Tájökológiai Lapok 9 (2): 415–428. (2011)

USING SPATIAL METRICS FOR ASSESSMENT OF THE LANDSCAPE STRUCTURE CHANGES OF THE BEŠA DRY POLDER

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Keywords: landscape metrics, landscape structure changes, Beša dry polder, GIS, landscape index

Summary: Anthropogenic impacts imposed in study area of the Beša dry polder from 18th century have considerably stated the landscape. We can observe rapid landscape structure changes by progress of urbanization and agriculture in the researched area. Aim of the paper is mapping and analysis of the landscape structure changes in years 1770, 1827, 1949, 1988, 2003, 2008 by GIS. By comparing groups of the landscape elements, individual horizons were significantly different. Significant changes were observed in the group of Forest and non-forest areas and Grassland areas permanent group whose share fluctuates significantly. Drainage interventions after 1827 caused decline in the aquatic ecosystems to about 10% of their original size. Representation of other landscape elements reflects the natural evolution of society – the expansion of built areas and road networks. We used mapping results of the analysis for subsequent landscape assessment by methods of landscape-ecological indexes that describes the dynamics and quantifying landscape structure. The results showed that, overall, the number of patches, decreasing their average size, has increased patch density as well as the total length of the circuit patches, mainly as a result of vegetation succession after 1989.

Introduction

Landscape ecology deals with the biological, physical and societal causes and consequences of spatial variation in landscapes. New spatial tools such as geographic information systems (GIS) and remote sensing have given geographers and ecologists unprecedented capacity to quantify land cover pattern and understand spatial heterogeneity and landscape structure (TURNER, CARPENTER 1998).

Land cover and its interrelation to the natural landscape basis is the salient point for the integration of the material and physiognomic attributes of landscapes. Its spatial differentiation is close to the structure denoted by FORMAN, GODRON (1986) as landscape elements or ecosystems. Land cover types in regional scale are at the same time close to the basic categories of the land use. Visual attributes of urban and agricultural landscape correspond with their basic functions and indicate the spatial organization of cultural landscapes. Analysis of functions is, however, indispensable mainly in the categories of forest and semi-natural landscape emphasizing the hierarchy of ecologically significant areas.

Landscape pattern is a mixture of natural and human-managed patches that vary in size, shape and arrangement and is the result of complex interactions of physical, biological and social forces (FORMAN, GODRON 1986, KRÜMMEL ET AL. 1987, TURNER 1990). The pattern emerging from these analyses is that overall landscape texture and patch shape and size are recurring underlying structural components landscape pattern. LI, REYNOLDS (1995) indicate these five attributes that theoretically describe landscape structure: a) number of cover types, b) proportion of each type, c) spatial arrangement of patches, d) patch shape, e) contrast between patches.

Landscape is a concrete space which developed as a result of various effects and processes of natural or anthropogenic character while these processes and effects had different impact and duration of exposure. Human activities changed natural environment which got new features and new environment quality originated. According to specific properties, we distinguish three landscape structures: primary landscape structure, secondary landscape structure (historical and current landscape structure) and socio-economic landscape structure.

The aim of our research was to evaluate the trends in the spatial structure of patches in the model area since the second half 20th century. Analysis was made only on those land use layers which were interpreted on the basis of aerial photographs (1949, 1988, 2003, 2008), since the older interpretation of the obtained layers of historical maps lack detail. Military maps, compared to aerial photographs, have purposely compiled legend, they capture only selected elements of the landscape, are much generalized and not very detailed. Aerial photographs, however, capture the landscape with all its details and their interpretation was uniform.

In the analysis of landscape structure and its changes, we can also focus on the evaluation of the indicators of spatial structure of patches by Forman, Godron (1986), Forman (1995), McGarigal (2002), McGarigal, Marks (1995). Patches (polygons) can be characterized using various indicators or indices which are currently an explicit part of some GIS software tools. Unlike the summary changes of some elements of landscape structure (e.g. a change in the proportion of forest, grassland, arable, etc.), the changes in the number of landscape elements in different categories, their average size, distribution, continuity, mosaics etc. are being observed – these characteristics have a significant impact on the functioning of landscape processes (Lipský, Kalinová 2001, Szabó, Csorba 2009).

