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## Interpretation of landscape values, typology and quality using methods of spatial metrics for ecological planning

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## 1. Introduction: research problem

This research focuses on landscapes studies with selected research area located in central Slovakia, Sitno area. The research purpose is to perform spatial analysis of the landscapes and patches within the landscapes, in order to assess, which parts of the selected study area have the highest environmental quality and value, for further environmental monitoring and management. This paper presents quantitative ecological assessment of the landscapes within the natural protected area located in Slovakia, central Europe. It contributes to the sustainable development and environmental management of the environmentally protected zones.

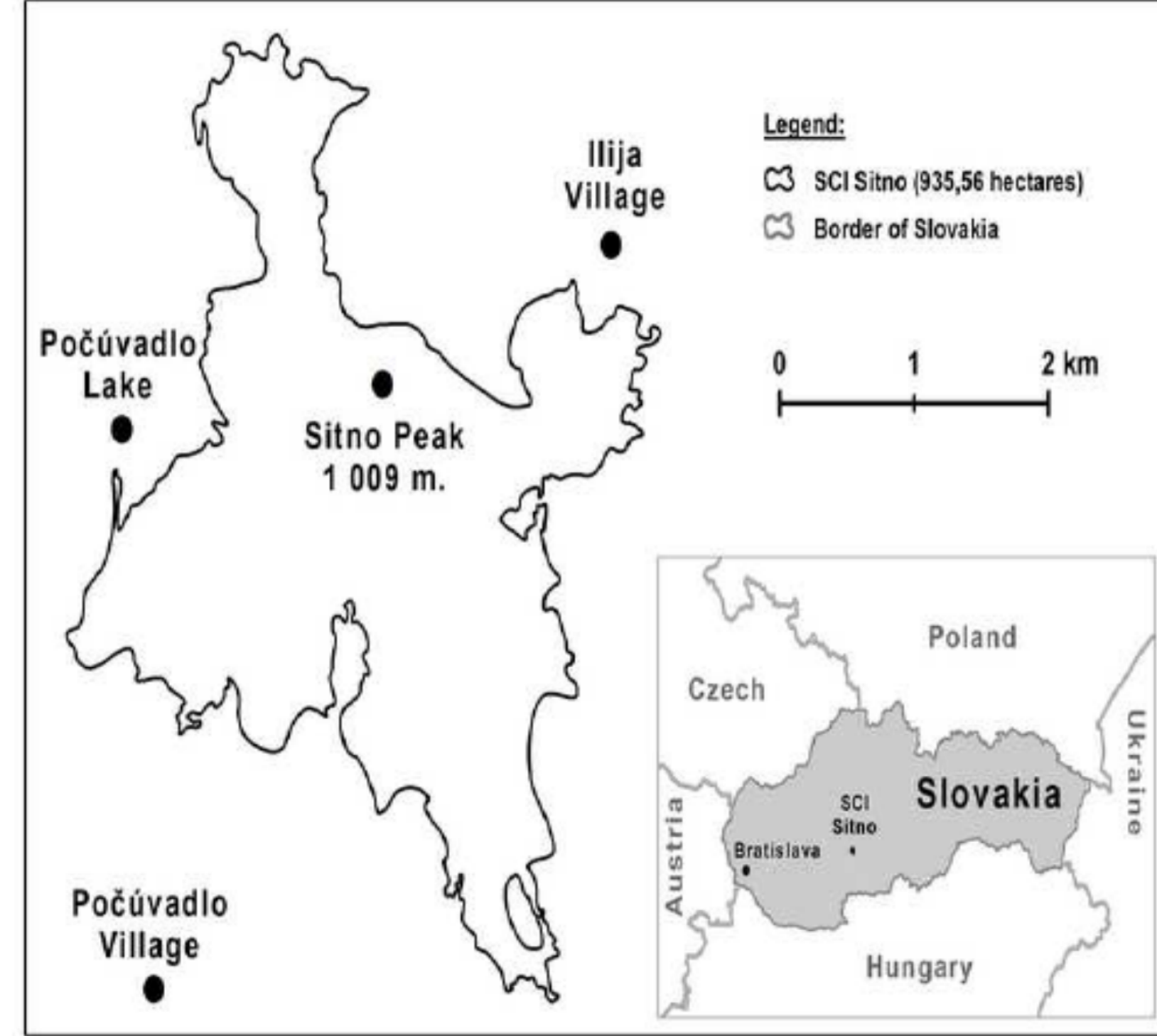


Table 1 Habitats representation and the area of Sitno Nature 2000 Site

CORINE Land Cover	Annex	EUNIS	Class Area			
Code	Description	Code	Description	ha	%	
<b>1. Artificial surfaces</b>					13,98	1,49
1.1.2.	Discontinuous urban fabric	X(1.1.2)	x	1,86	0,20	
1.2.2.	Road and rail networks and associated land	X(1.2.2)	x	12,12	1,29	
<b>2. Agricultural area</b>					53,32	5,69
2.3.1	Pastures	6510	Lowland hay meadows	E2.22	30,79	3,29
		X(2.3.1)	Large Carex beds	C3.26 (D5.21)	0,34	0,04
		6410	Molinia meadows on calcareous, peaty or clayey-siltladen soils	E3.51	2,54	0,27
		6110*	Middle European pioneerswards	E1.11 (E1.29)	1,54	0,16
		6210	Arid subcontinental steppic grassland	E1.22 (E1.23) E1.28)	2,74	0,29
		6240*	Sub-Pannonic steppic grasslands	E1.2 (E1.29)	13,89	1,48
6230*	Mat-grass swards	E1.71 (E4.31)	1,48	0,16		
<b>3. Forests and seminatural areas</b>					868,25	92,81
3.1.1	Broad-leaved forests	X(3.1.1)	Oak-hornbeam forests	G1.A16	2,44	0,26
		91G0*	Pannonic woods with Quercus, petraea & Carpinus betululus	A1.A16	231,29	24,72
		91H0*	Pannonian woods with Quercus pubescens	41.7374	10,67	1,14
		91M0	Pannonian-Balkan oak forests	G1.76	22,55	2,41
		9180*	Tilio-Acerion forest of slopes, screes and ravines	G1.B5	92,49	9,89
		9130	Asperulo-Fagetum beech forests	G1.G3	492,44	52,64
3.2.4	Transitional woodland shrub	40A0*	Continental deciduous thickets	F3.24	5,69	0,61
