Linking Landscape Pattern and Human Disturbance on a Regional Level: A Case Study in Beira Interior Region, Portugal

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Abstract

The land use and land cover pattern of landscapes are key elements of basic landscape structure; accordingly, this pattern has an important role in landscape management, nature conservation and preservation. In the other hand the human impact on the ecological environment has attracted a significant amount of attention. In this study, hemeroby index (HI) was used to quantify the degree of human disturbance, and the relationship between HI and landscape pattern metrics was explored in a region of Central Portugal. The main objectives of this study were to analyze the temporal and spatial characteristics of landscape pattern, and its relationship with different degrees of human disturbance. The Spearman's correlations were determined to reveal the statistical connections between the landscape metric parameters and the HI values. At a landscape level the Mean Perimeter-Area Ratio (MPAR) showed a significant statistical connection with the HI. At a class level most of the metrics can be used to estimate the spatial changes of the hemeroby level, with Mean Patch Size (MPS) and Mean Perimeter-Area Ratio (MPAR) showing significant statistical connection with the hemeroby index, for agricultural areas, pastures and seminatural areas.

Keywords

Landscape pattern, human disturbance, land use cover change, GIS

1. Introduction

Exploring the impact of human activities on the landscape pattern is an increasing concern, and monitoring and evaluating human interference has become one of the hotspots and important areas of landscape ecology research [1,2]. Some scientific research has been carried out on the spatial differentiation of human disturbance and its relationship with landscape patterns [3, 4].

According to the pattern and process paradigm, the land cover pattern predicts the ecological processes occurring in a given landscape [5], and landscape metrics are suitable to quantify the landscape patterns and reflect the structure or spatial configuration of the landscape [6].

The hemeroby index is an integrated indicator used in several studies (e.g., [3, 4, 7]) to express the impacts on ecosystems associated with the human-induced disturbance in a landscape [8]. The higher the degree of hemeroby, the more disturbed and transformed a landscape becomes due to human influence [9].

The study aimed to investigate the relation between human disturbance intensity and landscape pattern configuration and diversity. The objectives of this study are (1) to analyze the temporal and spatial characteristics of landscape pattern and human disturbance in the process of land use change in mainly rural territories, and (2) to explore the relationship between the landscape pattern metrics and the human disturbance under different disturbance intensities, in order to reveal how landscape-pattern-change tendencies can be used as indicators to estimate the anthropic changes in the landscape.

Proceedings of HAICTA 2022, September 22–25, 2022, Athens, Greece
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2. Materials and Methods

The Beira Interior region is an administrative division in eastern Portugal that includes two main subregions: Beira Baixa and Beiras/Serra da Estrela (Fig. 1). The region covers an area of 10919 km² and has a population of 325086 inhabitants. It has elevations ranging from 47 to 1993 m. This territory is mainly occupied by forest, agroforestry uses and agricultural land.

