical packages' that make it difficult to interpret the results.

Some statistical packages and software were created with the advance of computing in recent decades, accessible even for personal computers. Numerous researchers had the necessary resources to address multivariate problems, however updating and interacting with the particularities inherent to the application of multivariate techniques is not an easy theme from the theoretical and practical point of view, especially in new areas of study. In this sense, studies involving applications of multivariate analysis techniques have been valued, given the need for new materials with the approach.

METHODOLOGY

The municipality of São Vicente Férrer occupies an area of 114 km² with approximately 18,018 inhabitants and is in 'Latitude: 7°35'26" South' and 'Longitude: 35°29'30" West'. The municipality has a border with Natuba, Macaparana, and Vicência Municipalities (CIDADES BRASILEIRAS, 2021), as shown in Figure 1. It is located at an altitude ranging from 600 to 640 meters, having a 'hot and humid' climate (As'), with autumn and winter rains and an average annual temperature of 24.1°C (FERRAZ et al., 2006). According to the official system for mapping and classification of Brazilian vegetation, in the municipality, the predominant Atlantic Forest ecosystems are 'Montromophilic Forest Montana' and 'Ombrófila Forest of Lowlands'.

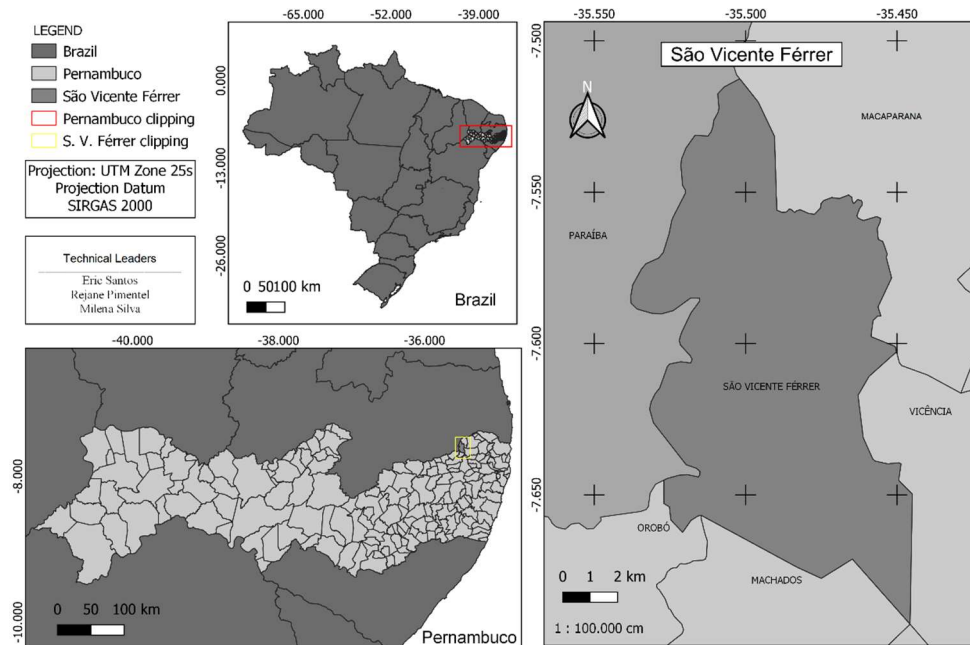


Figure 1: Location Map of the Municipality of São Vicente Férrer in Pernambuco, Brazil.