Study area

Study area belongs administratively to the Košice Region, Trebišov district and almost all of the area is located in the cadastral territory of the village Beša. The boundaries of the studied area are identical to the polder dike, only the northern part was set out by the cadastral boundary. Area covers 1756 ha, the flooded area of the polder is 1568 ha. Polder Beša is a dry reservoir belonging to the largest one in the Central Europe with volume 53 mil. m^3 and was built at the turn of the 1950s and 1960s in the frame comprehensive treatment of water regime of the Východoslovenská Lowland. The purpose is to reduce the flood wave of the rivers Laborec and Latorica. On the basis of a bilateral agreement between the Slovak Republic and Hungary, the level of the river Bodrog must be kept to a maximum of 936 cm. When this level is exceeded, it leads to filling of the dry reservoir. It has already been filled during the flood situation on the Laborec River eight times, mostly in the spring months in the years 1974, 1979, 1980, 1990, 2000, 2006, 2010, 2011. In terms of geomorphologic division (Mazúr, Lukniš 1980), it belongs to the Východoslovenská Lowland, subprovince Great Danube Basin, province Východopanónska Basin and subset Panonian Basin. Part of the territory falls to the Ramsar site of Latorica which is a part of the PLA (protected landscape area) of Latorica. In the retention area, there is locates of NATURA 2000 area of Bešiansky polder (2.65 ha) is located. In the dry polder area, there is a dense network of canals, wetlands and flooded material pits creating unique conditions for aquatic and marsh vegetation with a significant number of rare species.

Methods

Landscape structure data set

The production of maps of the landscape structure from the selected time horizons (1770, 1827, 1949, 1988, 2003 and 2008) was conducted in GIS. ArcView GIS 3.1 was used with extensions conducting the following operations:

- Making selective interpretative key, purpose-built mapping legend, working and output scale of maps,
- Georeferencing – geometric correction of "raw" historical maps and aerial photographs into a single cartographic projection of coordinate system S-JTSK,
- Identification of individual elements of secondary landscape structure based on the interpretation of historical maps from the 1st and 2nd military mapping (1770, 1827) and aerial color images (1949, 1988, 2003, 2008) which were arranged into subgroups and groups (Figure 1),
- Digitalization of spatial data by the method "on screen" (directly on the computer screen) with visual analogue interpretation – creating separate vector layers,
- Verification of the identified elements of the secondary structure of the landscape from the year 2008 in the study area by the means of field survey,
- Creating the flexible table database that stores all the relevant attribute information on the elements of the secondary landscape structure necessary for other statistical operations,
- Multitemporal analysis of the groups of secondary landscape elements during 1770–2008,
- Cartographic representation of information layers in an analogue form of output - thematic maps of the secondary landscape structure.

We identified 49 types of landscape elements according to Ružička (2000), which we classified into 31 sub-groups and 8 groups:

1. Group of elements of forest and non-forest wood vegetation
2. Group of elements of permanent grassland
3. Group of elements of agricultural crops
4. Group of subsoil elements and the substrate
5. Group of elements of water bodies and water flows
6. Group of residential elements and recreational areas
7. Group of technical elements
8. Group of transport elements