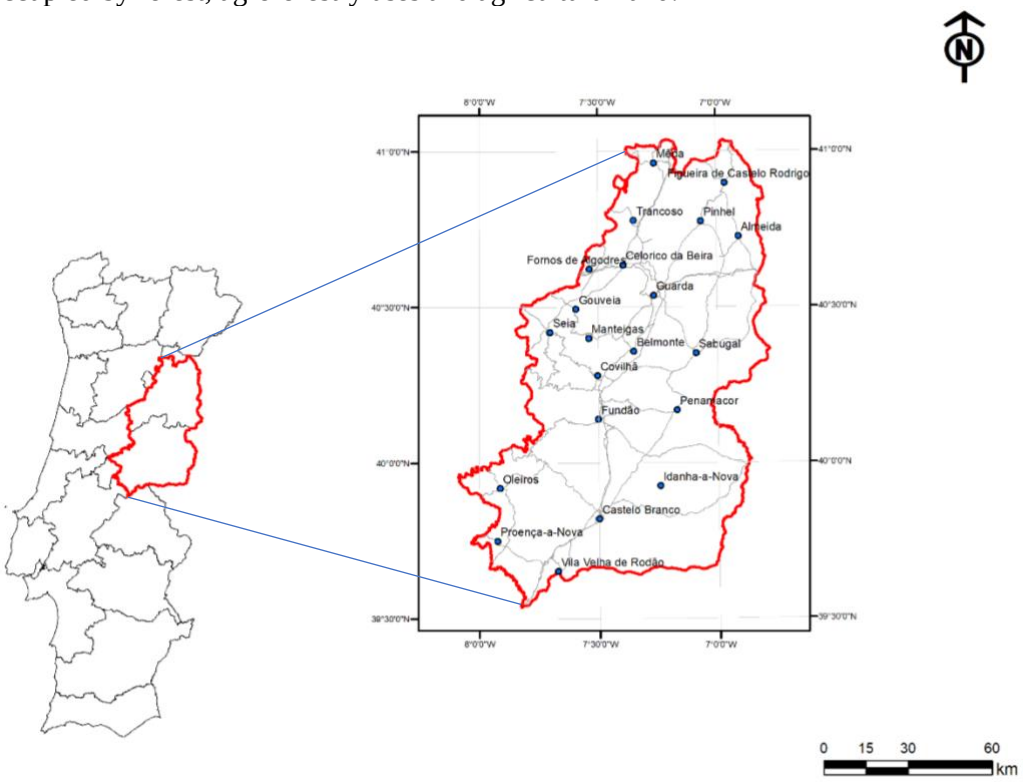

Figure 1: Location of the study area.

The Portuguese Land Use/Land Cover (LULC) databases (COS 1995; COS 2007; and COS 2018) were applied to calculate the landscape metrics. Patch level and landscape level metrics were calculated for 121 quadrats of 10 km^2 each, covering the study area, with the Patch Analyst extension of the Arc GIS 10.8 software.

The LULC classes were categorized in a scale of hemeroby levels ranging from ahemerobic (no anthropogenic influence) to metahemerobic (biocenosis completely destroyed). For that purpose, a seven-point scale was used to classify land use according to the degree of hemeroby by modifying [10] methodology. The average value was calculated for each 10 km^2 quadrat areas.

Landscape configuration was quantified through a set of metrics. Statistics describing the distribution of patch area such as Mean Patch Size (MPS) were computed as they provide central tendency. Mean Shape Index (MSI) provides indications of the fragmentation degree of the different land cover types. Total Edge (TE) includes all landscape boundary and background edge segments. Mean Patch Fractal Dimension (MPFD) and Mean Perimeter-Area Ratio (MPAR) describe landscape complexity [11]. The average value was also calculated for each 10 km^2 quadrat areas.

We revealed the statistical connections between landscape metrics and hemeroby index value for all 10 km^2 quadrates of the Beira Interior region on a landscape level with IBM SPSS Statistics 22 software. The distribution of the variables was analyzed with the Shapiro-Wilk test, but most variables did not follow the normal distribution; therefore, we applied the non-parametric Spearman rank correlation coefficient [12]. Based on land use maps from 1995, 2007, and 2018, we specified those class-level landscape metrics that show a statistically significant relationship with the hemeroby index at the 0.01 level of significance.

3. Results

In Figure 2 are presented the LULC maps for the three years (1995, 2007 and 2018), and changes in surface area of the LULC classes between 1995 and 2018. The main land use classes in the study area are cultivated land and forest land.

During the study period the cultivation of arable lands and the pasture area decreased in the last decades, and this abandonment induced an increase in seminatural and forests areas (Figure 2b).

