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«LANDSCAPE METRICS AS INDICATOR FOR ECOLOGICAL SIGNIFICANCE: ASSESSMENT OF SITNO NATURA 2000 SITES, SLOVAKIA»

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The study area is Sitno Nature 2000 Site. The "Natura 2000" framework focuses on conservation of valuable landscapes and nature, aims at the sustainable conservation of Europe's biodiversity and species richness across Europe (Jones-Walters, 2007). The development of a Natura 2000 ecological network is important policy initiative in support of protected sites. Sitno Natura 2000 study area is located in central Slovakia (Fig.1). It has been selected for the richness of its natural environment and anthropogenic impacts. For the last 30 years the areas has been used for the tourism and transmitting of digital and analogue data by army and commercial sphere. Therefore, there was built and developed technical infrastructure. The highest place of the study area called Sitno peak (1009 m), which is very popular and attractive tourism (walking and climbing). Presently, the area is under high priority nature and landscape protection. The area is needed to be zoned separately for human usage and for conservation. Ecological significance of landscape should be the zonation tool in terms of the framework Nature 2000. It is an objective approach to determine ecological values owners, local communities and state organizations.

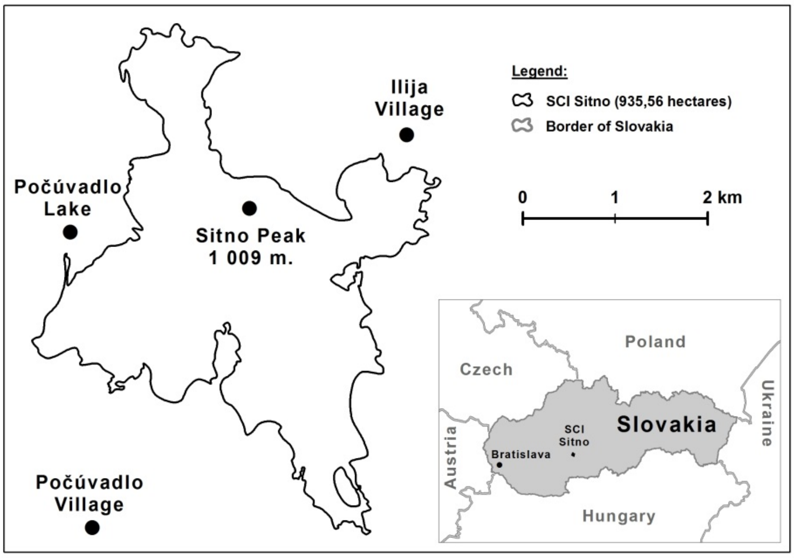

Fig. 1. Study area: Sitno Park within Slovakia.

The area of Sitno was protected in 1951, in order to conserve significant natural landmarks of Štiavnica Mountain. The study area has very few affected or disturbed natural environment, which provides suitable living conditions for some types of rare species of nature. The study area is protected under national (Slovak) and European conservancy system. The study area is almost 260 meters elevation (750 to 1009 m), and falls to four forests vegetation zones. The most widespread vegetation zones in that area are oak-beech and oak forest type nitrophilous beech. Forest age ranges from 60 to 160 years. Southern part of the study area is represented by natural forests. Its varied species composition of the forest is a unique ecosystem across the Carpathians. Economic activity is strictly limited in this area due to the degree of high protection. In the past, beech wood from the surrounding forests were used for production of wooden charcoal (Cvachová, 1991). According to Farbiak (1991) extensive forest complexes are refuge for many species of animals. In invertebrates, there are a considerable number of species represented by molluscs, butterflies and beetles. The study area is a large presence of roe deer and red deer. Also here occur thermophilic species and mountain species. All these facts make study area of Sitno, Slovakia ecologically significant. The tourism has impact on the landscapes by changes in land cover types, which is detected within the study area. Contemporary landscape changes are generated principally by human activity, directed at usage of landscapes (Turner et al., 1990; Ojima et al., 1994; Walker et al., 1999; Cassman et al., 2005). Urbanization, industrialization and intensive agriculture result in landscape changes, losses of ecological capacity, diversity and scenic beauty, as well as damage of cultural heritage (Bastian et al. , 2006).

This paper analyses landscape components (habitats), where human impacts are detected due to the intensive tourism. The landscape elements can be defined by attributes of the Earth's surface as well as by ecological significance of each one land's surface elements. Landscape represents biophysical unit – an aspect of landscape which is determined by its natural components: geological and geomorphologic structure, soil, water, climate, flora and vegetation, fauna (Bastian et al., 2006). In contrast to the biophysical unit, the term landscape describes elements that are determined by natural conditions as well as human impacts. The main purpose of this study is therefore to measure and interpret landscape's habitats of the study area.

