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CHANGES IN THE SECONDARY LANDSCAPE STRUCTURE AND THEIR CONNECTION WITH ECOLOGICAL STABILITY: THE CASES OF TWO MODEL AREAS IN THE CZECH REPUBLIC

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Abstract

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This paper characterizes changes in the secondary landscape structure over the past 170 years in two model areas in the Czech Republic, and investigates the following question "Is there is a connection between these changes and the ecological stability of identified biotopes?"
Analyses show that there are no areas within the Dunajovické kopce hills model area that can be characterized simultaneously by high ecological stability and stability of land use and land cover. On the other hand, areas of high or very high ecological stability exist in the alluvial plain model area without concurrent change in land use or land cover. These regions comprise almost one-quarter of the entire studied area.
In the Dunajovické kopce hills, 6.8% of the area was stable from the land use/land cover viewpoint during the considered period. In the alluvial plain area, meanwhile, this figure was approximately eight times greater, at 58.7%. This difference was mainly due to variations in landscape character and land use. The Dunajovické kopce hills present a landscape intensively used for agriculture, and in particular vineyards, while the alluvial plain is an example of one of the best preserved forest areas in the Czech Republic.

Key words: land use, secondary landscape structure, historical landscape structure, ecological stability, biotope, landscape element

Introduction

Secondary landscape structure is shaped by long-term human activities superimposed on the primary landscape structure formed by natural processes (Miklós, 1989). These human activities are socio-economic, political, religious and artistic influences and nature conservation, and thus the greatest changes mainly affect the landscape's secondary structure by changing both its appearance and functionality.

Pucherová (2007) advised that we can distinguish both historical and current landscape structures within this secondary landscape structure. Each of these represents a certain specific ordering of landscape elements over various time horizons. Moreover, each time period is reflected in certain specific attributes forming the overall landscape features. Although many of these shapes and attributes are maintained in the landscape despite cultivation and landscape management changes, the majority of them disappear over time, and the legacy of the past can become less obvious or even completely lost. According to Jančura (1998), historical landscape structures create the essential features of every landscape. These can manifest themselves as obvious dominants and dictate the entire landscape character or exist only in a hidden form, and thus be discrete objects of the secondary or current landscape structure. In recent decades, attention has been given to understanding the historical development of the cultural landscape with many authors studying changes in landscape form and use, its cover and also its structure over longer time periods (Wrbka et al., 2004; Bender et al., 2005; Haase et al., 2007; Hamre et al., 2007).

Based on the knowledge of a landscape structure's historical development, it is possible to evaluate the current landscape structure and its ecological stability (Stránská, Havlíček, 2008; Špulerová, 2008), plus the impacts of changes in landscape structure on biodiversity on local, regional and national scales (Olsson et al., 2000; Haines-Young et al., 2003; Wozniak et al., 2009).

Natural habitats play an important part in ecological stability and biodiversity. The EU devotes great attention to conserving natural habitats and based on the Habitats Directive 92/43/EEC (European Commission, 1992), the network of protected areas known as Natura 2000 was created according to a system of natural habitats. In order to specify the localities of this network in the Czech Republic, a methodology of biotope mapping (Guth, 2002) and a catalogue of biotopes (Chytrý et al., 2001) were created based on the aforementioned Habitats Directive.

As a part of the Transnational Ecological Networks in Central Europe project, field mapping of the secondary landscape structure within the territory of the Czech Republic as well as analysis of spatial changes in land use/land cover occurring since the mid-19th century were carried out based on old maps in several model areas partly or entirely covering the Natura 2000 localities. By analysing the interconnection between historical development and detailed mapping of the current landscape structure, it is possible to determine whether there is ecological stability in a given area, and also to examine what impact development of this landscape structure would have on that stability.

Based on examples of two chosen model areas, this article aims to demonstrate how the secondary landscape structure has changed over the past 170 years and to answer the question whether the areas of present high ecological stability are correlated with the land use/land cover changes which have occurred during the past 170 years.

Material and methods

Research into changes in secondary landscape structure was carried out at three levels. The first level is represented by **groups of landscape elements** and it includes arable land, permanent grassland, orchards, vineyards and hop-fields, forest, water areas and built-up, recreational and other areas. They are unambiguously identified based on maps described in detail in Table 1. This level gives only a rough definition of land use/land cover categories. Therefore, the second level of more homogenous landscape elements was distinguished during field mapping of current secondary landscape structures.. These are **subgroups of landscape elements** which are possible to distinguish in some map sources, with the most detailed unit of **landscape elements** differentiated only in orthophotos and specified by field surveys. While groups and subgroups of landscape elements explain land use, landscape elements themselves actually describe the quality or ecological stability of an area. Individual categories of land use/land cover and above all their further classification, are based on methods tested both in Slovakia (Ružička, Miklós, 1982; Petrovič, 2005; Pucherová, 2007) and in the Czech Republic (Pellantová et al., 1994; Vondrušková, 1994; Mackovčin, 2009).

Reconstructed maps of land use/land cover utilization were created from six time horizons, representing the mid-19th century, the end of the 19th century, 1930s, 1960s, 1990s and beginning of the 21st century (2005). These depict groups of landscape elements and in some cases also their subgroups,. The maps for the present day (2009) were created on the basis of field mapping and these represent the seventh time horizon.

