Tájökológiai Lapok 11 (2): 351-366. (2013) DOI: 10.56617/tl.3761

APPLICATION OF GEOINFORMATION TECHNOLOGIES FOR THE ASSESSMENT OF LANDSCAPE STRUCTURE USING LANDSCAPE-ECOLOGICAL INDEXES (CASE STUDY OF THE HANDLOVÁ LANDSLIDE)

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Keywords: landscape indexes, landscape structure, V-LATE, StraKa, Patch Analyst, GIS, landslide

Summary: New versions of geoinformation technologies and its various extensions enable to obtain quality and more accurate information about the landscape and its properties. The aim of the paper is to point out to the use of selected extensions in geographic information systems (GIS) which make the time-consuming and complex calculations within the analysis, assessment and interpretation of the landscape more effective. With the use of digital vector map, it is possible, by the means of GIS extensions, to calculate the number, shape, size, dispersion, diversity, neighboring relations of patches as well as many other indexes. In the paper, we deal with three extensions (V-LATE, Patch Analyst, and StraKa) that are compatible with ArcGIS/ArcView software. These specialized extensions were applied for the analysis of the spatial landscape structure in the area of the catastrophic Handlová landslide from the year 1961 which was analyzed also in terms of changes in landscape structure for the time period of 228 years.

Introduction

Rapid development of information technologies, which have changed many Earth sciences, did not avoid even the landscape ecology. The new versions of geoinformation technologies particularly geographic information systems (GIS) and their various extensions enable to obtain quality and more accurate information about the landscape and its properties. The condition of landscape and its changes can be interpreted with the use of selected landscape-ecological indexes which can identify trends in development of shape, size, edge length, diversity of landscape elements as well as the heterogeneity of area or other special purpose properties. Consequently, the obtained results can be applied in other practices of landscape-ecological and geographical research.

Assessment of spatial structure of the landscape patches and their specific properties has great importance in the current geo-ecological research. It appears in the works of several authors (MCGARIGAL and MARKS 1995, FRANKLIN and FORMAN 1987, GUSTAFSON 1998, JAEGER 2000, HERZOG et al. 2001, LIPSKÝ and KALINOVÁ 2001, MCGARIGAL 2002, DIBARI 2007, MOSER et al. 2007, ARAÚJO et al. 2008, SUNDELL-TURNER and RODEWALD 2008, GARDNER et al. 1987, GARDNER and O'NEILL 1991, BALEJ 2006, BOLTIŽIAR 2007, OLÁHOVÁ and VOJTEK, BOLTIŽIAR 2012, GAJDOŠ et al. 2012, KILIANOVÁ et al. 2009). Its justification lies mainly in maintaining the ecological stability of the landscape, sustainable development or landscape potential and plays an important role in identifying the socio-economic impact on the landscape. It is also useful in other methods and techniques of landscape-ecological research.

The aim of the paper is to point out to the use of selected GIS extensions which make the time-consuming and complex calculations, within the analysis, assessment and interpretation of selected landscape properties, more effective. They were applied for the analysis of the trend in development of spatial landscape structure in the area of Handlová landslide from the year 1961 which was identified via changes in the landscape structure using landscape-ecological indexes. The indexes represent algorithms which quantify specific characteristics of spatial structure of patches/polygons. They are calculated in relation to the defined spatial units (GULINCK and WAGENDORP 2002). There are indexes that quantify composition of landscape polygons regardless of their spatial distribution as well as indexes interpreting their spatial configuration (MCGARIGAL and MARKS 1995, FORMAN and GODRON 1986, FORMAN 2006). The composition deals with the number and occurrence of different types of landscape segments while configuration reflects their spatial arrangement (MCGARIGAL and MARKS 1995). Quantification of landscape with the use of indexes also includes the measurements of diversity, homogeneity or heterogeneity of the landscape.

In order to mathematically capture the quantifying properties of landscape structure by the means of a number of numerical indicators, several specialized software were developed. These numerical indicators are described in the works of CUSHMAN et al. (2008), CUSHMAN and MCGARIGAL (2008), LAUSCH and HERZOG (2002), TURNER and GARDNER (1991), etc.; therefore, we will not deal with them in more detail in this paper.

Selected landscape-ecological indexes can be divided into five categories:
1. Patch size indexes - Mean Patch Size (MPS), Median Patch Size (MEDPS), Relative Area (RA), Accessibility (Ai),
2. Shape indexes - Mean Shape Index (MSI), Area-weighted Mean Shape Index (AWMSI), Mean Fractal Dimension (MFRACT), Area-weighted Mean Patch Fractal Dimension (AWMPFD),
3. Edge indexes - Edge Density (ED), Total Edge (TE),
4. Core area indexes – Total Core Area (TCA), Disjunct Core Areas (DCA), Number of Core Areas (NCA), Core Area Index (CAI),
5. Diversity indexes - Shannon's Diversity Index (SDI), Shannon's Evenness Index (SEI), Dominance, Richness.

The particular extensions that can be used for calculations of landscape-ecological indexes are described in materials and methods of research.

Study area

The study area is represented by the Handlová landslide from the year 1961 with an area of 737.8 hectares (Figure 1.). It is located in the cadastral area of the Handlová Town within the geomorphological units of the Hornonitrianska basin and the Kremnica Mountains (MAZÚR and LUKNIŠ 1986).

