Use of Landscape Metrics and Multi-criteria Analysis to Identify Landscape Units Concerning of Vegetation of Quadrilátero Ferrífero - MG

Lourdes Manresa Camargos(✉), Nicole Andrade da Rocha(✉), and Ana Clara Mourão Moura(✉)

Universidade Federal de Minas Gerais (UFMG), Av. Antônio Carlos, 6.627, Belo Horizonte, Brazil
loumcamargos@hotmail.com, nicarocha.jf@gmail.com, anaclara@ufmg.br

Abstract. This article had the main objective to identify Landscape Unities corresponding to the vegetation in the Quadrilátero Ferrífero area, in Minas Gerais. The study looks to contribute with the identification of homogeneous areas in the shape of territorial unities, for the composition of methods about the territorial strategic planning. For this, nuclear area landscape metrics were used, shape index and fractal connectivity, identified as the main metrics which depict quality and vegetation fractal embrittlement condition. Afterward, a Multicriterial Analysis by Evidence Weight according to the priority level for each metric, for integration of the analysis and identification of the greater values fractal bearing in mind the three aspects. As a result, two main unities were obtained: notable vegetation landscape; and vegetation with a higher vulnerability to transformation. Was observed a concentration of notable landscapes of vegetation on the central and southeast Quadrilatero's areas, mainly at the Serra do Gandarela, Serra da Moeda and Serra do Caraça. In counterpart, the areas corresponding to the south and north of the Quadrilatero, besides being closer to the urban centers, has shown to be more likely to be transformed due to the isolation of the fragments. Stem from this analysis, the importance of the Conservation Units maintenance is bolstered, which are fundamental to the natural resource's protection. The landscape metrics is rated as an important tool of landscape analysis through pattern identification and the understanding of the dynamics of a geographic region. At last, the multicriteria analysis is understood as an important tool for supporting the decision making, being able to evaluate different variables to obtain interest rankings, in agreement with the demanded objectives.

Keywords: Landscape metrics · Multicriteria analysis · Strategic planning

1 Introduction

Studies on landscape and territory must understand the relationships of the environment and its dynamics, about the potentialities and vulnerabilities related to anthropic action,

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as well as about the cultural values that elect notable values. For this, is necessary to have an integrated view of the physical and biological factors of natural systems and their interactions with socioeconomic and political factors [1].

The study of landscape ecology is a way of identifying existing changes and conditions of the landscape, through the identification and characterization of fragments in the territory, analyzing the spatial distribution and the forms they present.

It is an area of knowledge that proposes the study of the structure, function and change of these heterogeneous regions, seeking to identify patterns of changes and study the dynamics of a geographical region through metrics of the landscape [2].

In addition, Landscape Ecology aims to characterize the most suitable fragments for environmental conservation and compose the spatial arrangements necessary to achieve biodiversity, species balance and the gene flow that constitutes the landscape mosaic, in order to allow a balance between green areas and human occupation [3, 4].

The quantitative data of the landscape structure are termed as indexes or metrics of Landscape Ecology. When quantifying the composition and configuration of the landscape, these data allow the comparison between landscapes or between the same landscape at different times, allowing the identification of the functional processes and ecological patterns of the landscapes, allowing to measure the spatial distribution of the patches, evaluating both the fragment individually, such as the general structure of the area and the role of each fragment in the set, with regard to size, density, isolation, distance, connectivity and complexity of the shape [5, 6].

In this sense, this article seeks to combine landscape metrics and multicriteria analysis in order to understand the landscape configuration, identifying vulnerabilities and potentialities.

Multicriteria analysis is a method of spatial analysis that is based on the integration of data according to the objectives of analysis, taking into account multiple criteria, making a simplification of the spatial complexity involved through layers of information of the main variables that characterize the phenomenon [7, 8].

Thus, through the recognition of landscape patterns, the article presents a reproducible script to identify Landscape Units of the Quadrilátero Ferrífero referring to the areas with remarkable landscape and areas that have greater vulnerability of transformation.

The choice for the landscape of the Quadrilátero Ferrífero as an object of analysis is justified due to its landscape complexity and its richness in natural resources, mainly its water resources. The area is the birthplace and cradle of important water resources, of mountains that are a reference for the landscape of Minas Gerais and of transition between the Atlantic Forest and the Cerrado, with emphasis on the rupestrian field vegetation that is located together with the crests of the saws.

