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The link between landscape pattern and vegetation naturalness on a regional scale

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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 Hungary, the naturalness of the vegetation was surveyed between 2003 and 2006, and the vegetation-based Natural Capital Index (NCI) was calculated for almost the entire area of the country. This field-based database gave us the unique opportunity to analyse the statistical connection between the naturalness of the vegetation and the landscape (land cover) pattern on a regional scale. In our study, we analysed the efficiency of the regional-level CORINE Land Cover (CLC) database for the estimation of the naturalness of the vegetation. This connection was analysed at the country scale using every (2272) Flora Mapping Unit (FMU), or 5.5 × 6.5 km quadrate, of Hungary. We calculated the shape-, edge- and size-related landscape indices for all FMUs on a landscape level (including all CLC patches) and a class level (the land cover polygons were classified according to their land cover characteristics and their level of hemeroby). We determined the Spearman's correlations to reveal the statistical connections between the landscape metric parameters and the NCI values. All of the investigated area-weighted landscape indices: Main Patch Size, (MPS), Main Fractal Dimension Index, (MFDI), Total Edge (TE), Main Shape Index (MSI) and Number of Shape Characteristic Points (NSCP) on the landscape level showed a significant statistical connection with the NCI, but the sign of its correlation with the NCI contrasted with the findings from previous studies on a larger scale. Our study shows that scale has a strong impact on the sign of the correlation between the naturalness of the vegetation and the landscape structure. On a class level, particularly the shape-related landscape indices of the "Forest and semi-natural areas" showed statistically significant correlations with the NCI. The correlation strongly depended on the method of classification of the CLC polygons. Furthermore, the spatial pattern of the land-cover-type-based CLC polygon categories showed higher correlation values with the NCI than CLC polygon classes, which were categorized according to their hemeroby state. These results show that although the sign of the spatial pattern change in the main land cover classes is scale-dependent, they can be used to estimate the increase or decrease in the naturalness of the vegetation better than the spatial changes of the hemeroby-level-based landscape pattern. We can predict the change in the naturalness of vegetation based on the spatial changes in the land cover pattern.

1. Introduction

According to the pattern and process paradigm, the land cover pattern predicts the ecological processes occurring in a given landscape (Herzog et al., 2001; Renetzeder et al., 2010; Tasser et al., 2008; Winter and Fischer, 2010; Wrbka et al., 2004; Zebisch et al., 2004). Landscape metrics indicators, calculated on the basis of land cover patches, may be suitable for estimating vegetation biodiversity and the naturalness of the vegetation (Herzog et al., 2001; Moser et al., 2002; Schindler et al., 2008; Szabó et al., 2012, 2013; Zebisch et al., 2004; Zhang et al., 2013). Studies using landscape metrics have usually applied land cover data; there are only a few examples in which the quality of the habitat patches was involved. Most of the examples involving quality (e.g., biodiversity, the naturalness of the vegetation) and landscape metric indicators were conducted on a local scale and described the relationship between the shape (complexity) of the patches and the naturalness of the vegetation. Landscape metrics calculated on the basis of patch geometries may be suitable to estimate the degree of naturalness of the

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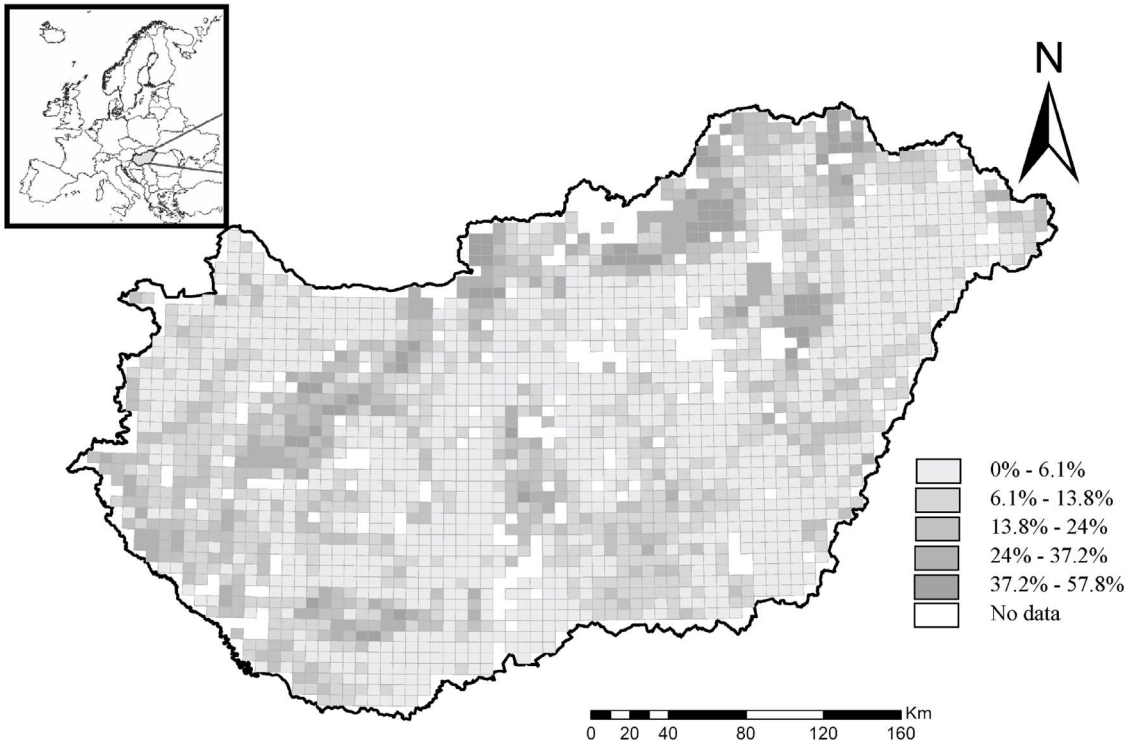