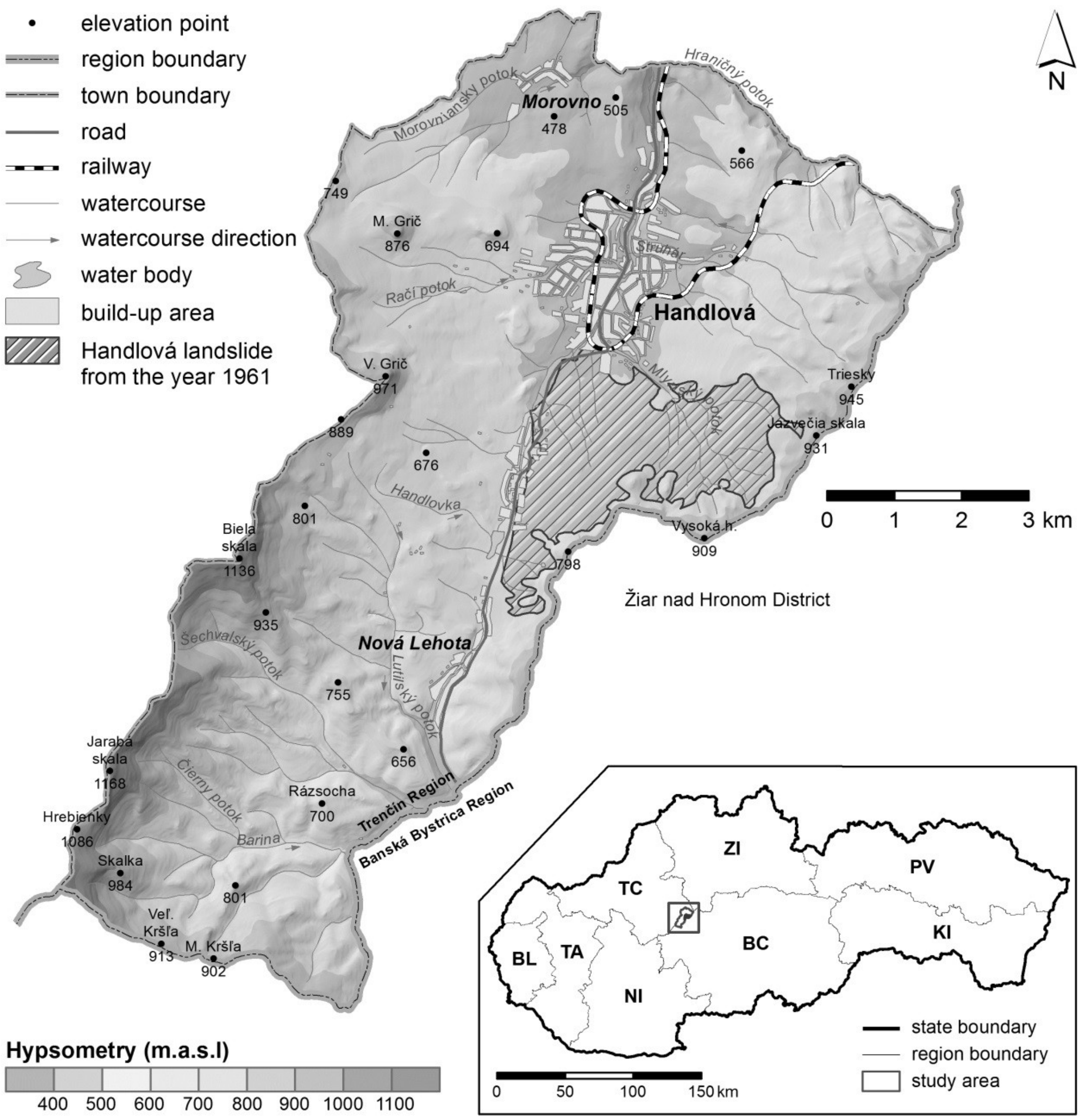

Figure 1. Study area – Handlová landslide from the year 1961
1. ábra A vizsgálati terület – a nyitrabányai földcsuszamlás 1961

The landslide, which was activated in the southeastern part of the town, belongs to one of the largest natural disasters that have occurred in Slovakia. It developed in the environment of Paleogene clays and marly shales (bedrock of landslide masses at the bottom of the landslide), upon which there are Neogene rocks - Baden clays, claystones and marls (they create bedrock in the middle part of the landslide slope) and the highest part is made of the so-called gravel series, consisting of coarse-graded sand, which ascends in the rift part of the landslide. Above these sediments, there are volcanic overlaying andesites and aglomerating tuffs forming partly the rift zone of the landslide and also occurring as slags in lower slope positions. In terms of formation and activation of the landslide movements, the most important are alternating positions of permeable and impermeable rocks along with the lift groundwater horizons. The specific feature of the area is the presence of permeable position of gravels at the top of the landslide which mediates constant saturation of landslide masses with the water. Total length of the landslide was 1800 meters (14.5 million m^3 of subsided material). The east side of the main landslide began to move about 14 days later. Its length reached 1 km and volume of the subsided material was about 5.7 million m^3 (NEMČOK 1982).

After the landslide stopped moving in the summer of 1961, there were recorded other movement activities in 1967, 1970, 1977, 1991. Remediation works were made focusing primarily on dewatering of the slope. In particular stages of survey and remediation, the network of monitoring objects was built and short-term monitoring was realized (WAGNER et al. 2008).

In the study area, the slope values range from 2º-35º which also has a significant impact on the landslide movement. Maximum altitude is 736 meters above sea level and difference between minimum and maximum elevation is 259 meters.

Based on the subsequent extensive engineering-geological and geotechnical surveys and measures, it was decided in 1980 to build a stabilization embankment. Furthermore, part of the Handlovka watercourse with its tributary was covered. The embankment is recorded as water structure and waste rocks began to deposit since 1983. The area is being monitored since 1993 (WAGNER et al. 2008).