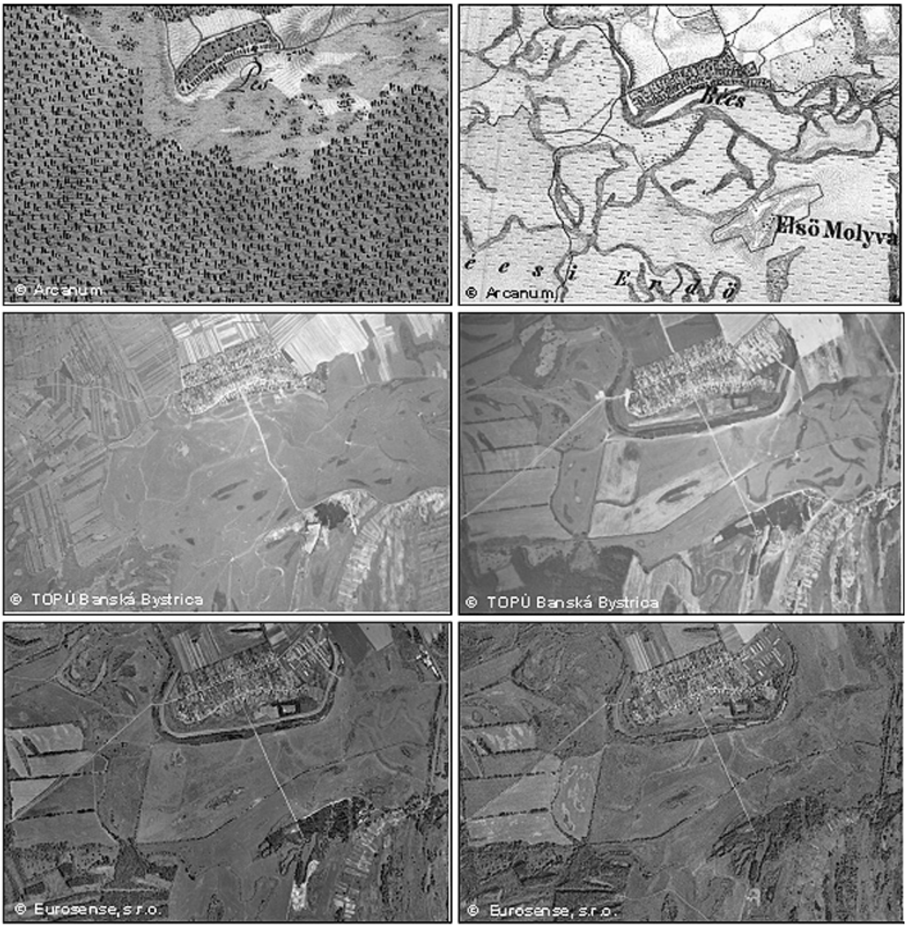

Figure 1. Parts of the used historical maps from the 1st and 2nd military mapping from 1770 and 1827, panchromatic aerial photographs dating from 1949 and 1988, color aerial orthophotos from 2003 and 2008

Landscape pattern metrics

Trends of development of the spatial structure of patches was evaluated according to selected indicators by Forman, Godron (1986), Forman (1995) and using specialized statistical program Patch Analyst 2.2 (McGarigal, Marks 1995). Analysis was made on the vectors GIS layers of the time horizons while we examined the following landscape metrics: number of patches (NP), mean patch size (MPS), median patch size (MEDPS), patch size standard deviation (PSSD), total edge (TE), edge density (ED), mean patch edge (MPE), mean shape index (MSI), mean patch fractal dimension (MPFD), area weighted mean patch fractal dimension (AWMPFD), patch density (PD). Most of the characteristics were observed both in the whole area and within the individual groups of landscape elements. Their detailed characteristics are the content of the works of the mentioned authors.

Results

In the process of multitemporal analysis (visual and the subsequent statistical analysis of thematic maps) and field survey of study area during 1770–2008 (tables 1, 2, Figure 2, 3), we came to a finding that the area was affected by a number of quite significant space-time changes which at the level of groups of landscape elements are analyzed briefly in the following parts of the paper.

Table 1. Area of individual groups of landscape elements in ha

Reclassified groups of landscape elements	*1770*	*1860*	*1949*	*1988*	*2003*	*2008*
Forest and no forest areas	1387,1	3,4	211,1	544,0	559,2	743,6
Permanent grassland areas	180,1	1107,0	1086,8	823,2	820,5	641,3
Agricultural areas	161,3	379,9	343,6	299,0	286,2	284,3
Uncovered substrate areas	-	-	5,5	3,5	3,5	3,5
Water and wetland areas	-	236,5	62,3	26,6	25,9	22,6
Urban areas	17,9	20,2	32,8	35,3	35,3	35,3
Technical areas	-	-	0,1	10,1	10,5	10,5
Transport areas	9,7	9,1	14,0	14,3	15,0	15,0

Table 2. Number of patches of individual groups of landscape elements

Reclassified groups of landscape elements	*1770*	*1860*	*1949*	*1988*	*2003*	*2008*
Forest and no forest areas	32	8	53	216	277	313
Permanent grassland areas	7	117	93	187	219	190
Agricultural areas	13	32	29	27	36	34
Uncovered substrate areas	-	1	3	13	13	13
Water and wetland areas	-	56	59	75	75	74
Urban areas	4	16	53	79	79	79
Technical areas	-	-	2	9	9	9
Transport areas	2	5	23	17	16	16
Sum	58	235	315	627	725	727

Group of elements of forest and non-forest woody vegetation**,** in terms of area of individual groups of landscape elements, exceeded the largest ratio within the observed period in 1770. The wet floodplain forest covered almost 90% of the whole territory, except for the village itself and its closer area which was agriculturally used mainly to the east of the urban area. In contrast, in 1827 the territory was covered with almost no forest, there were only small woods in southeastern part of the area. The area suffered significant deforestation for the purpose of acquiring land for pastures, meadows and arable land. Forested areas started to increase only after 1949. Smaller areas of woods in the mid-20th century were located in the western part of the current polder and also in the southern part and in the Moľva area (sand dune) in the SE part of the territory. Since the end of the century to the present, the share of this group of landscape structure increased from 31 to 43% due to succession processes. Forests are represented, regarding the composition, mainly by oak-hornbeam forests, near rivers are riparian willow-poplar forests. Large area in the southwestern part of the reservoir is currently covered by commercial forests with areas compartment and belt breaks. Non-forest woody vegetation outside the urban area is represented by the natural residual stands which for various reasons have not been degraded by agricultural activity.

