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Landscape structure versus the effectiveness of nature conservation: Roztocze region case study (Poland)

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ABSTRACT

The objective of the study was to examine the extent to which landscape metrics could be used as an indicator of efficient management of protection areas. The selected sampling areas were natural–landscape units distinguished within the Roztocze Region located in the central-east Poland. Among 446 units, those representing three typological groups determined by three factors were selected. The factors included (1) the area of the unit; (2) the dominant or characteristic type of ecosystem; and (3) the form of protection. Subsequently, thirteen landscape metrics were calculated with the application of the Fragstats software. The analysis revealed high correlation between the form of nature protection and the majority of the calculated indexes. National park units show the highest landscape diversity and stability of various types of ecosystems. This suggests high conservation efficiency. Landscape park units are distinguished by fragmented patchy composition, and spatial structure even less stable than that of the non-protected areas. The study results show that landscape metrics could be used as an indicator of efficient management of different forms of nature protection. They provide an insight into the structure and functioning of the environment at various levels of its organisation. We particularly found diversity metrics to be useful for indicating whether nature conservation goals are archived, and the size and density metric for measuring human interference in the landscape. The selection and interpretation of indexes should be determined by the specific character of a given area.

1. Introduction

The efficiency of nature conservation at the landscape level has been discussed along with its various aspects both at global and national level. Many factors of successful protection have been identified for each stage of protective measures: planning, management, monitoring, and funding (Quan et al., 2010). According to Margules and Pressey (2000), the extent to which a protected site fulfils its role depends on whether the objectives of representativeness and persistence have been met. In consequence, efficient conservation is the outcome of the ecological basis of the protected area's delineation, the durability of its existence, and the continuity of application of protective measures. Papageorgiou and Vogiatzakis (2006) treated public involvement and inter-sectoral coordination as major procedural elements of effective management of nature. The authors emphasise that the political culture of each country, determining legal frameworks, regulations, and land ownership, highly influences its nature policy output. Analogically, Pchałek et al. (2011) state that the effectiveness of nature conservation depends directly on a coherent legal system, i.e. on the selection, implementation, and enforcement of legislative tools of a given authority. Therefore, the efficiency of a given nature conservation law may be measured by accurately formulated regulations, efficient executive system, and consistent enforcement (Sommer, 2005). A number of authors (Jones and Stenseke, 2011; Kasprzyk et al., 2007; Trakolis et al., 2000) link successful nature conservation with the issue of public interest. According to the authors, lack of communication between scientists and managers, and poor level of public participation are among the largest obstacles for the efficiency of protection measures. Others (Brody et al., 2003; Noss and Scott, 1997) emphasise the importance of the considered scale. Factors causing ecosystem disturbances at the local level, such as water level decrease, may result from regional or even national conditions. The issue of conservation effectiveness goes beyond the borders of a given protected site and it should be discussed not only in reference to its management and protection systems, but with a more global and comprehensive approach. Effective protection cannot be executed solely by taking selective action addressing a

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given landscape component of a selected area. The incorporation of landscape issues into spatial planning at each stage of land use planning is required (Beatley, 2000; Chmielewski, 2012; Majchrowska, 2011).

As briefly outlined above, effective protection of a given area requires consideration of a number of methodological, organisational, and sociological issues. The issues are interconnected in such a way that the approach adopted at the designation level may affect successful protection. For example, the delineation of the boundaries of a protected area based on landscape forms may hinder the administrative process. On the other hand, it facilitates the definition of protection goals regarding each landscape unit, because they are coherent in terms of abiotic and biotic elements and land-use (Brody et al., 2003; Roe and Van Eeten, 2001; Sowińska and Chmielewski, 2011).

The effectiveness of nature conservation at the landscape level is primarily analysed by means of two different techniques. One of them is called the analytical approach. The subject of such an analysis is the estimation of efficiency of law regulations in reference to different levels: legislative (orders and bans), procedural (the system of norms' implementation), and organisational (institutional infrastructure) (Pchałek et al., 2011). A critical outlook is provided by a thorough analysis of legislative documentation, protection plans, organisational framework, sources of funding, etc. (Brody et al., 2003; Papageorgiou and Vogiatzakis, 2006). Interviews and questionnaires addressed to different groups of stakeholders, such as nature reserve staff members, local authorities, and land owners, permit the identification of conflicts negatively affecting the management system efficiency (Kistowski, 2004). The multi-aspect and multi-level character of the approach allow for the determination of gaps between the legislatively declared aims and the existing state of protection, and therefore the identification of the weakest link in the chain. The analytical approach has been standardised and recommended by the World Commission on Protected Areas (WCPA). The assessment of the management effectiveness of protected areas and protected area systems is based on six standard elements of protected area management, namely: context, planning, input, process, output, and outcomes (Hockings, 2000; Hockings et al., 2002). The method permits the evaluation of management effectiveness from four perspectives: management base, management mechanisms, management behaviour, and management effectiveness (He et al., 2012; Quan et al., 2010).