Methodological framework of ecological signification is based on quantifying habitats and their patches. According to McGarigal and Marks (1995), each landscape element can be measured by landscape metrics, e.g. size, density, shape, edge, diversity. The outputs values from landscape metrics directly indicate the quality of the on-going ecological processes at different levels. The result of the quantification process is interpreted by the degree of ecological significance of the landscape elements. The basis of the methodological framework is measurement of landscape elements according to principles of landscape metrics. Most of the landscape metrics are based on the mathematical–statistical approach that measures area, perimeter, length and shape. Many researchers have defined wide scale of landscape metrics (Pielou, 1975; Forman and Godron, 1981; McGarigal and Marks, 1995). Numerous metrics were developed to measure and describe composition and configuration of the land cover features. Landscape metrics became common tools in landscape pattern monitoring, assessment and planning since 1990s (Lausch and Herzog, 2002). For this study the most frequently used metrics was selected: identification of spatial composition and landscape configuration as Number of patches (NP), Patch's density (PD), Mean patch size (MPS), Patch's size standard deviation (PSSD) and Mean shape index (MSI). These metrics were selected since they have potential effects on the on-going ecological processes within landscape ecosystem (Forman, 1995), and used as predictor variables in the statistical analysis to examine the significance of habitat's patch and of the whole landscape.

On the base of the measured variables each habitat's patches were interpreted towards a quality of the on-going ecological processes. The output of the interpretation is determined by the level of ecological significance in the following levels (Hrnčiarová et al., 1997): 1) Very significant land cover patches 2) Significant land cover patches 3) Moderately significant land cover patches 4) Almost insignificant land cover patches 5) Insignificant land cover patches. With the increase of the level of ecological significance, the quality of landscape ecological processes in the landscape increases as well. According to Klaučo et al. (2012) the first step of the interpretative process was to assign level of the ecological significance (SA) for every habitat. The next step modifies the assigned degrees by the percentage proportion (P%) of habitat s metrics to the total number of the metric´ s value. Percentage proportion modified starting value of the ecological significance (SA) by the following scale: 0 – 20 % = SA same value; 21 – 40 % = SA, one level up; 41 – 60 % = SA, two levels up; 61 – 80 % = SA, three levels up; 81 – 100 % = SA, four levels up. The result value of the modification factor is partial ecological significance (SB). The value SC represents match average of values SB. It is the final ecological significance for habitats.

Landscape of the study area is diversified into three base categories (Table 1): 1. Artificial surfaces, where abstracted human impact, then 2. Agricultural area, without any part of arable land, and the last one is

3. Forests and semi-natural areas. Mentioned categories are divided into another 19 sub-categories. The number of categories is defined in accordance with used referenced scale and with the methodological concept of habitat classification. The study area is represented (91,81 % of Total Area) mostly by Forests and semi-natural areas. The number of patches (NP) in the study area reaches 105. Patch density (PD) shows distribution and concentration of patches in the landscape, with values 11,22 patches per 1000 ha. It is very small value, which indicates large and compact patches. Based on values from Table 1: A) Number of categories and sub-categories, B) Number of patches, C) Patch density and D) Class area (CA) and Total Area, one can state that study area is not fragmented in a wide range, but notably, however. From the Number of patches and their area we can assess Mean patch size (MPS). The output values of the MPS (Table 1) is based on the fact that Artificial surfaces has very small mean size (2,21 ha) within mutual relationship with NP and CA / TA occupy total landscape in partial form.

Table 1. Quantification of habitats by landscape metrics

LCC Code	Annex Code	NP1	NP2	PD1	PD2	MPS1	MPS2	PSSD1	PSSD2	MSI1	MSI2
Artificial surfaces	X	11	10,48	1,18	10,48	2,21	2,49	2,09	1,97	10,2	25,62
1.1.2.	X(1.1.2)	4	3,81	0,43	3,81	0,47	0,53	0,29	0,27	1,34	3,37
1.2.2.	X(1.2.2)	7	6,67	0,75	6,67	1,73	1,96	1,80	1,70	8,86	22,25
Agricultural areas	X	33	31,43	3,53	31,43	9,05	10,27	5,16	4,87	11,71	29,45
	65,10	15	14,29	1,60	14,29	2,05	2,33	1,89	1,79	1,70	4,27
	X(2.3.1)	1	0,95	0,11	0,95	0,34	0,39	0,00	0,00	2,15	5,40
	6410	5	4,76	0,53	4,76	0,51	0,58	0,45	0,42	1,40	3,51
	6110*	3	2,86	0,32	2,86	0,51	0,58	0,31	0,29	1,46	3,68
	6210	4	3,81	0,43	3,81	0,69	0,78	0,67	0,63	1,41	3,55
	6240*	4	3,81	0,43	3,81	3,47	3,94	1,84	1,74	1,96	4,93
	6230*	1	0,95	0,11	0,95	1,48	1,67	0,00	0,00	1,63	4,11
Forests & semi- natural areas	X	61	58,08	6,52	58,11	76,85	87,22	98,48	93,15	17,88	44,91
3.1.1	X(3.1.1)	2	1,90	0,21	1,91	1,22	1,38	0,91	0,86	1,77	4,44
	91G0*	18	17,14	1,92	17,15	12,85	14,58	30,96	29,28	1,88	4,72
	91H0*	5	4,76	0,53	4,76	2,13	2,42	2,67	2,53	1,33	3,33
	91M0	4	3,81	0,43	3,81	5,64	6,40	3,24	3,07	1,61	4,06
	9180*	7	6,67	0,75	6,67	13,21	15,00	21,15	20,01	1,78	4,47
3.1.3	9130	14	13,33	1,50	13,34	35,17	39,92	37,07	35,06	1,90	4,77
3.2.4	40A0*	4	3,81	0,43	3,81	1,42	1,61	0,52	0,49	1,58	3,96
	X(3.2.4)	5	4,76	0,53	4,76	1,37	1,55	1,96	1,86	1,91	4,81
3.3.2	8150	1	0,95	0,11	0,95	0,29	0,33	0,00	0,00	1,60	4,03
	8220	1	0,95	0,11	0,95	3,55	4,03	0,00	0,00	2,52	6,32
Total landscape value		105,00	100,00	11,22	100,00	88,11	100,00	105,72	100,00	39,80	100,00