Material and methods

For a detailed understanding of the development of the study area, it was necessary to deal also with the analysis of landscape structure and its changes. The background material was represented by maps from the years 1783/1785 (map of the First Military Survey in a scale of 1 : 28 800), 1845 (map of the Second Military Survey in a scale of 1 : 28 800), 1936 (map of the Third Military Survey in a scale 1 : 25 000), 1956 (topographic map in a scale 1 : 25 000), 1987 (topographic map in a scale 1 : 25 000) and aerial photography from the year 2003 (scale 1 : 2 000) and 2009 (scale 1 : 2 000) which were updated with field survey in 2011.

After georeferencing maps, we created a polygon layer of landscape structure. We identified 26 landscape elements which were then classified into groups. The classification was based on the work of RUŽIČKA (2000) who divides landscape elements into 6 basic groups which were adjusted, considering the aim of the paper, to 8 groups according to OLÁHOVÁ and BOLTIŽIAR (2009), MOJSES and BOLTIŽIAR (2011):

1. Group of elements of forest and non-forest woody vegetation
2. Group of elements of permanent grasslands
3. Group of elements of agricultural crops
4. Group of bedrock and substratum elements
5. Group of elements of watercourses and water bodies
6. Group of residential elements and recreational areas
7. Group of technical elements
8. Group of transportation elements

Based on the landscape elements, we analyzed and assessed selected properties of the landscape with the use of the following three extensions in GIS:

StraKa

StraKa is a GIS toolbox for the analysis of landscape structure. It represents a programmed set of solutions for complex formulas collectively published by FORMAN and GORDON (1986). The tool is designed in the form of toolbox – user extension of ArcGIS software and is fully functional under ArcInfo license. In the basic ArcView license, the only tools that work are Geometry, Number of Entities, Statistics, and Shape of Patch. Toolbox is divided into two toolsets: Index of Landscape and Description of Landscape. Toolbox was created during the years 2007-2008 at the Department of Geoinformatics, Palacky University in Olomouc (PECHANEC et al. 2008).

Vector-based Landscape Analysis Tools Extension (V-LATE)

V-LATE provides a set of frequently used so-called metric functions (landscape indexes) to study and determine the landscape structure. The extension was developed within the SPIN project at the University of Salzburg in GIS laboratory of the Department of Geoinformatics. It works with vector-based data of polygon topology having shapefile format. GRID and geodatabase files are not supported. Projection on-the-fly is not yet supported by this extension and it works only with the projected data. V-LATE uses seven different types of analyses: area analysis (area calculations), form analysis, edge analysis, core area analysis, proximity analysis, diversity analysis, and subdivision analysis.

Patch Analyst

Patch Analyst is an extension which allows spatial analysis of the landscape, supports the modelling of habitats, biodiversity conservation, and forest management. Patch Analyst for ArcGIS is available in two versions: Patch for processing polygon layers and Patch Grid for raster (grid) layers. Menu of Patch Analyst version 3.12 consists of 12 functions which are divided into four thematic groups. The first group includes production of new layers, the second group deals with setting the parameters, the third group works with attribute modeling, and the fourth group works with spatial operations.

When analyzing the landscape of the study area using landscape-ecological indexes, we analyzed only two time horizons 2003 and 2011 due the fact that they are developed on the basis of aerial photographs that enable more detailed digitization of landscape elements compared to already generalized maps.

Results

The maps of landscape structure for the whole period of years 1783-2011 represent a unique and time-extensive database (228 years) about the study area (Figure 2.). Based on these maps, each time period was analyzed in terms of impact of the landslide on the landscape structure.

Slope deformations in the study area represent a dominant barrier that significantly affects the land use. Intensive remediation works along with stabilization measures were carried out in the area. A common feature of landslides is that they not only remove, destroy and weaken soil and mainly vegetation cover, but they also negatively distort and change elements of the landscape structure.

Prior to 1960 in the landslide area, the group of elements of permanent grasslands (ø 377.4 hectares) and the group of elements of agricultural crops (ø 238.7 hectares) prevailed regarding their area. After the landslide in 1960, the group of elements of forest and non-forest woody vegetation (ø 587.3 hectares) prevailed. This was caused by overbuilding the landslide with stabilization embankment and its following recultivation (especially planting out Picea abies).

The group of residential elements and recreational areas was affected by the landslide especially in the composition of landscape elements. Before the catastrophic landslide (until 1960), the landscape element of individual housing covered approximately 2 hectares of the study area. After the year 1960, the area of this landscape element had only 0.8 hectares. It was destroyed as a result of the landslide, but the group of residential elements and recreational areas did not extinguished because after the year 1985, a new landscape element of cottages and recreational areas was built there (ø 3 ha).

Group of transportation elements and group of elements of watercourses and water bodies were affected by the landslide mainly through the transhipment of the main road connecting the Handlová Town and Žiar nad Hronom Town and regulation and overlay of the Handlovka watercourse.

Furthermore, the landslide affected the group of technical elements mainly by destroying and overwhelming the mine workings.

Until 1960, the study area was used mainly for agricultural purposes, particularly for grazing cattle and to a lesser extent for crop cultivation. Changes in the landscape structure of the study area were particularly significant after 1960 when the landscape was changing from agricultural to natural. The causes of the transition of agricultural landscape to natural landscape after 1960 were instability and tendency for landslides which prevented the agricultural utilization of the landscape. Subsequently, the Picea abies was planted out and was mixed with other woody vegetation and during 50 years, it went through the plant succession to the climax stage forming a mixed forest. This supported the stability of the area after the year 1960 which led also to the transformation from agriculturally utilized landscape to natural landscape.