		X(3.2.4)	Temperate thickets and scrub	F3.1	6,84	0,73
3.3.2	Bare rocks	8150	Medio-European upland siliceous screes	H2.32 (H2.5)	0,29	0,03
		8220	Siliceous rocky slopes with chasmophytic vegetation	H3.11	3,55	0,38
<b>Total area (TA) / hectares (ha)</b>				935,56	100 %	

The study area of Sitno Natura 2000 Sites is located in Slovakia, central Europe. This area (Fig.1) belongs to the pan-European Natura 2000 network of ecologically protected areas.

Natura 2000 sites are defined as pan-European reserved nature zones, which meet the requirements of high environmental criteria and belong to natural heritage of Europe. These landscapes are under strict environmental protection due to their high ecological value, unique species, rich biodiversity and other characteristics. Selected under Natura 2000 programme, habitats and endangered species of high ecological value and significance are considered as primary targets of nature conservation. Sitno Natura 2000 Sites include unique landscapes with rare and endangered species. Therefore, they have high environmental and natural value, as important part of the Slovakian and European natural heritage. At the same time, there are detected anthropogenic impacts on Sitno Natura 2000 Sites, caused by the uncontrolled tourism and other factors.

## 2. Methodology

In this research we performed spatial analysis of Sitno landscapes using methods of landscapes metrics calculation and quantification. This includes measurements of landscape elements, assessment of ecological significance, zoning of area into areas of ecological significance with different value levels. Methodologically, the landscape metrics assessment included calculations of Number of Patches (NP), Patch's density (PD), Mean patch size (MPS), Patch's size standard deviation (PSSD) and Mean shape index (MSI). This is done using information on area, size, density and shapes of the landscapes. Patches, separate parts of the landscapes, were classified using code classification, which allowed to divide landscapes into three ground categories: 1) Artificial surfaces 2) Agricultural areas 3). Forests and seminatural areas. These categories were further sub-divided into 19 sub-clusters, which were defined according to the reference scale and methodological concept of habitat classification.