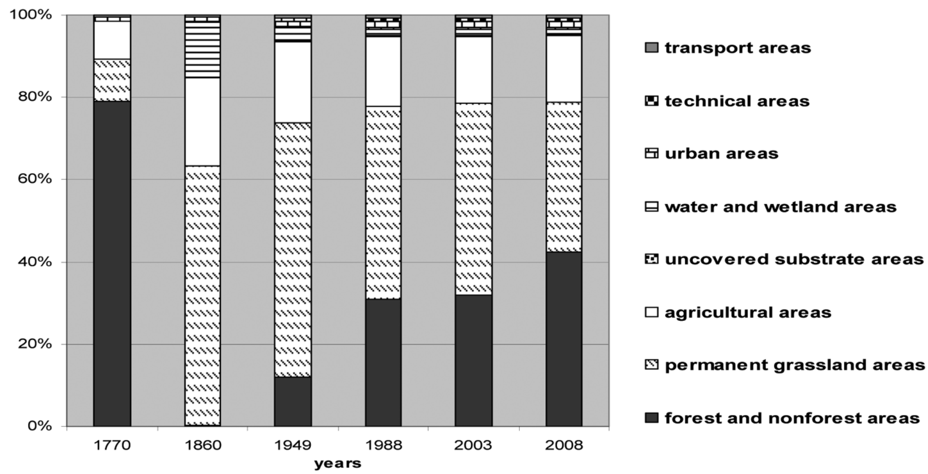

Figure 2. The share of size of groups of individual elements of the secondary landscape structure of study area in %

A group element of permanent grassland in terms of size was the largest group in the period 1827–1949. It occupied an area of almost 1300 ha which is over 70% of the whole area. The smallest share was in 1770 when almost the whole area was forested and there were no significant agricultural activities in the study area. Since 1988, the elements of this group have almost constant share, which is around 45%. Currently, their share realizes a slight 34%. This group is represented mainly by meadow vegetation towards S, SW and W from the village of Beša in the polder retention reservoir itself, but mainly by unused grasslands that since 1949, but especially since 2003 are largely overgrown by plants or seedings that are characterized by scattered groups of shrubs and scrub communities, as well as solitaire, mostly willows. These occasionally flooded meadows serve as pasture. Line herbaceous vegetation covers with its crops also the dike of the polder itself.

Group of elements of agricultural crops has got a relatively equal representation across all horizons between 15–20%, except for 1770, when its proportion was the lowest. Arable land carries, until the collectivization period in the 1960s, the character of small-scale fields, later large-block fields. The arable land was always located to the north of the urban area of the community, outside the wet areas and the polder retention reservoir. It is now represented by homogeneous areas of large-block fields. Among other landscape elements, we can find small-scale fields in a smaller extent, especially near the village. Along with the vineyards and orchards they form mosaics of patches, especially in the

SE part of the area. Some of them have already been abandoned. This group of elements currently occupies 284,3 hectares which refers to 17% of the area.