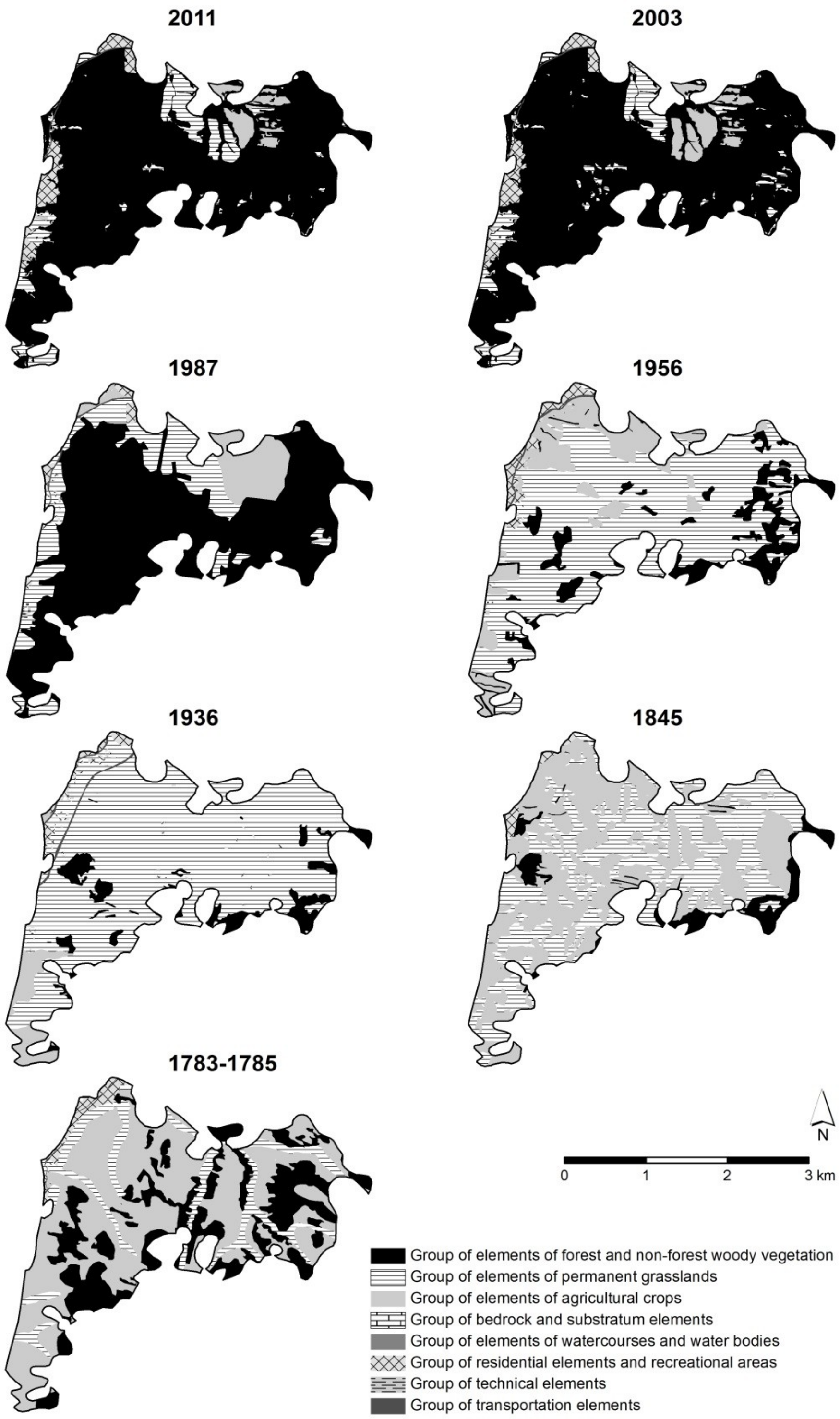

Figure 2. Landscape structure of the Handlová landslide in the years 1783-2011
2. ábra A nyitrabányai földcsuszamlás tájstruktúrája 1783-2011

Landscape-ecological indexes

The patches (landscape elements) in the landscape can be classified according to their origin or the mechanism by which they originated. When analyzing the different types of patches, we wanted to point out the causal mechanisms and the actual variability of the patches so that we can get an overview of the development, stability and future trend of the patches.

However, all these phenomena cannot be understood as a simple cause and effect relationship because in the landscape there are many random (stochastic) impacts (FORMAN and GODRON 1986).

We analyzed the following selected properties of patches applying landscape-ecological indexes in GIS: their size, shape, number, location in the landscape, etc.

In both years, the highest number of patches (NP) has the landscape element of meadow vegetation. Since 2003, the number of patches in the area decreased which was caused by the modification of some of the patches within the group of elements of permanent grasslands to the group of elements of forest and non-forest woody vegetation and also by the change from patches of landscape element of shrub vegetation to the landscape element of mixed forests. Permanent grasslands have undergone plant succession, turned into shrub and thus were included into the group of elements of forest and non-forest woody vegetation. The shrub vegetation went through the climax stage and was assigned to the landscape elements of mixed forests. The number of patches in the group of elements of permanent grasslands as well as in the group of elements of forest and non-forest woody vegetation decreased since smaller patches of landscape elements were linked.

Furthermore, the patch density (PD) decreased in the study area which is caused by the same processes as those regarding the number of patches.