The Quadrilátero Ferrífero (Fig. 1) is in the center-southeast portion of Minas Gerais and occupies an area of about 18,000 km^2. The area is home to 52 municipalities, including the capital, Belo Horizonte.

The region has great environmental, mineral and geological importance in the state, having as its landscape reference the Serra do Gandarela, Serra da Piedade, Serra do Curral, Serra Rola Moça, Serra da Moeda, Serra do Ouro Branco and Serra do Caraça.

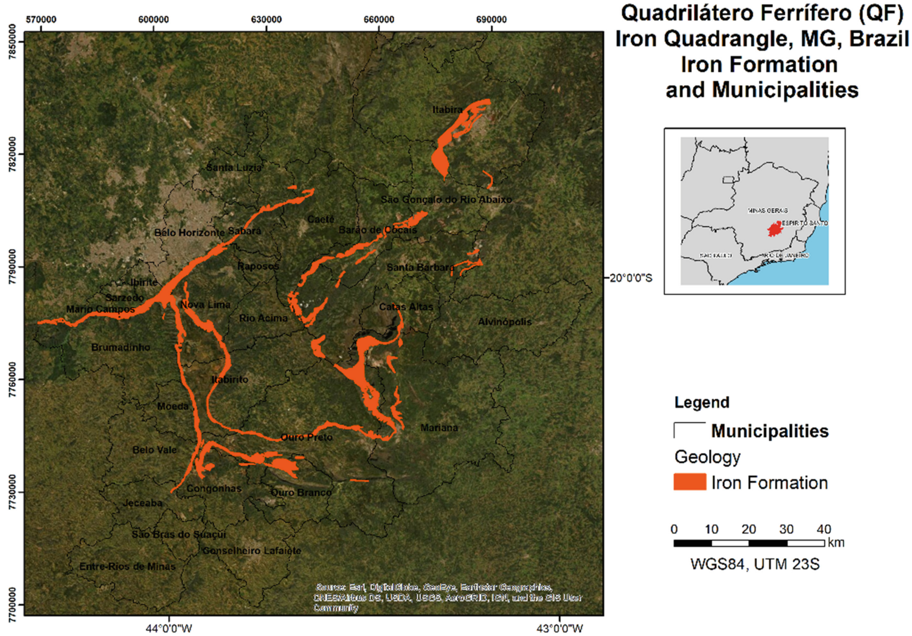

Fig. 1. Location of Quadrilátero Ferrífero

The limit of the Quadrilátero Ferrífero used in the present work corresponds to the boundaries of the municipalities where iron was found and was defined during studies by the Geoprocessing Laboratory of the School of Architecture at UFMG. This delimitation was made because the Quadrilátero Ferrífero itself is only the delimitation of the ferriferous area, but for territorial planning purposes it was decided to carry out the cut including the municipalities.

The Quadrilátero Ferrífero is a priority area for biodiversity conservation in Minas Gerais, being classified as an "Area of Special Biological Importance" [9]. The region's vegetation is composed of the transition between the Cerrado and Atlantic Forest biomes, with emphasis on the vegetation of Campos Rupestres. For this reason, the forests and fields of that region are extremely important for the maintenance of wild flora and fauna, especially of endemic, rare and endangered species.

Currently, Serra do Gandarela is one of the last physical and natural remnants in good condition present in the Quadrilátero Ferrífero. The region is of great importance due to the existence of aquifer recharge fields, its heterogeneous morphology, flora with species of Campos, Cerrado and Atlantic Forest, remnants of primary forests, in addition to the existence of geological heritage [10].

As it is a region of conflicts of interest, this work seeks to identify the Landscape Units of vegetation in the Quadrilátero Ferrífero, as a contribution to studies of strategic planning proposition, aiming at the protection or requalification of fragments. In this article, the metrics of the landscape calculated from the land cover data for the Campos and Atlantic Forest will be considered, as they are the main components of the local vegetation.

2 Methodology

The flowchart in Fig. 2 indicates the methodological steps in the development of the study.