Geoprocessing and Multivariate Analysis

The image used for photointerpretation was obtained from Landsat 8, available in the United States Geological Survey: Earth Explorer image catalog, for January 23, 2021. After applying the Lang et al. (2009) equations, the calculations of the landscape metrics were performed by obtaining the area, edge, core, and proximity among the fragments. The multivariate analysis was performed on the results obtained in km². The analysis was made in two main stages: (1) elaboration of the proximity matrix and (2) cluster analysis. The use of multivariate statistical methods allows identifying clusters of fragments with similar ecological units and dynamics of the landscape. (1) PROXIMITY MATRIX: The construction of the proximity matrix was used in calculations of indicators in the exploratory analysis phase of spatial data or other multivariate analyses (Prass et al. 2007). This study used the quadratic Euclidean distance to construct the proximity matrix of the area, core, and edge data. (2) CLUSTER ANALYSIS: Cluster analysis is a technique used to classify unit objects or cases into clusters. Cluster analysis allowed analyze the forest fragments in each cluster like each other, but different from other clusters (MALHOTRA, 2006). The Ward method consists of a hierarchical grouping procedure in which the similarity measure used to classify the clusters is calculated as the sum of squares between the two clusters made over all variables in the total set was used to perform the groupings. This methodology tends to result in similar characteristics due to its minimization of internal variation between variables.

RESULTS AND DISCUSSION

The calculation of the area and shape of the fragments is considered one of the most important research processes because the area is the measure of the structure closest to reality and consequently is among the most widespread in landscape ecology studies. Its importance is also linked to the fact that the edge and core measurements are made directly or indirectly on the area. The results of the study area

calculations indicate that most of the Atlantic Forest fragments are small, with the existence of some exceptions.

Cluster analysis allowed separate Atlantic Forest fragments observed in four clusters, (Figure 2). The formed clusters have characteristics of size in common and great internal similarity and great external dissimilarity, concerning the ecology parameters of the analyzed landscape.

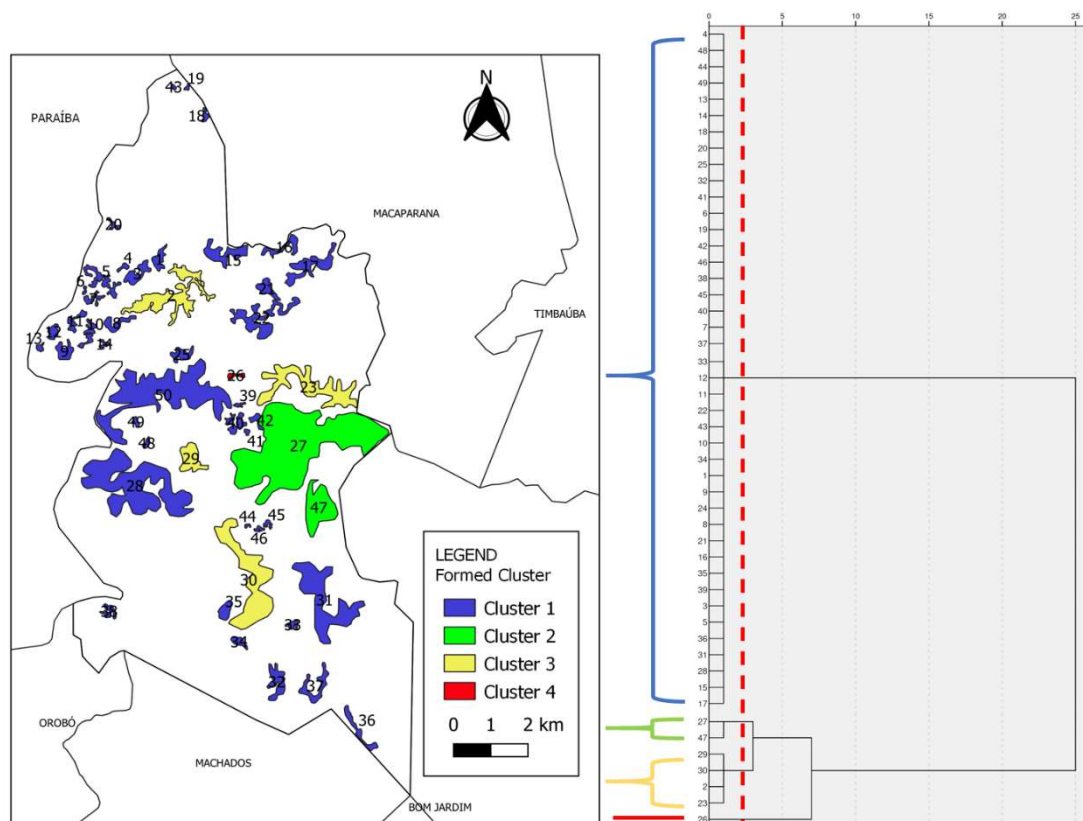


Figure 2: Scheme of distribution of forest fragments by the dendrogram.