Patch size indexes

The mean patch size (MPS) in the study area increased. However, the value and size of some landscape elements in the group of elements of forest and non-forest woody vegetation and group of elements of agricultural crops decreases. Especially, the value of landscape elements that are strongly influenced by man decreased.

As an example we can mention the landscape element of forest path, where its size is affected by the forest management and plant succession. Moreover, it is the landscape element of small-area and narrow fields where the agricultural land became fallow land. The landscape elements in the group of residential elements and recreational areas, group of elements of watercourses and water bodies, group of transportation elements, and groups of bedrock and substratum elements (mainly the landscape element of natural rock formations) retain the stable values of mean patch size. The size of these groups of the landscape elements have not changed for a long time; therefore, they have stable values of mean patch size in this time period. MPS values increase due to the increase in size of landscape elements, which is linked to the landscape elements with the decreased size of their area. For example, the value of mean patch size of the landscape element of shrub vegetation declined due to plant succession and thus the value of mean patch size of landscape element of mixed forests increased.

The median patch size (MEDPS) decreased which is related to the mean patch size and complexity of the patch shape.

The patch size indexes also include the accessibility index (Ai) and relative area (RA) which were calculated using the StraKa extension. Relative area (RA) of some of the landscape elements increased (mixed forest, meadow vegetation with trees, small forests, etc.) which means that also their size widened. Accessibility index (Ai) in the study area increased due to increased size of landscape elements in 2011. However, also the shape and distribution of patches in the landscape has an impact on the accessibility of patches.

Shape indexes

The mean shape index (MSI) approximates 1 in the landscape elements of solitary forests (1.2), other water bodies (1.2) and in the landscape elements of residential and recreational areas and thus their shape is nearly circular which is due to their small size. Conversely, the most complex shape have the landscape elements in the group of the transportation elements (e.g. main-national roads which are significantly elongated or even have a linear character), in the group of elements of forest and non-forest woody vegetation (e.g. forest path (3.4), linear gappy woody vegetation (2.8), small forests (2.3), mixed forests (2.1)), and in the group of the elements of permanent grasslands (grass balk 2.3) which is due to large area of these landscape elements and due to other elements complicating their shape (e.g. through permanent grassland areas may pass a linear woody vegetation, etc.). The mean shape index for all groups of landscape elements is about the same in both years. Mean value is 1.7 which means that the patches are slightly elongated.

Values of area-weighted mean shape index (AWMSI) slightly increased in the study area. It indicates that there are geometrically more complex shapes of patches which are typical for natural or unchanged landscape. Fragmentation caused by human activities, simplifying the shapes of patches, is not so evident.

The mean fractal dimension (MFRACT) has the lowest values (1.4) in the group of residential elements and recreational areas (landscape elements of playgrounds, cottages and recreational areas, parking lots and other parking areas) and in the group of elements of forest and non-forest woody vegetation (landscape element of shrub vegetation 1.4). On the contrary, the highest values are reached in the group of elements of forest and non-forest woody vegetation (landscape element of solitary forests 1.8), in the group of elements of permanent grasslands (meadow vegetation 2.0 and meadow vegetation with trees 1.9), and in the group of residential elements and recreational areas (landscape element of individual housing 1.7). The low value of mean fractal dimension is typical for a landscape that is agriculturally utilized and conversely high value indicates the natural landscape. In the study area, the value of mean fractal dimension is about 1.5 which indicates more or less natural shapes of the landscape structure.

Regarding the area-weighted mean patch fractal dimension (AWMPFD), both time horizons have the same values (1.4). AWMPFD is assessed similarly as fractal dimension and its values range from 1.3 to 1.8 which means that more complex shapes of landscape elements dominate in the study area.

Edge indexes

Edge density (ED) reaches the highest value in both time horizons in the landscape elements of mixed forests, meadow vegetation, meadow vegetation with trees, and orchards. These landscape elements have slightly upward trend of the index because of the rising fragmentation of their sizes and generally their larger size (e.g. meadow vegetation is interwoven with the linear woody vegetation and groups of tree vegetation, etc). The lowest values of edge density are in the landscape elements of solitary forests, other water bodies, parking lots and other parking areas, etc. which is caused by their small size and low fragmentation.

Edge density decreases which is due to less fragmentation of sizes of particular landscape elements compared to the year 2003.

The total edge (TE) decreases in the study area which is caused by the decrease in the number of landscape elements as well as in their size.

Core area indexes

Before the analysis of core area indexes, it was necessary to create core areas of patches (boundary polygons) in ArcGIS Desktop 10 software with the use of the V-LATE extension which is further described in the material and methods of the paper. Using these boundary polygons, we determined the total core area (TCA), disjunct core areas (DCA), and core area index (CAI).

Core area indexes integrate the size, shape and edge distance of patches in a single measurement. They reflect the transition zone of adjacent landscape elements using the boundary polygon (see MCGARIGAL and MARKS 1995, NEEL et al. 2004).

In the study area, the value of the total core area (TCA) increased due to a larger number of patches with core areas in 2003. The largest total core area of patches have the landscape elements of mixed forests, meadow vegetation with trees, meadow vegetation, orchards, and parks and residential vegetation with trees and shrubs. This is due to their large size. Conversely, the smallest value of TCA have the small sized landscape elements (solitary forests, other water bodies, groups of trees, etc.).

The disjunct core areas (DCA) decreased in the study area which is related to the decrease in the number of landscape elements. The more landscape elements in the landscape structure, the higher number of disjunct core areas (DCA).

The number of core areas (NCA) also decreased which is caused by a smaller number of patches in 2011.