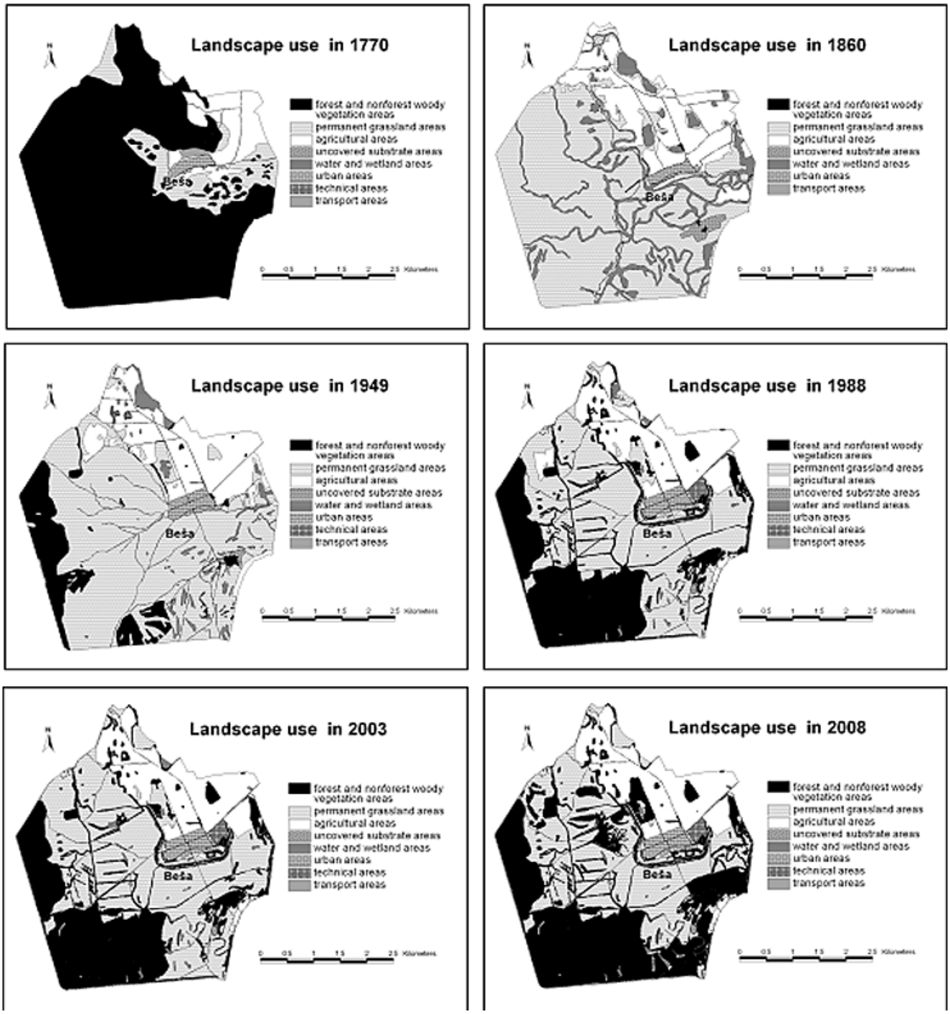

Figure 3. Landscape structure area of Beša polder in selected times horizons

Group of subsoil elements and the substrate are mostly only small-scale sites of natural or artificial origin, in our case mainly the sand dune Mol'va, located in the eastern part of the area. South to the village, there is a small sandpit mined occassionally even today. Together, this group covers an area of 3,5 hectares which is 0,2% of the whole area.

Group of elements of water surfaces reached the highest area in the year 1827 (4%). As in the past, it is now also represented by a network of periodic lakes and of dead branches as well as other smaller streams and channels, but to a smaller extent than in the 19th century.

Group of residential elements and recreational areas is the village of Beša with characteristic rural buildings, represented mainly by family houses and gardens. The urban area has had expansionary trend since 1770 and during almost 170 years has tripled its size. Later there were built mainly administrative buildings, sports grounds, cemeteries and other civic amenities along with residential vegetation. At present, these elements occupy 2% of the area.

Group of technical elements in the area has evidenced especially from the mid-20th century and it includes agricultural buildings (farms and farmyards), areas of water management as well as other construction and technical objects in the countryside. It also includes smaller landfills located within the boundaries of the village and also outside it, and also field dunghills. Together these elements occupy 2% of the area.

Group of transport elements was in the past represented mainly by loose network of mostly unpaved field roads. At present, its density is much higher and it is represented by roads – important main roads, roads in residential zone, and paved and unpaved communications. In 2008 they occupied an area of 15 ha which represents 1% of the study area.