The first cluster (Cluster 1) is formed by most of the Atlantic Forest fragments of the municipality, having among its main characteristics the irregularity in the shape of the margin and the area not being a common characteristic to the fragments, since the cluster aggregates fragments of the small and large area. Its distribution occurs from the north to the south of the municipality. Its existence may be associated with environmental regularization of the agricultural properties of the municipality or natural regeneration of previously deteriorated fragments.

The Atlantic Forest fragments included in the first cluster present characteristics that, according to different Landscape Ecology studies, indicate environmental fragility (CASEMIRO, 2009; DANTAS et al., 2017). Even so, these fragments play an important ecological and functional role in the landscape, providing habitat and resources for different animals that move between forest remnants (FAHIG, 2020).

The two largest fragments of forest form the second cluster (Cluster 2) has the dimension as its dominant common characteristic. According to the principles of Landscape Ecology (CASEMIRO, 2009), we can affirm that this grouping represents the landscape matrix, which is the most important element of the point of view of biodiversity conservation, considering its dominant role, and the probable presence of mother trees, greater number of families and plant species, and consequently greater number of animals.

We can also highlight that these two fragments have a less irregular margin shape when compared to the other fragments analyzed.

The third cluster (Cluster 3) has as its main characteristic the irregular shape of its margin. Its dimensions are similar and represent a medium area when compared to the clusters discussed earlier. Located between the matrix fragments, they are essential and can serve as an ecological corridor between the fragments of Cluster 1 and Cluster 2. The four forest fragments that are part of Cluster 3 are irregular in their form, even with their large areas, the irregularity in their shape represents an environmental aggravating factor allowing a greater edge effect, as pointed out (CASEMIRO, 2009).

Finally, the Atlantic Forest fragment number 26 were isolated in Cluster 4. It should be estimated that this isolation occurs not because of size but because of the rectangular shape, resulting not only in the absence of a nucleus but also a species of edge overlap, which in this work represents the distance of 100m between the edge boundaries of the fragment.

CONCLUSIONS

These techniques of multivariate cluster analysis permit the formation of groups of Atlantic Forest fragments using the similarities of the variables of the ecology of the landscape under analysis. We can affirm that this methodology is a valuable tool in understanding the spatial distribution of Atlantic Forest fragments in the municipality of São Vicente Ferres and in understanding the dynamics of the local landscape.

The data showed that cluster analysis was a useful methodology for better management of the preservation and conservation of forest fragments, due to the cluster permit to establish similarities that provide parameters for the creation of public policies and better management of the areas. It directs the actions to the most threatened fragments. More research must be done on the most conserved fragments so that recovery actions are done in the other.

It was concluded that the application of the cluster analysis technique proved to be extremely useful in the interpretation of the data and in the efficient indications for decision-making. Considering this perspective, the application of multivariate statistics will permit more accuracy in the conclusions and decisions.

The environmental fragility linked to the landscape metrics characteristics of the Atlantic Forest fragments included in Cluster 1, make them a priority for environmental restoration actions.

Cluster two, in turn, has the most comfortable environmental conditions, in view of its size, shape and location. Among the fragments, those present in Cluster 2 are the most suitable for the creation of a conservation unit.

Cluster three, as mentioned in the results, plays a key role in the conservation of Atlantic Forest fragments in the municipality, with the reforestation and expansion of these fragments its role as an ecological corridor, linking the larger fragments (Cluster 2) with the smaller fragments (Cluster 1 and Cluster 4) becomes more efficient.

Unfortunately, Cluster 4, due to its environmental conditions, is the most vulnerable fragment and if

no recovery action is done it is doomed to disappear. Other fragments of Cluster 1 will have.

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