Fig. 1. NCI values of 5.5 × 6.5 km FMU quadrate areas of Hungary based on botanical field survey between 2003 and 2006.
Source: Czúcz et al., 2012.

vegetation (Lausch et al., 2015; Venturelli and Galli, 2006).The area-weighted means of pattern-level indicators (i.e., land cover indicators) in a sample quadrate were correlated with the botanical data collected during field work of the same quadrate (e.g., biodiversity, naturalness of vegetation; Gimona et al., 2009; Lausch and Herzog, 2002; Tischendorf, 2001; Uuemaa et al., 2013). Landscape metrics on a regional level were only weakly correlated with the diversity of vegetation (Gimona et al., 2009).

Vegetation may be characterized on the basis of the evaluation of field surveys (Alexander et al., 2016 Deák et al., 2015Deák et al., 2015). Different evaluation systems were developed, and in Hungary, social behaviour types (Borhidi, 1995) are often used to express the information about plant communities' stability, regeneration ability, naturalness and degree of disturbance. The method was adopted for national conditions from the system of Grime (1979). Furthermore, a new possibility is the application of the Natural Capital Index (NCI), which reflects the qualitative and quantitative (spatial) characteristics of the natural or semi-natural vegetation (Czúcz et al., 2012; ten Brink, 2000, 2007; ten Brink et al., 2002). Both indicators use vegetation data of field surveys, and the main difference is that SBT values are determined at the level of quadrats on a large scale, whereas the NCI is determined on a regional scale for almost the entire country. Hemeroby is used in ecological studies to express the degree of human influence on ecosystems and is associated with the human-induced disturbance in a landscape (Jalas, 1955). The calculation is based on land use, the share of neophytic and therophytic species, and soil characteristics (Sukopp, 1976) and may be used as the inverse of naturalness (Anderson, 1991; Jalas, 1955). The higher the degree of hemeroby, the more harmful the human influence and the more disturbed and transformed a landscape becomes (Machado, 2004).

Combining the indices of naturalness and landscape metrics can provide a possibility to accelerate surveys; i.e., if there is a strong statistical relationship between a landscape metric and a measure of vegetation naturalness, the latter's value can be predicted using the characteristics of habitat patches and their spatial pattern. Currently, most researchers prefer using landscape change tendencies as indicators for vegetation naturalness instead of using indicators requiring vegetation mapping (Bürgi and Russel, 2001; Frank et al., 2012; Frondoni et al., 2011; Kerényi and Szabó, 2007; OECD, 2001; Rüdisser et al., 2016; Walz, 2008, 2011; Walz and Syrbe, 2013; Zebisch et al., 2004). However, it is difficult to calculate the changes in naturalness on the basis of the changes in landscape patterns because the statistical relationship between landscape metrics indicators and naturalness is not linear (Blaschke, 2006; Tischendorf, 2001). Several authors emphasize that their class-level landscape pattern can be used more effectively in the estimation of naturalness than those landscape level analyses that were calculated on the basis of the total number of the patches (Lausch and Herzog, 2002; Renetzeder et al., 2010; Szabó et al., 2012, 2013; Tischendorf, 2001).

Regarding the limited accessibility of vegetation based landscape naturalness indicators on an appropriate scale, no research has been conducted to a country wide extent using data on a medium scale. In this study, we applied medium scale data of naturalness (Natural Capital Index) with landscape metrics calculated from the CLC 2006 database and revealed whether there was a deterministic relationship between the data based on field vegetation surveys and the landscape metrics derived from the spatial characteristics of habitat patches on a 1:100 000 scale. We investigated whether hemeroby- or land-cover-based categorization had a stronger correlation with the NCI. We also aimed to study the scale sensitivity of this connection. Furthermore, we intended to ascertain whether the relationship in our regional-level analyses had the same sign as previous, high resolution, large scale analyses and to reveal how landscape-pattern-change tendencies can be used as indicators to estimate the changes in the naturalness of the vegetation.

2. Materials and methods

2.1. Case study area

Hungary (Fig. 1.) is located in Central Europe (between N 45.48—48.35 and E 16.50—22.48). Its total area is 93 033 km^2, it has