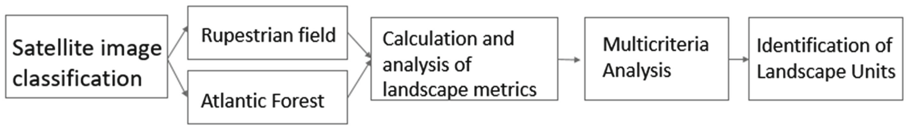

Fig. 2. Methodological flowchart

First, to identify the classes used, the soil cover map of IDE SISEMA (state Spatial Data Infrastructure) was obtained and a reclassification was made to obtain the classes that were used in this article, namely the Campos Rupestres (Rupestrian Fields) and the Mata Atlântica (Atlantic Forest), as shown in Fig. 3. The option to adopt an existing classification is justified by the intention of working with official data, although we have also already carried out a high-quality classification with the use of RapidEye images in 5 m spatial resolution and digital processing.

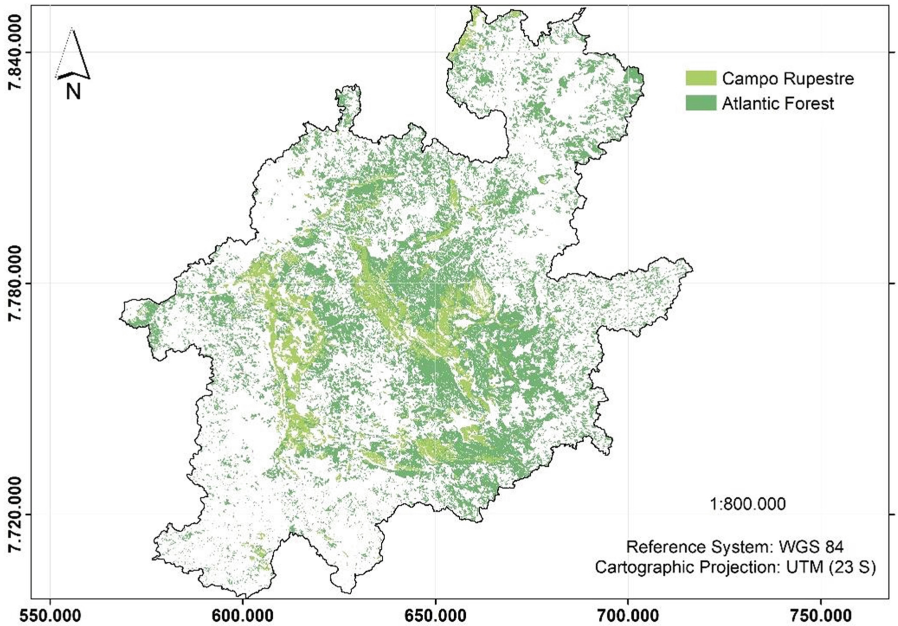

Fig. 3. Land cover classes

We chose to analyze the Campos Rupestres and Mata Atlântica class separately, as it is understood that each ecosystem represents a different importance, having different characteristics of fauna and flora.

Among the set of metrics indicated by the studies of Landscape Ecology, three were chosen, due to previous studies that indicated them as "drivers" variables, main indicators of the conditions of the fragments [11, 12].

The main landscape metrics used were extracted from the categories of area, shape and connectivity, using the metrics described in Fig. 4. This step was performed in the ArcGIS 10.7 software, with the Patch and V-Late Beta 2.0 extensions.

Fig. 4. Landscape metrics - (a) - core area: the fragment on the left has a less robust core than the one on the right due to the elongation of the shape and proximity of the internal area to the edges; (b) - shape index: perimeter/area ratio that makes the fragment on the right more exposed to transformations, (c) - connectivity: favoring stepping-stones. Source: MOURA, 2010 [13].

Finally, the Multicriteria Analysis step was performed using the Evidence Weights method, generating a classificatory index to identify landscape units according to the degree of importance of vegetation preservation in the Quadrilátero Ferrífero. The study is also applicable to the choice of areas for requalification since it indicates a hierarchy between the most qualified and protected fragments versus the most fragile and at risk of transformation.

3 Partial Results and Discussion

The results and discussions are related to the products of the methodological steps, which are, respectively: calculation and analysis of landscape metrics and multicriteria analysis to identify landscape units.