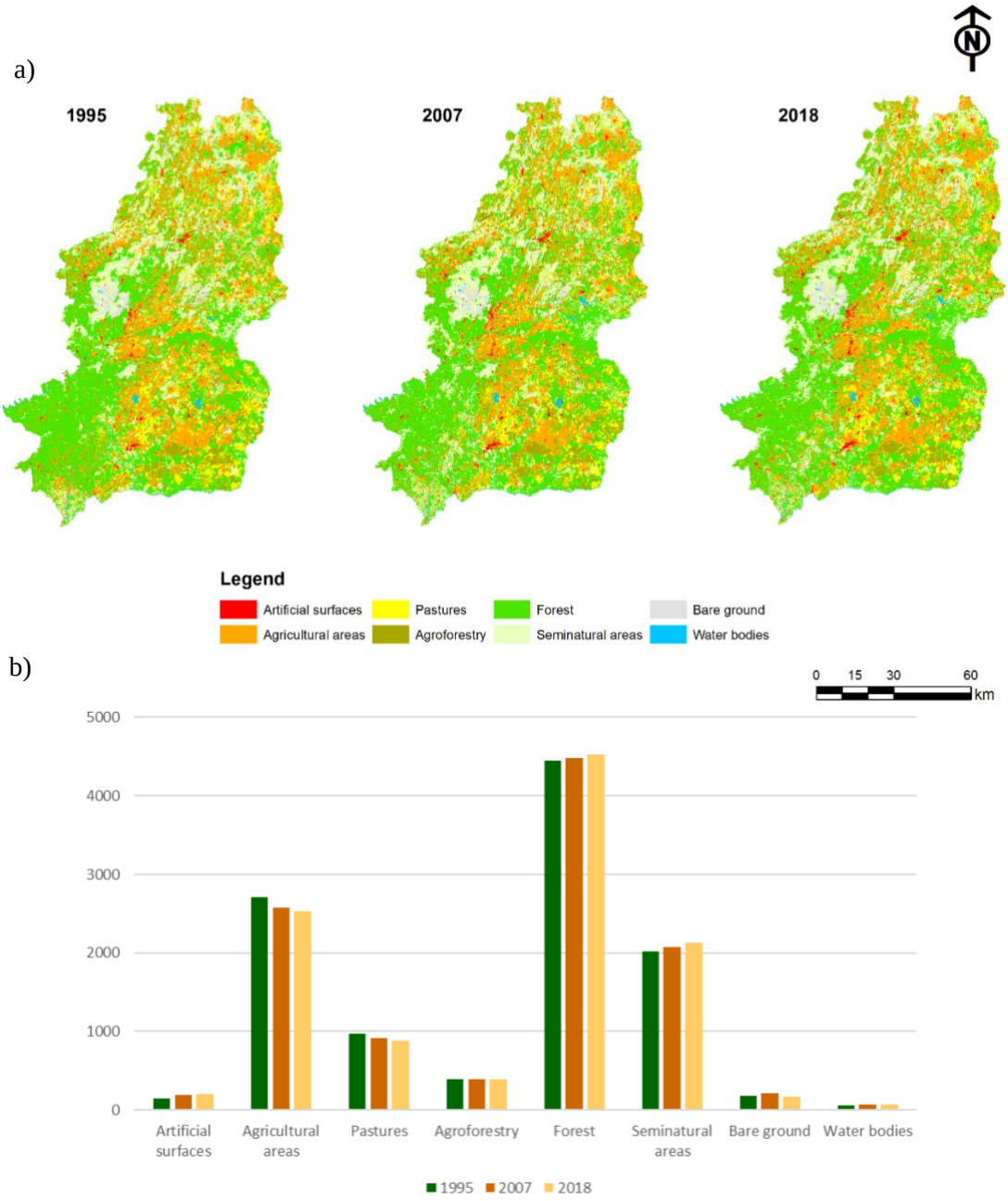

Figure 2: Land cover maps and Land use changes between 1995 and 2018: a) land cover maps; b) total area per land use (km^2).

According to our estimations, the average hemeroby index value maintained stable during the study period: 3,65 in 1995; 3,62 in 2007; and 3,64 in 2018. Corresponding to an α-euhemerobic level (moderate to strong human impacts).

As shown in Table 3, at a landscape level the index Mean Perimeter-Area Ratio (MPAR) showed a strong negative correlation with the hemeroby index ($p < 0.01$) in 1995, 2007 and 2018. That suggests

that complex landscapes are good indicators of low levels of hemeroby. In fact, areas of more intensive agricultural and forestry use tend to occupy large areas of territory with low spatial diversity. The other metrics did not show a significant relationship with the hemeroby index.

At a class level Mean Patch Size (MPS) and Mean Perimeter-Area Ratio (MPAR) showed significant correlation with the hemeroby index, for agricultural areas, pastures and seminatural areas.

Table 3

Spearman's correlations between the hemeroby index and the landscape metrics in 1995, 2007 and 2018.