On the contrary, the core area index (CAI) increased in the study area due to a smaller size of the total core area in 2003. The average value of CAI in the study area during the whole period is 85.5%.

Diversity indexes

Shannon's diversity index (SDI) represents the landscape diversity based on two components, the number of different types of patches and their size proportion. It grows with the increasing number of patch types or if the spatial representation of different types becomes uniform. The maximum value is reached when the maximum number of patches of the groups of landscape elements is represented equally in the landscape structure (BALEJ 2006). Although the species diversity in the study area slightly decreases (which is affected by the decline in the number of particular landscape elements - mixed forests, meadow vegetation, shrub vegetation, glades, etc. and also due to their size and distribution in the study area), the average value of SDI is 0.9 which means that the study area is heterogeneous.

Shannon's Evenness Index (SEI) expresses the distribution and representation of landscape elements (MCGARIGAL and MARKS 1995). It has a value of 0.3 in the study area which means that the distribution of patches in the landscape structure is uniform.

The Dominance has a value of approximately 2.4 in the study area which means that there are less landscape elements with the equal proportion of the size. Dominance slightly rises in the study area which means that the number of landscape elements with the same proportion of the size decreases.

The Richness increases in the study area which is caused by a new landscape element of playgrounds. This landscape element was added up in 2005.

Table 1. Landscape-ecological indexes of landscape elements in the year 2003
1. táblázat A tájelemek tájmetriai mutatói 2003-ban

2003														
Landscape-ecological indexes														
Landscape Element	**NP**	**MPS**	**MEDPS**	**RA**	**Ai**	**MSI**	**AWMSI**	**MFRACT**	**AWMPFD**	**ED**	**TE**	**TCA**	**NCA**	**CAI**
		Ha	**ha**	**%**						**ha**	**m**	**ha**		**%**
113	22	27,38	0,08	81,66	43,44	2,07	5,24	1,58	1,38	81,32	59997,5	544,81	38	90,43
121	2	0,22	0,12	0,06	0,79	2,31	2,55	1,55	1,56	1,07	789,63	0,01	2	3,28
122	8	0,07	0,05	0,08	0,94	1,32	1,35	1,49	1,46	1,32	973,47	0,03	8	5,23
123	3	0	0	0	0,08	1,17	1,16	1,77	1,75	0,11	80,38	0	3	0
124	7	0,55	0,57	0,52	2,24	1,41	1,47	1,38	1,38	3,48	2568,14	1,62	8	42,25
132	3	0,44	0,25	0,18	1,6	2,76	2,62	1,57	1,52	2,38	1752,86	0,23	3	17,71
151	1	2,74	2,74	0,37	1,97	3,41	3,41	1,49	1,49	2,71	1999,82	0,85	5	30,84
152	4	0,38	0,23	0,21	1,12	1,31	1,31	1,38	1,37	1,52	1118,36	0,58	4	38,27
221	61	0,61	0,18	5,02	19,78	1,64	1,79	2	1,39	29,47	21741,27	20,08	80	53,87
222	14	1,3	0,1	2,46	5,13	2,06	2,54	1,9	1,38	8,11	5985,55	13,25	17	73,02
231	4	0,06	0,04	0,03	0,44	1,48	1,51	1,54	1,51	0,65	483,2	0,01	4	4,1
241	1	0,68	0,68	0,09	0,65	2,33	2,33	1,48	1,48	0,93	683,57	0,17	2	24,58
312	2	6,12	5,72	1,66	3,18	1,81	1,82	1,34	1,34	4,31	3180,13	9,17	2	74,93
321	13	1,82	0,74	3,22	8,29	1,73	1,81	1,43	1,35	12,2	9002,91	15,94	16	67,21
411	2	0,17	0,05	0,05	0,23	1,24	1,11	1,43	1,36	0,42	312,41	0,12	2	36,14
421	5	0,06	0,03	0,04	0,44	1,3	1,3	1,7	1,44	0,64	473,18	0,06	5	18,46
441	2	0,77	0,02	0,21	0,36	1,94	1,37	1,56	1,33	0,99	726,8	0,98	2	63,83
522	1	0,07	0,07	0,01	0,11	1,21	1,21	1,45	1,45	0,15	110,74	0	1	0
611	20	0,03	0,03	0,07	1,36	1,39	1,32	1,73	1,54	1,94	1431,55	0	20	0
631	11	0,27	0,11	0,4	2,41	1,64	1,68	1,53	1,42	3,79	2793,83	0,9	13	30,56
651	0	0	0	0	0	0	0	0	0	0	0	0	0	0
671	8	2,48	0,3	2,69	6,43	2,22	2,75	1,51	1,41	11,06	8160,45	12,94	17	65,27
681	3	1,4	0,7	0,57	0,87	1,25	1,3	1,35	1,3	1,83	1351,82	2,97	3	70,67
691	1	0,32	0,32	0,04	0,25	1,31	1,31	1,38	1,38	0,36	262,64	0,1	1	30,93
721	2	0,23	0,13	0,06	0,46	1,46	1,57	1,43	1,43	0,68	500,34	0,08	2	17,88
811	2	1,01	1,01	0,27	3,21	4,66	4,66	1,61	1,61	4,5	3317,26	0	2	0