During the interpretation, the levels of ecological significance (SA) were assigned to every habitat. This process is based on the analysis and assessment of ecological processes in the landscape. The next step modifies the assigned degrees by the percentage proportion (P%) of habitat's metrics (NP, PD, MPS, PSSD and MSI) to the total number of the metric's value. Percentage proportion modified starting value of the ecological significance (SA). The result value of the modification factor is partial ecological significance (SB). The final ecological significance for the habitats (value SC) is presented as match average of values SB.

## 3. Techniques

The output of this interpretation is defined by the stepwise levels of ecological values: 1) very significant 2) significant 3) moderately significant 4) almost insignificant 5) insignificant.

The final results are presented as calculated numerical values which are assigned for each land cover patch within the landscape. The interpretation of these quantified data allows to define ecological value and quality of the landscapes. The ecological value, or significance, of the landscape elements is represented by the numerical values which indicate quality of the complex ecological processes within the landscape.

This enables to assess it as high-level value (very precious) or low-level value (not significant). These degrees are used for zoning of the protected areas. This process quantitatively divides study area into different zones with approach to landscape conservation. The final results consist in assessed ecological values for landscapes in Sitno Natura 2000 Site.

## 4. Results

The main result of this work is determined ecological significance of Sitno Natura 2000 Site. The ecological significance of landscape elements represents numerical values (degrees), which interpret quality of the on-going ecological process in landscape. The zoning of the protected area is done according to the degrees of the ecological significance. This process objectively divides study area into different zones with separately regime for nature conservation and landscape usage. It is characterized as a process based on the objective and ecological approach that respects human sustainable development.

### 4.1 Landscape elements of the study area

Landscape of the study area is diversified into three base categories: 1. Artificial surfaces, where abstracted human impact; 2. Agricultural area, without any part of arable land; 3. Forests and semi-natural areas. Mentioned categories are divided into 19 sub-categories (Table 1). The number of categories is defined in accordance with used referenced scale and with the methodological concept of habitat classification. The most representative landscape element within the study area is Asperulo-Fagetum beech forests (9130), as shown in Table 1. It occupies 52,64 % of the total area (TA). The study area is represented (91,81 % of TA) mostly by Forests and semi-natural areas. The number of patches (NP) in the study area reaches 105.

The 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. The study area is not fragmented too much, though, notably, as shown in Table 2: A) Number of categories and subcategories, B) Number of patches, C) Patch density and D) Class area (CA) and TA. The Mean patch size (MPS) was determined from the Number of patches and their area.