	TE			MSI			MPS			MPFD			MPAR		
	1995	**2007**	**2018**	**1995**	**2007**	**2018**	**1995**	**2007**	**2018**	**1995**	**2007**	**2018**	**1995**	**2007**	**2018**
Landscape level (All classes)	0.159	0.068	0.057	0.710	-0.008	0.055	0.017	-0.028	0.096	-0.070	-0.119	-0.008	**-0.325***	**-0.332***	**-0.263***
Class level															
Artificial surfaces	0.055	0.134	0.148	0.003	0.078	0.098	0.105	0.158	0.169	-0.097	-0.005	0.014	-0.167	-0.164	-0.131
Agricultural areas	**0.260***	**0.241***	0.226	-0.143	-0.120	-0.103	**0.600***	**0.551***	**0.509***	-0.506	**-0.453***	**-0.416***	**-0.734***	**-0.669***	**-0.600***
Pastures	**0.423***	**0.276***	0.222	**0.267***	0.164	0.110	**0.494***	**0.355***	**0.299***	-0.008	-0.063	-0.043	**-0.515***	**-0.416***	**-0.337***
Agroforestry	**0.350***	**0.245***	0.177	0.274	0.185	0.135	**0.393***	**0.279***	0.216	0.002	-0.012	-0.005	**-0.460***	**-339***	-0.243
Forest	-0.057	-0.098	-0.076	0.125	0.031	0.012	**-0.269***	-0.212	-0.127	0.177	0.101	0.051	0.193	0.154	0.099
Seminatural areas	-0.140	**-0.289***	**-0.279***	0.011	-0.149	-0.088	**-0.259***	**-0.405***	**-0.415***	0.133	0.018	0.099	0.200	**0.253***	**0.334***
Bare ground	-0.246	**-0.307***	**-0.375***	**-0.245**	**-0.306***	**-0.381***	-0.209	**-0.253***	**-0.341***	-0.099	-0.205	**-0.297***	0.123	0.064	0.170
Water bodies	0.106	0.194	**0.261***	0.009	0.073	0.147	0.143	0.246	**0.290***	-0.120	-0.090	0.006	-0.247	**-0.278***	-0.242

*Correlation is significant at the 0.01 level.

According to the change in hemeroby index value verified between 1995 and 2018 (Figure 3), the naturalness degree increased in 60% of the quadrats and decreased in the remaining quadrats, with a clear difference between the eastern and western part of the study region. This tendency could be related to the land abandonment that induced an increase in semi-natural areas in the east part of the Beira Interior region, and an increase in the intensive monocultural forest in the west part of the region.

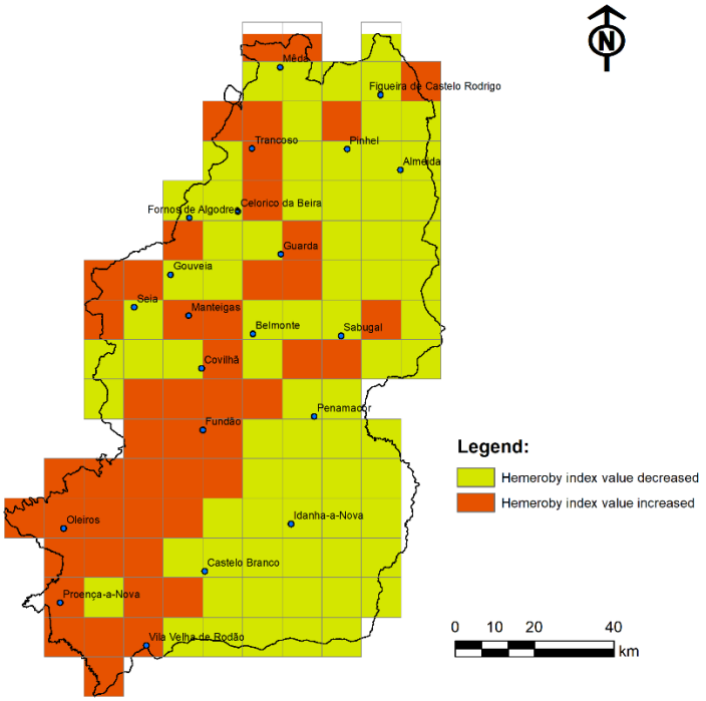

Figure 3: The estimated change in the hemeroby index values in Beira Interior region between 1995 and 2018.

4. Conclusions

We can conclude that landscape metrics could be appropriate for describing the hemeroby level of the landscape and for predicting the possible changes of vegetation-based naturalness at a regional scale, confirming the results of previous studies in different countries.

At a landscape level the Mean Perimeter-Area Ratio (MPAR) showed a significant statistical connection with the hemeroby index. At a class level Mean Patch Size (MPS) and Mean Perimeter-Area Ratio (MPAR) show significant statistical connection with the hemeroby index for agricultural areas, pastures and seminatural areas.

The use of a set of structural and hemeroby indicators can be useful for planners and decision-makers to analyze trends in land use patterns at a regional level and to design of new policies for reducing the anthropic impacts on ecosystems.

5. Acknowledgements

This work is supported with Portuguese national funds by FCT - Foundation for Science and Technology, I.P., under the project UIDB/00681/2020.

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