3.1 Analysis of Landscape Metrics

Core Area: The core area metric allowed us to calculate which fragments have an internal protected area greater than 500 m, signaled by the red color in Fig. 5. In this sense, these fragments are of great relevance, as they are more protected from the external actions of the edge effect, which are changes in the structure, composition or abundance of a fragment in its border or edge.

Therefore, they are fragments that must be prioritized in the definition of the most notable vegetation landscapes of the Quadrilátero Ferrífero from the data of the core area, the regions with lesser or greater presence of protected internal areas of the forest and rupestrian fields are identified, as shown in Fig. 5.

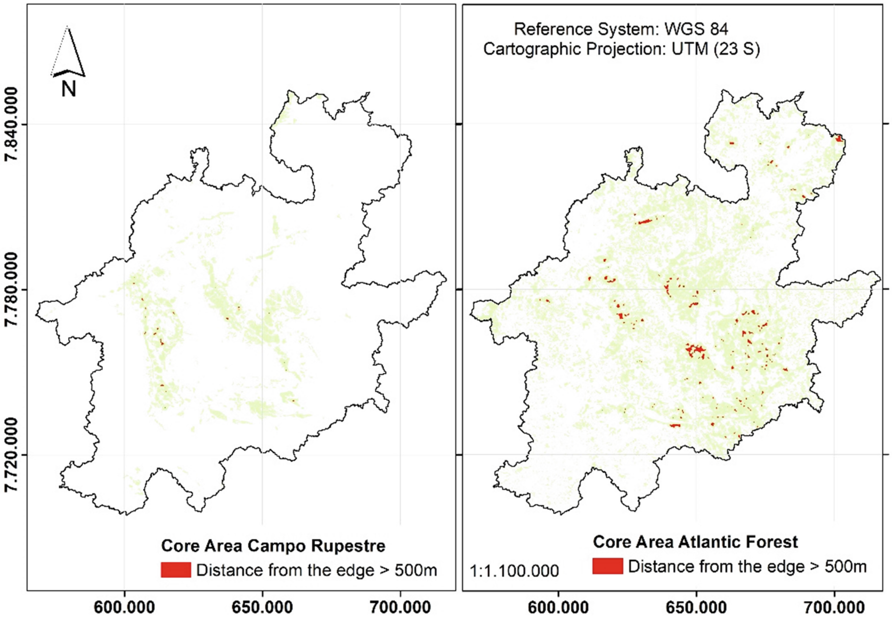

Fig. 5. Core area metric (Color figure online)

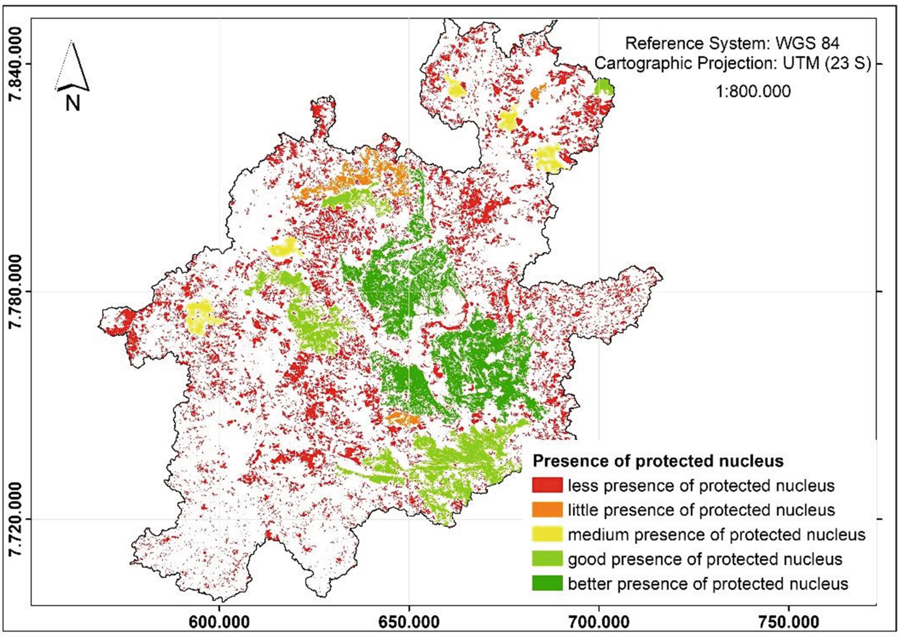

Fig. 6. Presence of protected nucleus

Thus, the regions that have a nuclear area with a distance from the edge greater than 500 m, are those that have a more protected core. Once the nuclei were located, fragments that have these conditions were selected, ranked according to the number of nucleus areas contained in them (Fig. 6).