The second approach is based on the application of the GIS technique. Remote sensing permits a shift of the discussion on nature conservation effectiveness from the ecosystem to the landscape level. This tool is primarily used to map, measure, analyse, and monitor the mosaic of the existing ecosystem, and to define the directions of changes and state of its transformation (Coppin et al., 2004; Shijo et al., 2009; Khalyania et al., 2013). Based on the above, conclusions are determined regarding the efficiency of protection actions and elements of the protection system requiring strengthening in order to maintain or enrich the values of the protected ecosystems. Remote sensing is also used to map the spatial configuration of protected areas. This visual presentation tool permits the determination of the degree of coverage for single and aggregated policies across diverse types of ecosystems, and the identification of areas that should be covered by future plans in order to obtain a more consistent management framework (Brody et al., 2003). Landscape metrics representing the spatial structure of landscapes in a quantitative manner are also used to assess conservation efficiency. The patchy structure reflected by a set of adequate indices may be treated as an indicator of the functioning of different ecosystems (Aragon et al., 2011; Ferguson, 1996; Yeha and Huang, 2009), as well as ecological stability and diversity (Hess et al., 2006; Lombard et al., 2003; Saveraid et al., 2001; Wiersma et al., 2004). The number, area, shape, and edge metrics suggest the level of anthropogenic transformation. They indirectly determine whether one of the main objectives of nature conservation, namely maintaining the natural state of environment, is met (Chmielewski, 2012). Landscape structure also provides information on conflict fields. Therefore, it may be used as an indicator of coherent landscape management (Lenz and Stary, 1995). Landscape metrics are calculated for both administrative borders (Hassett et al., 2012; Moser et al., 2007) and for different kinds of natural units (Lausch and Herzog, 2002; Liu et al., 2003; Syrbe and Walz, 2012; Troyer, 2002; Uuemaa et al., 2005). However, in the case of nature conservation effectiveness analysis the second type of area based on landscape borders seems to be more proper.

The approach adopted in the present study is coherent with the technical approach. The objective of the study was to examine the extent to which commonly used and easily obtained landscape metrics could be used as an indicator of efficient nature conservation at the landscape level. The Roztocze region (231,400 ha), located in the central-east Poland near the Ukraine border, was selected as the study area. Due to the region's outstanding natural and cultural values, the main elements of the system of protected areas here include one national park (surrounded by a vast buffer zone of 38,000 ha) and three landscape parks. The study area also includes 16 natural reserves. Almost the entire region is covered by the Natura 2000 network. The Roztocze National Park (8482 ha) covers the most valuable forest ecosystems, particularly fir woods and the Carpathian beech complexes, as well as peat-bog ecosystems in a semi-natural state. The Szczebrzeszyński landscape park (20,209 ha) was established for the purpose of maintaining the unique historical field mosaic structure of the upland areas, and the dense mosaic of loess ravines. Elements typical of the Krasnobrodzki landscape park (9390 ha) are sand dunes and dry valleys covered by pine and fir forests. The South Roztocze landscape park (20,256 ha) includes numerous limestone outlines constituting the highest elevations of the Roztocze region.

2. Methods

The first stage of the study involved the delineation of elementary spatial units, called as natural–landscape units, based on the method elaborated by Chmielewski and Solon (1996) and modified by Sowińska and Chmielewski (2008). The system of units was defined using spatial overlapping of different kinds of landscape borders and with the application of the ArcGis 10.0 software. They were: (1) main tectonic structures; (2) main geomorphologic structures; (3) water divisions; (4) soil types; (5) main complexes of phytocoenosis; (6) built-up areas; (7) landscape interiors and view openings. A series of digital maps was used for this purpose: (1) map of tectonic blocks and trenches (1:50,000); (2) geomorphologic map (1:50,000); (3) atlas of water division (1:50,000); (4) detailed geological map (1:50,000); (5) numeric terrain (vertical accuracy 0.6 m, horizontal accuracy 15/15 m or 30/30 m); (6) soil map (1:25,000); (7) topographic map (1:25,000); (8) orthophoto map (pixel cell size of 0.25 m, 2009); (9) forestry maps (1: 25,000). The natural–landscape units are recognised as the most suitable for the analysis of the correlation between landscape structure and nature conservation effectiveness due to a number of reasons. They are relatively homogeneous in terms of several features affecting the landscape structure. Previous studies also revealed their potential usefulness for the process of delineation of protected areas, and management of environmentally and culturally valuable areas (Chmielewski and Solon, 1996; Sowińska and Chmielewski, 2011). Finally, landscape units are particularly relevant, because the majority of decisions regarding resource management and conservation are made at this particular scale of landscape (Aragon et al., 2011). By aligning management actions, policies, and plans with