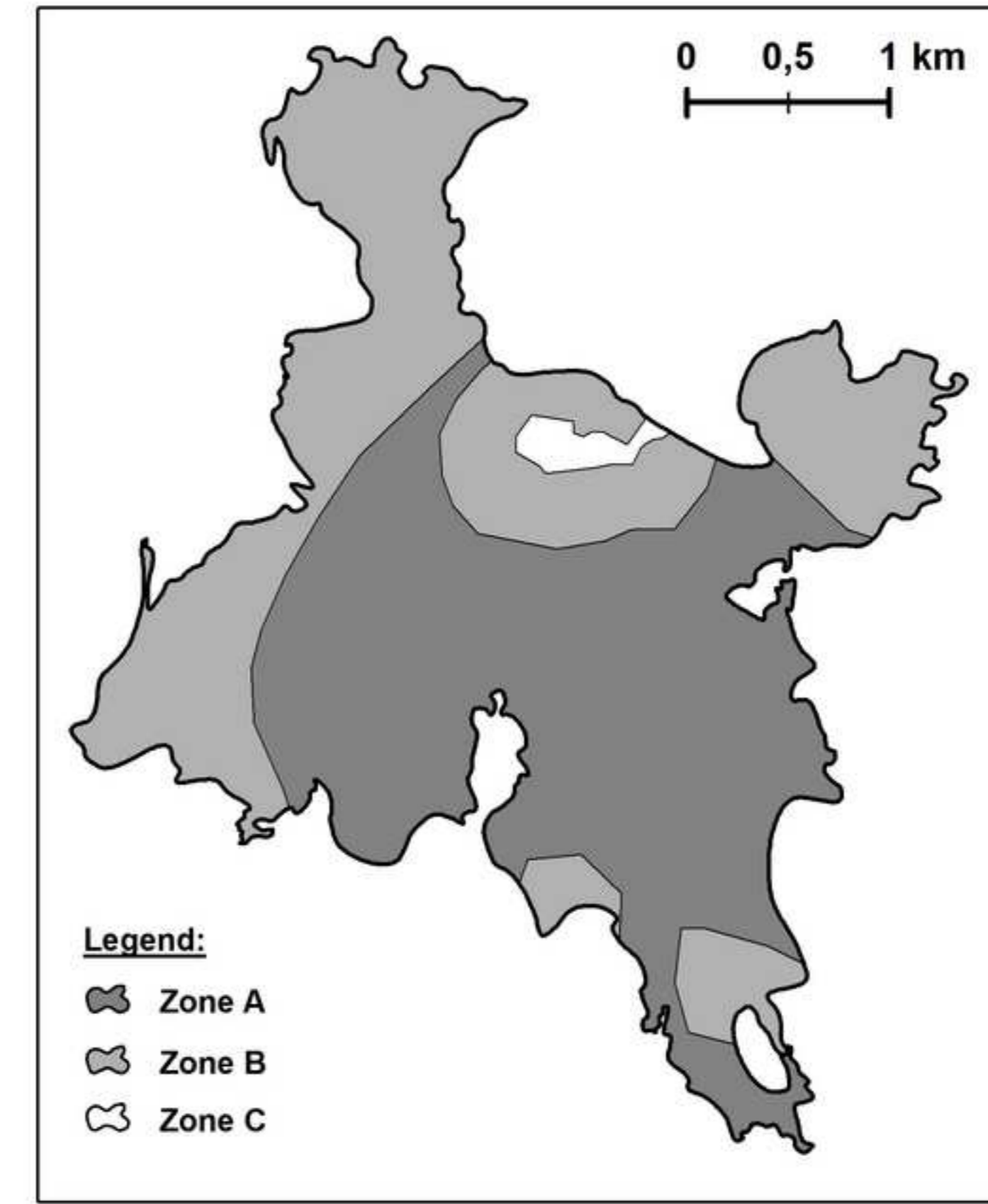
Table 2 Quantification of habitats by landscape metrics

LCC Code	Annex Code	NP1	NP2	PD1	PD2	MPS1	MPS2	PSSD1	PSSD2	MSI1	MSI2
<b>Artificial surfaces</b>											
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
	X	33	31,43	3,53	31,43	9,05	10,27	5,16	4,87	11,71	29,45
<b>Agricultural areas</b>											
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	
<b>Forests &amp; semi-natural areas</b>											
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
<b>Total landscape value</b>		105,00	100,00	11,22	100,00	88,11	100,00	105,72	100,00	39,80	100,00

Table 3 Determination of ecological significance of study area

LCC Code	Annex Code	Sa	NP		PD		MPS		PSSD		MSI		Sc
			P(%)	Sb	P(%)	Sb	P(%)	Sb	P(%)	Sb	P(%)	Sb	
<b>Artificial surfaces</b>													
X		5	5		5		5		5		5		5
1.1.2.	X(1.1.2)	5	3,81	5	3,81	5	0,53	5	0,27	5	3,37	5	5
1.2.2.	X(1.2.2)	5	6,67	5	6,67	5	1,96	5	1,70	5	22,21	5	5
<b>Agricultural area</b>													
X		2	2		2		2		2		2		2
6510	2	14,2	2	14,2	2	2,33	2	1,79	2	4,27	2	2	2
X(2.3.1)		3	0,95	3	0,95	3	0,39	3	0,00	3	5,40	3	3
6410	2	4,76	2	4,76	2	0,58	2	0,42	2	3,51	2	2	2
6110*	1	2,86	1	2,86	1	0,58	1	1,29	1	3,68	1	1	1
6210	2	3,81	2	3,81	2	0,78	2	0,63	2	3,55	2	2	2
6240*	1	3,81	1	3,81	1	3,94	1	1,74	1	4,93	1	1	1
6230	1	0,95	1	0,95	1	1,67	1	0,00	1	4,11	1	1	1
<b>Forests &amp; semi-natural areas</b>													
X		2	2		2		2		2		2		2
X(3.1.1)		2	1,90	2	1,91	2	1,38	2	0,86	2	4,44	2	2
91G0*	1	17,1	1	17,15	1	14,58	1	29,28	2	4,72	1	2	2
91H0*	1	4,76	1	4,76	1	2,42	1	2,53	1	3,33	1	1	1
91M0	1	3,81	1	3,81	1	6,40	1	3,07	1	4,06	1	1	1
9180*	1	6,67	1	6,67	1	15,00	1	20,01	2	4,47	1	2	2
3.1.3	9130	2	13,3	2	13,3	2	39,92	3	35,06	4	4,77	2	4
3.2.4	40A0*	1	3,81	1	3,81	1	1,61	1	0,49	1	3,96	1	1
	X(3.2.4)	3	4,76	3	4,76	3	1,55	3	1,86	3	4,81	3	3
3.3.2	8150	2	0,95	2	0,95	2	0,33	2	0,00	2	4,03	2	2
	8220	2	0,95	2	0,95	2	4,03	2	0,00	2	6,32	2	2
<b>Total landscape value</b>		3	3		3		3		3		3		3