Changes of landscape metrics

The number of patches in the area of the Beša polder reached 315 in 1949 (Table 4) and by 2008 rose to a value of 727 which is a 100% increase. This phenomenon was mainly due to increase in number or emergence of new areas of forest and non-forest woody vegetation, influence of its succession in recent decades as well as planting trees for economic purposes in the southern part of the territory. This phenomenon is also evident in the visual comparison of aerial photographs. Overall, the area of mean patch size was reduced (Table 4) by almost half. Table 3 with the changes in mean patch size for each group allows a detailed study of the trend of this feature. Reduction in the mean patch size was recorded for all areas with the exception of technical elements and elements of transport which increased their size in the younger time horizons. Overall, however, it is conditioned by the emergence of new small succession patches of forest and non-forest vegetation and subsequent gradual reduction or fragmentation of the original vast area of permanent grassland since 1949 which is a positive phenomenon for the stability of landscape structure. The median patch size has got a more representative value. This landscape metrics is generally slightly decreasing in the area (Table 4). Conversely, within the majority of each group of elements (Table 3), we can notice its increase. The most significant is in the group of forest and non-forest woody vegetation at the expense of median patch size decrease of the group of permanent grassland. Calculated values of the index of standard deviation of patch size document the fact that there is an overall tendency of equalization of patch size in the study area. The same situation is also in various types of patch groups. The cause can be seen in the above mentioned succession as the number of new patches is increasing. The patches have a tendency to compensate their size, the number of different-sized patches is decreasing. When analyzing the perimeter of patches, we notice a very slow trend of its slight increase which is mainly due to an overall increase of new patches. This situation is different in each group. When assessing the edge density of patches which represents the proportion of perimeter of patches to their size, we have come to a finding that its value throughout the whole area hardly changed. Differences, however, are evident when analyzing patches of individual classes.

Table 3. Landscape metrics of different period at groups of landscape elements

Years	*Groups of landscape elements*	*NP*	*MPS*	*MEDPS*	*PSSD*	*TE*	*ED*	*MPE*	*MSI*
1949	1	53	39822,9	4758,3	108314	44366,9	0,003	837,1	2,1
	2	93	116858	12520,7	333468	170607	0,01	1834,5	2
	3	29	118478	42721,9	153027	49314,6	0,003	1700,5	1,7
	4	3	18486,8	10492,5	12510,7	2505,2	0,001	835,1	1,7
	5	59	10552,7	4319,4	25203	31873,4	0,002	540,2	1,7
	6	53	6179,9	563,3	18899,3	19033,8	0,001	359,1	1,5
	7	2	315,7	171,6	144,1	171,6	0,001	85,8	1,4
	8	23	6098,6	2263,4	9907,7	87964,9	0,005	3824,6	10,6
1988	1	215	25288,3	4940,4	104831	188223	0,011	875,5	2,5
	2	193	42671,5	8830,4	91208,2	263878	0,015	1367,2	2,3
	3	28	106796	13457,8	183882	40683,7	0,002	1453	1,6
	4	13	2663,8	438,4	6447,7	3294	0,001	253,4	1,6
	5	74	3595	2362,1	4265,6	47457,6	0,003	641,3	3,3
	6	79	4473,7	768,7	11953,1	22653,1	0,001	286,7	1,5
	7	9	11228,3	188,7	30762,8	2347,9	0,001	260,9	1,6
	8	16	8919,5	1899,2	15827,9	86093,4	0,005	5380,8	11,5
2003	1	276	20259,2	6410,9	71307,8	253435	0,014	918,2	2,4
	2	223	36795,9	7702,4	87771,3	288355	0,016	1293,1	2,3
	3	36	79493,8	18458	123896	45869,8	0,003	1274,2	1,6
	4	13	2663,8	438,4	6447,7	3294	0,001	253,4	1,6
	5	74	3506,3	2397,4	3727,1	47317,8	0,003	639,4	3,4
	6	79	4473,7	768,7	11953,1	22653,1	0,001	286,7	1,5
	7	9	11626,6	198,4	30640,2	2561,6	0,001	284,6	1,6
	8	15	9983,9	2291,6	17019,8	90752,6	0,005	6050,2	12,4
2008	1	313	23757,8	7071,4	72947,6	312357	0,018	997,9	2,4
	2	191	33578	6268,9	80581,3	233785	0,013	1224	2,3
	3	34	83603,6	20390,7	126286	44845,1	0,003	1319	1,6
	4	13	2663,8	438,4	6447,7	3294	0,001	253,4	1,6
	5	73	3098,1	2397,4	2537,7	45936,4	0,003	629,3	3,4
	6	79	4473,7	768,7	11953,1	22653,1	0,001	286,7	1,5
	7	9	11626,6	198,4	30640,2	2561,6	0,001	284,6	1,6
	8	15	9983,9	2291,6	17019,8	90752,6	0,005	6050,2	12,4

Note: 1 - Forest and non-forest areas, 2 - Permanent grassland areas, 3 - Agricultural areas, 4 - Uncovered substrate areas, 5 - Water and wetland areas, 6 - Urban areas, 7 - Technical areas, 8 - Transport areas

Table 4. Landscape structure changes indices for Beša polder (1949 -2008)