Shape - Shape Index: The purpose of analyzing the shape index is to check if the fragments have problems caused by the edge effect. The closer to 1, the more regular or more circular the fragments are [14] and the more distant from 1, the more irregular and more propitious to the edge effect.

The shape index is calculated to represent the perimeter/area ratio of the fragments. In this sense, the more regular the shape, the larger the internal area of the fragment and the smaller the interaction with the surrounding matrix. Therefore, it will also be less prone to the edge effect.

Therefore, it is understood that the closer to 1 the shape index, the more regular and protected the fragments are (Fig. 7). To a degree of importance, fragments with a shape index close to 1 (dark green) are more notable than very irregular fragments (light green), which are possibly already subject to the external actions of the edge effect.

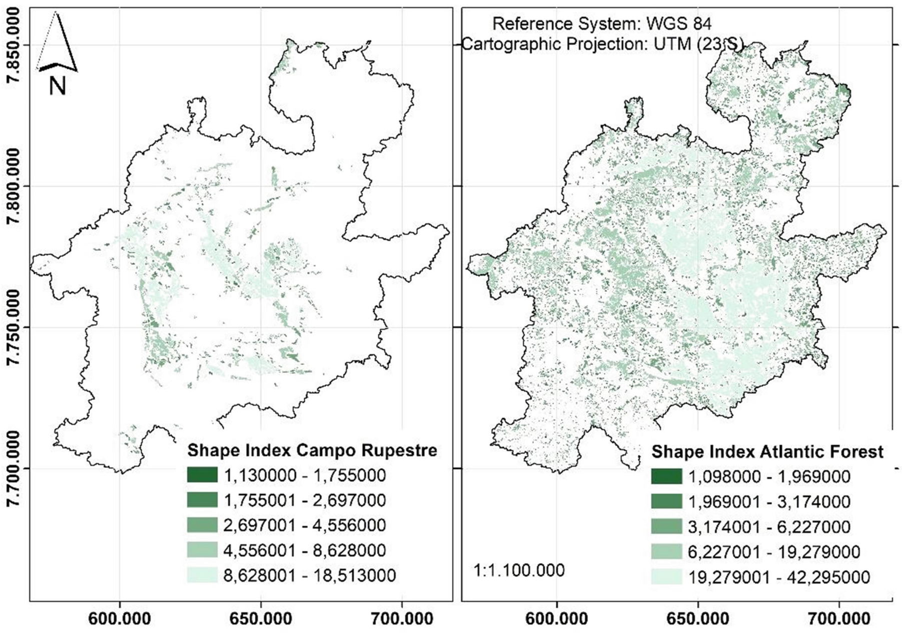

Fig. 7. Shape Index Metric (Color figure online)

From the data of the shape index metric, fragments with irregular, irregular and regular shapes from the regions of the Atlantic Forest and rupestrian fields were identified (Fig. 8). In this sense, the more regular the fragment, the more protected the border effect will be.