Outputs values of MPS (Table 2) focus on fact that Artificial surfaces have very small mean size (2,21 ha) within mutual relationship with NP and CA / TA occupy total landscape in partial form. 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 most significant patch value is located in habitat of Tilio-Acerion forest of slopes, screes and ravines (9180\*), where MPS is 13,21 ha and CA is 92,49 ha. Comparable patch is Pannonic woods with Quercus petraea & Carpinus betululus (91G0\*) but CA represent almost 3 time more value. Each one patch of habitat 9180\* indices big size, and it looks like compact biotope, which is not common in Slovakian environment. This habitat is endangered due to its small scale and fragmented appearance. Another remarkable habitat is Pannonic woods & Quercus petraea & Carpinus betululus (91G0\*). Its values of MPS, CA and NP indicate small size for some patches within the habitat. Patch size standard deviation (PSSD) is focused on the significance of the size difference among the patches within the landscape (Table 2).



## 4.2 Ecological significance of study area

Ecological significance of landscape elements is based on the described above methodology. The Table 3 illustrates starting value (SA) of each one habitat. It is a baseline value of the ecological significance, where degrees are assigned according to Hrnčiarová et al. (1997). The study area has ecological significance at degree 3. Modification (SB) of this starting was realized according to: - Value outputs of the landscape metrics for each habitat and their percentage proportion to the metric's total number. - Scale degree which has stable or moving values by increasing method. 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 above values represent background materials for the diversification of the study area on zones with special regime of nature and landscape conservation within each zone accordingly.

## 4.3 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. They also provide a wide range of provisioning, regulating and sociocultural ecosystem services (Kettunen et al., 2009). 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. According to the mentioned above situation, we may conclude that human impact is not destructing natural processes, naturalness and natural functioning (self-regulatory processes) within the habitats. The spatial organization of the study area has been described according to the final ecological significance and partial ecological interpretation of the landscape metrics (Figure 2). 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. 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.

## 6. Conclusion

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 output values could express a spatial processes in the landscape, such as perforation, dissection, fragmentation, shrinkage or attrition. The final ecological significance of the study area – Sitno Natura 2000 site - is at degree 3, what means that the area is represented by moderately significant land cover patches – habitats. It indicates the same value as the one at the initial level. According to the value of the ecological significance, the study area has been diversified into three zones, where each one indicates specific level of conservation. The zones and the final degree of the ecological significance of habitats are retroactively compared to historical and cultural human development that started in this area as early as in 1st century BC. Theoretically, such a long period of intense human impacts on the local environment should completely destroy natural environment. Nevertheless, this area demonstrates rather good natural ecosystems conditions and well functioning ecological processes within the habitats. The human impact is now observed only in small range of size not more than 1,50% from total area of Sitno Natura 2000 Site. It can be explained, first, by low population density within the study area comparing to other EU areas, secondly, by accurate usage of the living area by the local population in general, and thirdly, by high resilience of the elements of landscapes towards any human impacts.

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