	NP	MPS	MEDPS	PSSD	TE	ED	MPE	MSI	PD
1949	315	55748,3	5424,1	199159,2	405837,5	0,023	1288,4	2,4	0,17
1988	627	28007,5	4195,6	91611,5	654630,3	0,037	1044,1	2,6	0,35
2003	725	24221,7	4694,5	73552,7	754239,3	0,043	1040,3	2,5	0,41
2008	727	24155,1	4759,8	71182,9	756183,9	0,044	1040,1	2,5	0,41

The edge density of patches in the group of forest and non-forest vegetation per unit area (ha) increased significantly due to its gradual expansion to different directions while the edges of areas have gradually become more complex. Similar development of edge density of patches is also evident for other groups of elements. In the study area for the last 20 years, the mean length of patches stabilized. The cause can be seen in a significant increase in the number of new small patches (forest and non-forest woody vegetation) and the disappearance of larger patches from the area (permanent grassland). Index of mean patch shape, which is characterized by complexity or regularity of their shapes, shows that all patches have an irregular shape while for the last 60 years this shape is maintained or is not changing. The same situation is in patches within individual groups of landscape elements. Since the area did not recorded new "foreign" types of patches with geometrically completely different shapes which would significantly undermine the finality, the same trend can be expected in the next years. The last landscape metrics that we evaluated was the number of mosaics (density) of patches. It refers to the horizontal division of the landscape and it is therefore an important structural characteristic. In the study area, the mosaics increased mainly due to vegetation succession, thus creating several new areas (patches) and also several large patches broke into smaller ones. We can say that in the past 60 years, the total fragmentation of the landscape has increased.

Discussion

Landscape pattern is constantly influenced by many factors and events that reflect to natural conditions and the degree of human impact. Spatial structure of the landscape (shape, distribution) provides specific characteristics by which we can characterize that part of the landscape. If we want to assess the structure of the landscape using the pattern as indicator, we must choose the relevant parameters of pattern.

The driving force of landscape changes are disturbance processes of more or less extent. Slight distortion causes the creation of several smaller patches and corridors which ultimately increase the heterogeneity of the landscape. Result of disturbances of significant size may be the dissolution of several landscape patterns and corridors and ultimately the absolute transformation of the landscape matrix.

The term structure refers to "the spatial distribution of energy, material and species in relation to the sizes, shapes, numbers, kinds and configuration of the ecosystems" (Forman, Godron 1986). Landscape pattern respective structure is a complex product of many underlying processes. Structure defines a spatial framework for process manifestation and puts certain constraints on them. Landscape pattern and landscape process have a mutual impact (Bartel 2000).

It is necessary for good understanding of the ecological consequences of changes in landscape pattern to describe the pattern with suitable indexes. However not all indexes are suitable (Hulshoff 1995). Sometimes the indices do not give enough information on changes in the geographical position of the patches and several indices have to be considered in combination with other indices to get meaningful information.

Knowing the development of land use changes is necessary for the purpose of planning nature and landscape conservation to identify areas of their conflicts with economic use. Human factors (economic, social and political) have played the main role in the continuing development of the landscape structure (Black et al. 1998, Nikodemus et al. 2005, Špulerová 2008, Muchová, Petrovič 2010). Area of the dry polder Beša is a landscape space consisting of different ecosystems (forests, natural meadows and grasslands, aquatic ecosystems, and agro-ecosystems). These ecosystems are characterized by high degree of biodiversity. Ecological stability of the landscape is hampered by human activity including artificial flooding of the polder at the time of extreme floods in the region of Východoslovenská Lowland. Other factors that negatively affect the ecological stability of the area are on one side intensive agricultural production (Michaeli, Hofierka, Ivanová 2010). On the other side, it is abandonment of agricultural land after 1989 which is reflected in landscape structure changes. We recorded a gradual overgrowing of meadows and grasslands by succession with tree species. These trends are typical especially for the former socialist countries of Central and Eastern Europe. Significant changes in landscape structure over the past 60 years, as a result of intensification of agriculture, can be seen also in other European countries. Many pastures and small fields, with many small biotopes of both linear and point elements have been aggregated into large fields without small biotopes (Ihse 1995, Palang, Mander, Luud 1998, Malatinszky 2008, Penksza, Malatinszky 2004, Oroszi, Kiss 2006, Gerard et al. 2010).