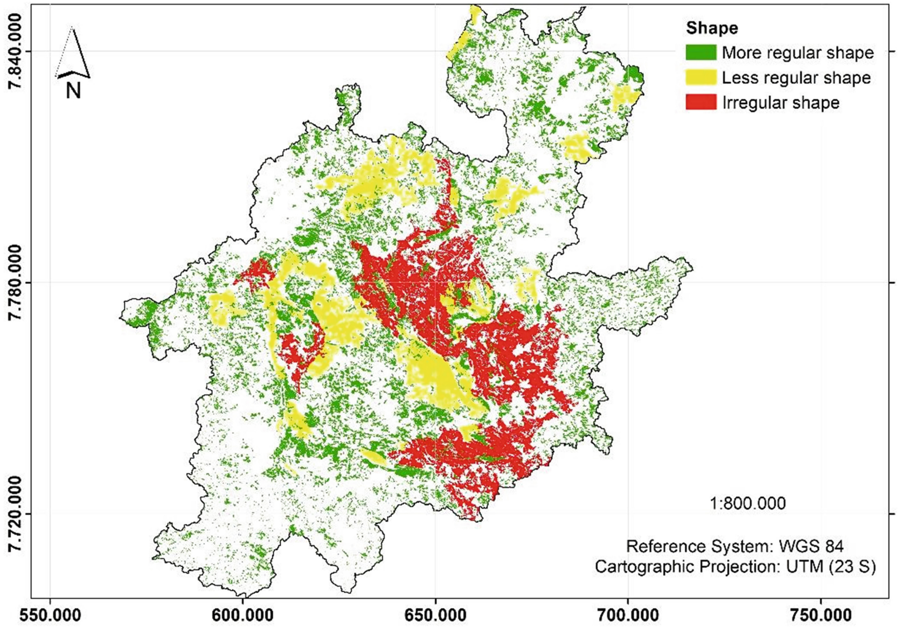

Fig. 8. Shape index

Connectivity: Finally, the landscape was analyzed according to the connectivity category. For this, it was calculated how many 'neighboring fragments' exist in a 200 m buffer area from the edge of each fragment. In this sense, the smaller the number of neighboring fragments at this distance of 200 m, the more isolated the fragment is and the more susceptible to external actions and the loss of environmental diversity, as it does not favor the gene flow between areas. The greater the number of these neighboring fragments, the more protected they are and the richer the condition of gene flow.

From the data on the number of neighboring fragments at a distance (buffer) of 200 m from each fragment, a ranking of connectivity was identified for both forest regions and rupestrian fields. As a result, regions with exceptionally low connectivity were identified; low connectivity; medium connectivity; high connectivity and remarkably high connectivity, as can be seen in Fig. 9 and Fig. 10. Therefore, the red and orange colors represent more isolated fragments, while the light green and dark green colors represent more protected fragments.

3.2 Multicriteria Analysis

Multicriteria Analysis is a method of spatial analysis that has been widely used mainly in the last twenty years in a digital way (although it was already used in an analog way in the 1960s by McHarg, 1969). It is based on the systemic approach and is based on data integration according to the objectives of analysis, considering multiple criteria [7].

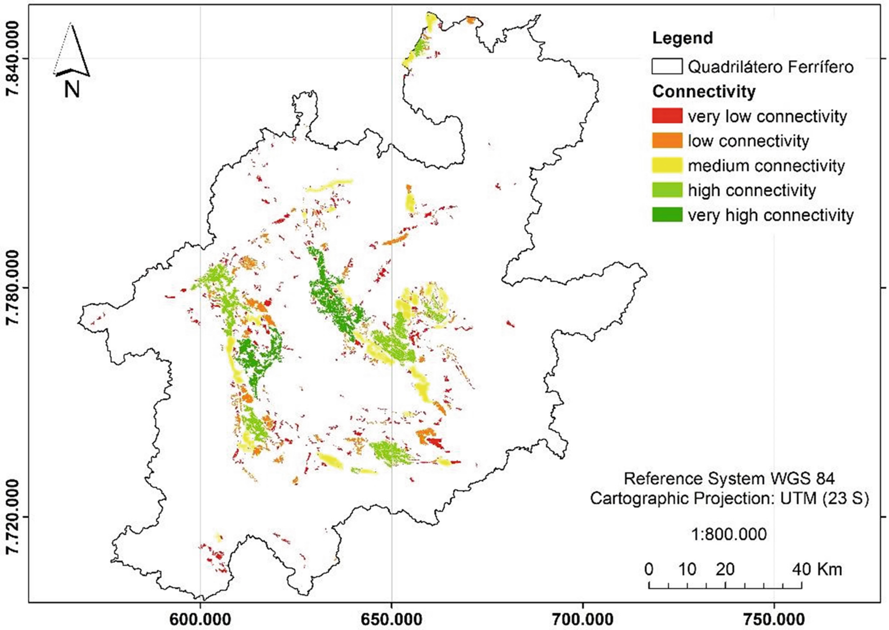

Fig. 9. Campo rupestre connectivity.