Landscape element: 113 Mixed forests, 121 Small forests, 122 Groups of tree vegetation, 123 Solitary forests, 124 Shrub vegetation, 132 Linear gappy woody vegetation, 151 Forest path, 152 Glades, 221 Meadow vegetation, 222 Meadow vegetation with trees, 231 Unused permanent grasslands without tree vegetation, 241 Grass balk, 312 Small-area and narrow fields, 321 Orchards, 411 Bedrock baring, 421 Natural rock formations, 441 Tailings pile, 522 Other water bodies, 611 Individual housing, 631 House gardens, 651 Playgrounds, 671 Parks and residential vegetation with trees and shrubs, 681 Cottages and recreational areas, 691 Parking lots and other parking areas, 721 Farms, farmyards, 811 Main-national roads

2. táblázat A tájelemek tájmetriai mutatói 2003-ban
Table 2. Landscape-ecological indexes of landscape elements in the year 2011

2011														
Landscape-ecological indexes														
Landscape element	**NP**	**MPS**	**MEDPS**	**RA**	**Ai**	**MSI**	**AWMSI**	**MFRACT**	**AWMPFD**	**ED**	**TE**	**TCA**	**NCA**	**CAI**
		ha	**ha**	**%**						**ha**	**m**	**ha**		**%**
113	18	33,71	0,08	82,20	35,90	2,07	5,44	1,60	1,38	71,10	52456,66	556,88	33	91,79
121	3	1,07	0,31	0,44	1,70	2,21	2,09	1,49	1,41	2,68	1980,07	1,67	3	52,14
122	8	0,07	0,05	0,08	0,94	1,32	1,35	1,49	1,46	1,32	973,47	0,03	8	5,23
123	3	0,00	0,00	0,00	0,08	1,17	1,16	1,77	1,75	0,11	80,38	0,00	3	0,00
124	6	0,58	0,51	0,47	2,11	1,35	1,40	1,37	1,36	2,91	2149,32	1,65	6	47,21
132	3	0,44	0,25	0,18	1,60	2,76	2,62	1,57	1,52	2,38	1752,86	0,23	3	17,71
151	2	1,14	1,05	0,31	1,63	2,14	2,15	1,43	1,43	2,20	1625,37	0,78	3	34,05
152	2	1,28	0,58	0,35	1,51	1,81	2,08	1,39	1,41	2,04	1506,26	1,20	3	46,77
221	37	0,80	0,17	4,01	13,96	1,72	1,91	2,00	1,40	21,37	15768,68	16,86	52	56,99
222	14	2,14	0,10	4,06	7,79	2,10	2,26	1,90	1,36	11,72	8645,40	22,35	17	74,65
231	4	0,06	0,04	0,03	0,44	1,48	1,51	1,54	1,51	0,65	483,20	0,01	4	4,10
241	1	0,68	0,68	0,09	0,65	2,33	2,33	1,48	1,48	0,93	683,57	0,17	2	24,58
312	2	0,44	0,11	0,12	0,50	1,51	1,58	1,43	1,40	0,90	663,74	0,32	2	36,21
321	13	1,82	0,74	3,22	8,29	1,73	1,81	1,43	1,35	12,20	9002,91	15,94	16	67,21
411	2	0,17	0,05	0,05	0,23	1,24	1,11	1,43	1,36	0,42	312,41	0,12	2	36,14
421	5	0,06	0,03	0,04	0,44	1,30	1,30	1,70	1,44	0,64	473,18	0,06	5	18,46
441	2	0,77	0,02	0,21	0,36	1,94	1,37	1,56	1,33	0,99	726,80	0,98	2	63,83
522	1	0,07	0,07	0,01	0,11	1,21	1,21	1,45	1,45	0,15	110,74	0,00	1	0,00
611	20	0,03	0,03	0,07	1,36	1,39	1,32	1,73	1,54	1,94	1431,55	0,00	20	0,00
631	11	0,27	0,11	0,04	2,41	1,64	1,68	1,53	1,42	3,79	2793,83	0,90	13	30,56
651	1	0,64	0,64	0,09	0,31	1,58	1,58	1,39	1,39	0,61	448,88	0,32	1	49,40
671	7	2,74	0,30	2,60	6,12	2,31	2,79	1,52	1,41	10,45	7711,57	12,62	16	65,80
681	3	1,40	0,70	0,57	0,87	1,25	1,30	1,35	1,30	1,83	1351,82	2,97	3	70,67
691	1	0,32	0,32	0,04	0,25	1,31	1,31	1,38	1,38	0,36	262,64	0,10	1	30,93
721	2	0,23	0,13	0,06	0,46	1,46	1,57	1,43	1,43	0,68	500,34	0,08	2	17,88
811	2	1,01	1,01	0,27	3,21	4,66	4,66	1,61	1,61	4,50	3317,26	0,00	2	0,00

Landscape element: 113 Mixed forests, 121 Small forests, 122 Groups of tree vegetation, 123 Solitary forests, 124 Shrub vegetation, 132 Linear gappy woody vegetation, 151 Forest path, 152 Glades, 221 Meadow vegetation, 222 Meadow vegetation with trees, 231 Unused permanent grasslands without tree vegetation, 241 Grass balk, 312 Small-area and narrow fields, 321 Orchards, 411 Bedrock baring, 421 Natural rock formations, 441 Tailings pile, 522 Other water bodies, 611 Individual housing, 631 House gardens, 651 Playgrounds, 671 Parks and residential vegetation with trees and shrubs, 681 Cottages and recreational areas, 691 Parking lots and other parking areas, 721 Farms, farmyards, 811 Main-national roads

Table 3. Overall landscape-ecological indexes for the study area in the years 2003 and 2011
3. Táblázat A vizsgált terület összesített tájmetriai mutatói 2003-ban és 2011-ben