On the other side, the category of Forest and semi-natural areas occupies wide range of the landscape and is diversified into big sum of NP and MPS. The final degree of the ecological significance is assessed by the mathematical average using partial ecological significance. The study area has final ecological significance (SC) at degree 3, but this value is needed to be diversified to the main class categories of habitats which are represented in the study area. "Artificial surfaces" occupy only 1,49 % of the total area and have final ecological significance at degree 5. "Agricultural areas" occupy 5,69 % and have value of SC at degree 2. Finally, the last class is represented by "Forests and semi-natural areas", which occupy 92,81 % and have degree 2 as well. The mentioned values represent background data for the diversification of the study area on zones with special regime of nature and landscape conservation within each zone accordingly.

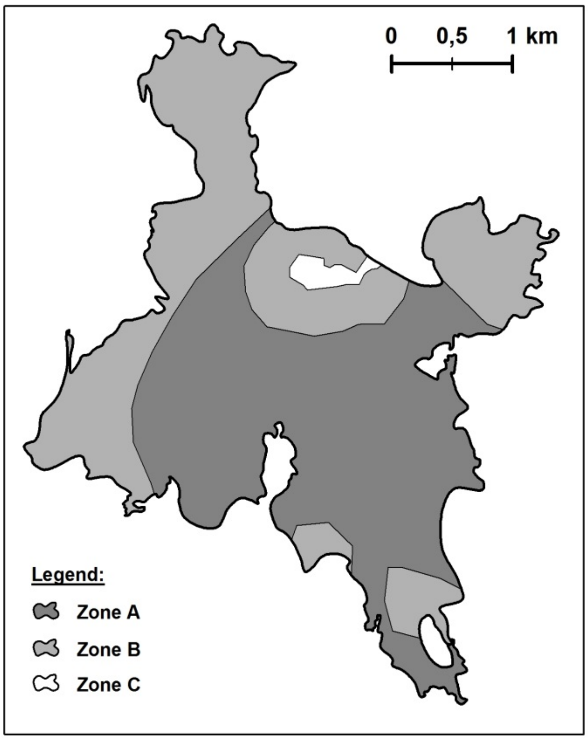

Figure 2. Zone map of ecological significance of Sitno Natura 2000 area, Slovakia

Diversifying study area on zones Natura 2000 sites are designed according to the ecological and biogeographical criteria, in order to meet specific conservation objectives that are to be achieved by the appropriate conservation measures. Sitno Natura 2000 Site represents type of the protected area, where human impacts are detected, though not in a wide range. The final ecological significance of the study area is in the same range as at the initial level. One may conclude that human impact is not destructing natural processes, naturalness and natural functioning (self-regulatory processes) within the habitats. The spatial division of the study area is classified according to the final ecological significance and partial ecological interpretation of the landscape metrics. Every part of the study area represents zone with different regime of conservation. Three different types of zones are described and defined as parts of the holistic nature of the protected area, diverse in natural values, originality, ecosystem extent, human actions and human land use types (Figure 2). First, "zone A" represents the "silent" zone, i.e. the most stringent level of protection, "zone B" is an area under limited using, and finally, "zone C" is an area suitable for human sustainable development.

The main result of this work consists in determined ecological significant areas of habitats that are under protection s system of Natura 2000 Sites. The patches quantification of habitats is the partial result that influences process of determination of ecological significance. The interpretative process examines land cover patches by the set of landscape metrics for the area, size, density and shape (NP, PD, MPS, PSSD and MSI). The ecological significance of landscape elements represents numerical values (degrees), which interpret quality of the on-going ecological process in landscape. According to the degrees of the ecological significance the protected area was zoned (Figure 2). This map divides study area into three (3) different zones with separately regime for nature conservation and landscape usage: Zone A, Zone B and Zone C. This division is based on the objective and ecological approach that respects human sustainable development. This research contributes to the methodological development of the ecological landscapes protection using landscape metrics and spatial analysis.

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