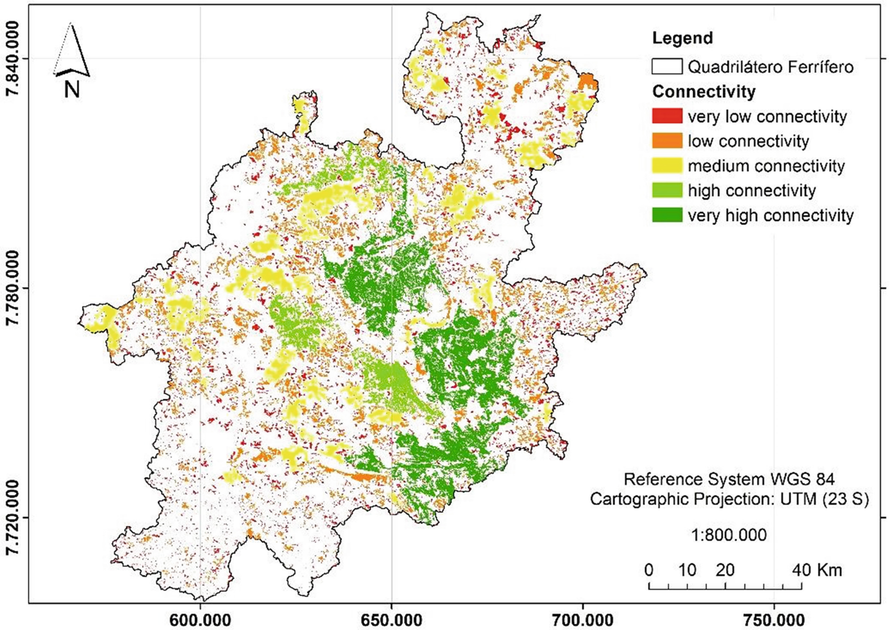

Fig. 10. Atlantic forest connectivity

In Multicriteria Analysis, the stage of integration of variables can occur mainly by the methods of Combinatorial Analysis and Weights of Evidence. In the first, the combination of variables occurs in pairs, gradually, as the researcher judges the process and proposes new combinations. In the second method, all variables are integrated at the same time, associating each one with a defined importance weight, and obtaining as a result a classification ranking of a potential or of a vulnerability. While the Combinatory Analysis results in a qualitative and nominal classification (selecting compositions from the research objectives), the integration by Weights of Evidence results in the hierarchy of the analyzed spatial elements according to the investigated values. Those spatial elements of higher hierarchy stand out in the set of variables studied, placed according to the relative importance of each variable in the set.

For the identification of Landscape Units according to the level of importance of the Quadrilátero Ferrífero vegetation, the Multicriteria Analysis was performed by Evidence Weights, a method in which the judgments of the variables of interest are made simultaneously from a defined weight of importance. For this, weights were assigned to each variable (highlighting the most important criteria in a relative way) and scores were assigned to each caption component according to the degree of relevance.

The justification for the values adopted for the grades was to assign the grade 2 to the classes with the most important characteristics for vegetation. Classes with less important characteristics for the vegetation were classified with grade 1. As for example, for classes with index values of a form closer to 1 (more regular and protected forms)