Landscape-ecological indexes									
2003	PD (#/100 ha)	NP	MPS (ha)	Ai	MEDPS (ha)	TE (m)	ED (ha)	MSI	AWMSI
	0,27	202	3,65	4,07	0,15	129797,82	175,93	1,73	4,66
	MFRACT	AWMPFD	SDI	SEI	Richness	Dominance	DCA	TCA (ha)	CAI (%)
	1,48	1,38	0,88	0,27	25	2,34	33 patches of 202	624,9	84,7
2011	PD (#/100 ha)	NP	MPS (ha)	Ai	MEDPS (ha)	TE (m)	ED (ha)	MSI	AWMSI
	0,23	173	4,26	3,59	0,13	117212,93	158,88	1,76	4,85
	MFRACT	AWMPFD	SDI	SEI	Richness	Dominance	DCA	TCA (ha)	CAI (%)
	1,54	1,38	0,85	0,26	26	2,405	28 patches of 173	636,2	86,2

Discussion and conclusion

To assess the trend in the development of spatial landscape structure of the study area applying landscape-ecological indexes, we used three selected methods represented by specialized software. These extensions are compatible with the ArcGIS software and work with vector data. In the initial phase of the landscape research applying landscape-ecological indexes, we also considered to use the Fragstats software. However, it was replaced by the extensions of V-LATE and Patch Analyst which contain comparable amount of formulas for computing landscape-ecological indexes.

The first method for calculating landscape-ecological indexes uses the StraKa toolbox and deals with the indexes that are described in the work of FORMAN and GODRON (1986). From all of the indexes, we purposefully selected for our research the index for calculating the relative area of patches and accessibility index.

The second method represents the V-LATE extension and it was used to calculate the core areas indexes (number of core areas, total core area, core area index, disjunct core areas) and diversity indexes (Richness, Dominance). These indexes were characterized according to MCGARIGAL (2002), MCGARIGAL and MARKS (1995), and MCGARIGAL and CUSHMAN (2005).

The third method analyzed diversity, shape, size and length of patch edges in the landscape. We used the Patch Analyst extension and calculated results were assessed according to same authors as in the second method.

There are other software can be used to calculate landscape-ecological indexes such as LEAP II or LANDISVIEW, but these are not compatible with the ArcGIS/ArcView software and therefore they were not used for our research.

New extensions for GIS enable to perform the research in a better and easier way. In the paper, we introduced some of the GIS extensions that are used for the assessment and analysis of landscape structure and can replace the lengthy calculations.

Applying landscape-ecological indexes in the study area, we found out that the number of patches declined mainly because of the plant succession. The mean patch size has a growing trend due to the increase of areas of landscape elements which is related to the landscape elements with the decreased area. The patches have slightly elongated shape and geometrically complex shapes of patches dominate which is typical for natural landscape. Edge density of patches decreased which is caused by less fragmentation of areas of landscape elements as compared to the year 2003. In terms of diversity, the study area is heterogeneous. The distribution of patches is uniform and only few landscape elements with the same proportion of area can be found in the study area. The most stable are landscape elements in the group of residential elements and recreational areas, group of elements of watercourses and water bodies, group of transportation elements, and groups of bedrock and substrate elements because they have small size and their location in the landscape does not change.

Generally, we can point out that the development of the study area will be directed to natural landscape unless there will be another landslide movement that could significantly affect the landscape structure. Human impact will not be significant in the future since the study area is geologically instable. The construction of new residential blocks or other structures is not possible and agricultural production is limited. There are only small-area and narrow fields because the heavy machinery cannot be used and the land can be cultivated only outside the areas of remediation and stabilization works. The human impact would be probably seen mainly in the field of forestry (forest felling, planting new trees), recreation (gardening area in the western part of the landslide), and monitoring and regulating the area in terms of landslide activity.

Acknowledgments

The paper was prepared within the following projects: VEGA 1/0893/11 "Transformation of Nitra region in changes of socio-economical conditions and it´s regional development perspectives" and KEGA GP No. 023UKF-4/2011 "Terrain geoecological research as a base for creating of education equipment".

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TÉRINFORMATIKAI TECHNOLÓGIÁK ALKALMAZÁSA A TÁJSTRUKTÚRA ÉRTÉKELÉSÉRE TÁJMETRIAI MUTATÓK HASZNÁLATÁVAL (ESETTANULMÁNY: A NYITRABÁNYAI FÖLDCSUSZAMLÁS)

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Kulcsszavak: tájmetriai mutatók, tájstruktúra, V-LATE, StraKa, Patch Analyst, GIS, földcsuszamlás

Összefoglalás: A térinformatikai technológiák új verziói és a hozzájuk tartozó változatos kiegészítő csomagok lehetővé teszik, hogy minél pontosabb információkat kapjuk a tájról és annak jellemzőiről. Munkánk célja, hogy bemutassa három kiválasztott kiegészítő csomag használatát térinformatikai rendszerekben, amelyek a tájstruktúra értékelése során alkalmazott időigényes és összetett számításokat hatékonyabbá teszik. A digitalis vektoros térképek használatával, és a kiegészítő csomagok segítségével, lehetővé válik, számos más index mellett, a foltok számának, alakjának, méretének, diverzitásának, szomszédsági viszonyainak a kiszámítása. Ebben a cikkben három kiegészítő csomaggal (V-LATE, Patch Analyst, és StraKa) foglalkozunk, amelyek kompatibilisek az ArcGIS/ArcView szoftverekkel**.** Ezeket a speciális kiegészítéseket a térbeli tájstruktúra elemzésére használtuk a nyitrabányai földcsuszamlás területén, amelyet a tájstruktúra változása szempontjából is értékeltünk.