Analysis of the development of landscape structure can obtain statistical data about land cover which provide information about landscape macrostructure, but do not provide the correct idea about the current territorial composition of landscape elements. The intensity of anthropogenic pressure on the landscape mosaics has a significant impact on the landscape stability and biotic communities (Lipský 1995, Miller, Brooks, Croonquist 1997, Zagyvai 2008). We can conclude that landscape structure, expressed in land use and land cover, spatial arrangement, shape, size, quality and connectivity of patches, lines and small interactive elements, plays the main role in landscape dynamics.

Landscape changes accordingly in a somewhat different way, while at certain times man tries to steer and redirect the evolution by planned actions. Studying and monitoring all the interfering changes that occur in the landscape is impossible. Also the changes of one component seldom reflect the overall change of the landscape (Antrop 1998). The main task of the polder is to catch the floodwater in flood emergency situations while the magnitude and frequency can not be estimated. Development of landscape structure and land use is somewhat limited by the given facts. For such specific areas is therefore necessary to develop the management actions.

Conclusions

Satellite imagery and GIS provided the information base, environment and analytical tools to visualize and quantify landscape structural changes simply and quickly (APAN, RAINE, PATERSON 2002). Observing the landscape structure is a suitable tool to obtain detailed analytical perspective to a specific territory with an emphasis on maintaining the stability of an ecologically sensitive area. The obtained data on changes of landscape structure can serve as a basis for land-planning documentation as a part of the landscape-ecological planning. They provide also basis for the evaluation of other landscape features (e.g. biotic significance territory, landscape heterogeneity).

Landscape ecological indices also showed that they are appropriate tools for assessing the trend of development of patch properties and prediction of their further development. Overall, the number of patches increases, their mean size decreases, mosaics of landscape increases as well as the total length of the patch perimeter which is mainly the result of vegetation succession. Other structural parameters of patches have not significantly changed over the last 60 years.

Based on the before mentioned facts as well as gained results, we do not understand the research of landscape changes of Beša polder only in the context of the analysis of its condition and structure (statistical-spatial analysis), but also as the study of its development evaluated through the properties of patches of individual groups of elements and their spatial distribution in different time horizons.

To ensure stability and reduce vulnerability of the landscape, management measures must be adopted, but first of all implemented. These measures should be focused on removing ruderal shrubs and trees and on regular mowing of meadows (eventually grazing). In case of more frequent flooding of the polder, there is a risk of spreading of invasive plants species and allochthonous shrubs and trees there.

Acknowledgements

The contribution was prepared within the grant project of the Ministry of Education of the Slovak Republic and the Slovak Academy of Sciences No. 2/0051/11 "Significance and ecosystem services of historical structures of agricultural landscapes" and KEGA GP No. 023UKF-4/2011 „Terrain geoecological research as a base for creating of education equipment."

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TÁJMETRIA ALKALMAZÁSA AZ EGYKORI BEŠA ÁRTÉR TÁJSZERKEZET-VÁLTOZÁSÁNAK ÉRTÉKELÉSÉRE

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Kulcsszavak: tájmetria, felszínborítás változása, Beša ártér, GIS, tájindex

Összefoglalás: A vizsgált területen, a Beša egykori árterületén a 18. század óta jelen lévő antropogén hatások jelentősen meghatározzák a tájat. Gyors tájszerkezeti változásokat tapasztalhatunk az urbanizáció és a mezőgazdaság kiteljesedésével. Cikkünk célja a tájszerkezet GIS-központú térképezése és vizsgálata a következő évek nyomán: 1770, 1827, 1949, 1988, 2003, 2008. A tájváltozó-csoportok egyéni szintű összehasonlításával jelentős különbségeket tapasztaltunk. Jelentős változásokat mutattunk ki az Erdei és nem erdősült területek, illetve a Gyepterületek csoportokban, amelyek részaránya jelentősen fluktuál. Az 1827 utáni vízelvezetések hatására a vizes élőhelyek eredeti kiterjedésük kb. 10%-ára csökkentek. A többi tájváltozó vizsgálata a társadalom természetes fejlődését: a beépített terület és az úthálózat növekedését tükrözi. A terepi térképezés eredményeinek elemzése során a tájdinamikát és a tájszerkezet mennyiségi elemzését vizsgáló indexet használtunk. Eredményeink alapján összességében elmondható, hogy a növekvő foltszám, miközben az átlagos foltméret csökkent, növelte a foltdiverzitást és a teljes foltkerületet, amelynek fő oka az 1989 óta eltelt időszak természetes szukcessziós folyamata volt.