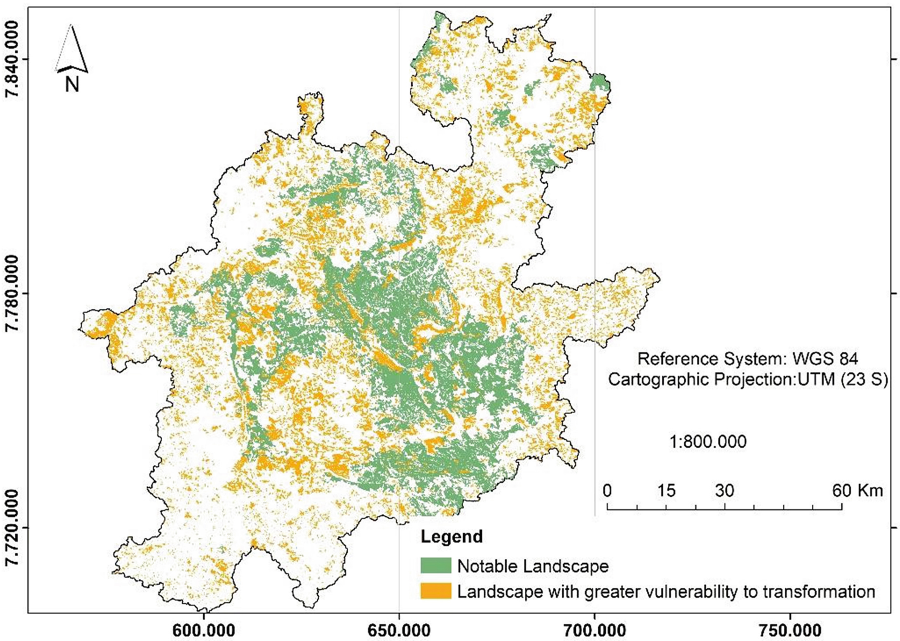

Fig. 11. Map of landscape units

was given a score of 2, while for index values of more distant forms of 1 (a more irregular and unprotected form) a score of 1 was given.

Once the marks were assigned to the legend components, it was necessary to define the weights for each variable, so that map algebra could be performed. The team decided that the variables would have different importance, depending on the specialist knowledge about the area. The assignment of weights can be done by data-driven or knowledge-driven, in processes of listening or taking opinions [15]. For this work, the team judged the connectivity metric as the most important, weighing 50%. The metric of form was considered with a weight of 20% and the metric of nuclear area, with a weight of 30%.

Thus, combining the variables generated by the calculation of landscape metrics, according to their degree of importance, it was possible to obtain the following Landscape Units in the Quadrilátero Ferrífero represented in Fig. 11.

4 Conclusions

The studies of the vegetation cover through the network of its fragments are particularly important to know the characteristics of a landscape, through the identification of patterns and the dynamics of a geographic region. With that, it is also possible to understand how society deals with environmental preservation and conservation issues. The characterizations of the existing conditions are the basis for the construction of opinions and decision making.

This article stands out by combining studies of landscape metrics with multicriteria analysis, presenting the potential of combining these methodologies in the identification of landscape units, assisting researchers and managers in the identification of areas that require greater attention and that need policies and preservation projects.

With the combination of the two methodologies it was possible to identify two main units in the Quadrilátero Ferrífero: remarkable landscapes of vegetation; and vegetation with greater vulnerability to transformation and that need attention regarding the loss of green areas.

In the development of the study of landscape metrics, it was identified which fragments have protected cores and which have unprotected cores; fragments with a more regular shape and fragments that have a more irregular shape and are more susceptible to the edge effect; and, finally, which fragments are most connected to each other and which are most disconnected.

It was observed that fragments with greater connectivity coincide with fragments with a more protected core, both present in central spots of the Quadrilateral. However, the most regular fragments are also the most isolated fragments (less connectivity) and have a poorly protected core. It is also noticed that these last more isolated fragments, are more spread along the Quadrilátero Ferrífero and are smaller in area, when compared with the large central green patches.

Finally, to identify the two landscape units in the studies of green areas in the region, the Multicriteria Analysis method was used to arbitrate weights of importance for each metric or variable in the systemic approach of integrating values. The connectivity metric was judged to be the most important, with a weight equal to 50%, the form metric was considered to have a weight of 20% and the core area metric to a weight of 30%.

As a result, there was a concentration of remarkable landscapes of vegetation in the central and southeastern area of the Quadrilátero corresponding, for the most part, to the Serras do Gandarela, Serra da Moeda and Serra do Caraça. On the other hand, the areas to the south and north of the Quadrilátero, in addition to those close to urban centers, were more susceptible to transformation. Based on this analysis, the importance of maintaining the Conservation Units is reinforced, which are fundamental for the protection of natural resources.

It should be noted that the process presented here is defensible and reproducible. Defensible because it applies a clear model for choosing variables in the form of metrics, defining notes in the form of classifying the legend components and deciding on the relative weights of the variables involved. These are decisions that can be revised at any time in stages of calibration vis-a-vis with each reality and with the research objectives. For this same reason, they are reproducible processes, since a user can easily obtain satellite images and perform their classifications, if there is no classification of available ground cover for their territory, followed by the application of integration metrics and algebras. In the case study in question, ArcGIS software was used, but the processes could also be executed with free applications, such as QGis and Fragstats.

The partial and final results obtained are integrated with other studies of landscape analysis, being a first step for the characterization of the physical and anthropic conditions of the environmental landscape.

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