The map sources consisted of topographic maps. The analogue form used in the first four sources was scanned and geo-referenced either by the MATCART software program (Brůna et al., 2002; Čada, 2006) or with the help of control points in the programme ArcGIS 9.2 and 9.3 while using the method of backward interpretation. When using this method, the default map is represented by the current map, and it serves as the most accurate and highest-quality piece of work. It is upon this map that vectorization of the map from the previous time period is based, wherein the borders of delimited areas change only where there is real change in comparison to the default map. This vectorized map then serves as the basis for vectorization of the still older map, and so on (Skokanová, 2008).

In addition to this spatial identification, the quantification of individual landscape elements and changes in land use/land cover occurring during historical development was established using GIS tools. These changes are determined through the overlap of reconstruction maps, where the resulting map layer illustrates how many times the land use/land cover has changed. Values between 0 (for no change) and 6 (for the maximum number of changes) are assigned to the number of changes.

Sliver polygons of elongated shapes with very small or zero areas can occur when maps are overlapped. These are most likely caused by errors in map processing due to ageing of the map source or during geo-referencing, rather than depicting real changes in land use/land cover. Although these polygons can be largely eliminated through the method of backward vectorization, they can still occur. Therefore, certain modifications were carried out during which polygons of area smaller than 50 m^2 were removed, together with all polygons less than 1.5 m in width. These criteria were established based on testing carried out at the authors' workplace.

Changes in landscape structure were also assessed by means of selected indicators observed for individual groups of landscape elements. These indicators were calculated using the Patch Analyst for ArcGIS, version 4 software programme and established as follows: the number of patches, the mean patch size, area weighted mean

T a b l e 1. Map sources and their characteristics.

Period	Name	Date of creation	Scale	Positional error
1830s	2nd Austrian military survey	1822, 1841	1:28 800	11–30 m
1880s	3rd Austrian military survey	1875, 1876	1:25 000	13–30 m
1930s	Revised maps of the 3rd Austrian military survey	1932, 1944	1:25 000	10–15 m
1950s	Czechoslovak military topographic maps	1959, 1960	1:10 000	10–15 m
1990s	Czechoslovak topographic base maps (ZABAGED 2)	1993, 1994	1:10 000	5–10 m
2000s	Czech topographic base maps (ZABAGED)	2004, 2005	1:10 000	5–10 m

patch fractal dimension and mean shape index. Shannon's diversity and evenness indices were used to establish landscape diversity. Formulas for calculating indices are stated, for example in McGarigal and Marks (1995) and Steinhardt et al. (1999).

Field mapping was based on available map resources. Orthophotos from 2009 were used as the main map source together with the digitalized layer of biotope mapping in the Czech Republic which was created to establish the network of Europe's significant protected areas under Natura 2000. These resources were supplied by the Agency for Nature Conservation and Landscape Protection of the Czech Republic. This data was revised in the field and corrected according to the current situation, and the borders of individual landscape elements were delimited and marked.

When delimiting the borders of landscape elements, their ecological stability was defined as "the ability of an ecological system to sustain itself despite the influence of disturbing element and to reproduce its substantial characteristics in conditions of external disturbance" (Míchal, 1994, p. 179). This was taken into account together with the structure and species composition of the community. The classification of ecological stability levels was based on the conception of Míchal (1994). Each element was given significance for ecological stability with a value from 0 to 5 based on selected criteria, including species composition, nativity of the species according to biotopes, extent of the patch and the type of cultivation. Level 0 is allotted to landscape elements which lack importance for ecological stability. These include the majority of anthropogenic elements such as waste dumps and active quarries, as well as the built-up areas. Level 1 covers landscape elements with little importance for ecological stability, including large vineyards, agricultural land and artificial water areas. Level 2 also comprises landscape elements, which are relatively unimportant in ecological stability. These consist of small vineyards and cultural meadows and pastures. Landscape elements with medium-level importance in ecological stability include the regulated streams, forest plantations, semi-cultural meadows and pastures. The final two levels possess varying degrees of importance from an ecological stability viewpoint. Firstly, there are natural meadows and pastures, near-natural water streams and semi-natural forest landscape elements which are very important for ecological stability, and secondly there are the natural rock communities, natural water bodies and natural forest landscape elements which have exceptional importance in ecological stability.

Ecological stability as defined by Míchal (1994) can be compared to the hemeroby in Naveh and Liebermann (1984). Additionally, Rennetzeder et al. (2010) consider hemeroby to be fundamental to their studies, and they assess the relationship between hemeroby and landscape structure at national and international levels, but only for one segment of time. The principles of hemeroby for multiple time segments, however, have been applied by Fu et al. (2006) and Steinhardt et al. (1999), amongst others.

A map depicting current secondary landscape structure was created based on field mapping. This was then compared to reconstruction maps which showed the historical development of land use/land cover, and the most stable landscape segments were then delimited by analyzing the spatial changes in land use/land cover, thus demonstrating the relative stability in land use development. These were compared with areas showing medium to high ecological stability values. This comparison enabled the establishment of their mutual relationship. Areas used in a stable way and showing medium to higher levels of ecological stability should form the skeleton of ecological stability for a given area.

Characteristics of the Dunajovické kopce hills and alluvial plain model areas

The **Dunajovické kopce hills** model area comprises 444.3 ha in a fertile, intensively cultivated landscape. It is situated in the southern part of the South Moravian Region of the Czech Republic, among the municipalities of Březí, Dolní Dunajovice and Brod nad Dyjí, and its area includes the Dunajovické kopce hills National Nature Monument (NNM – Fig. 1). It consists of a relatively narrow belt of hills with elevation from 190 m to 286 m a.s.l. spreading in a north-south direction and separated by deep valleys. Its distinctive elongated ridge is composed of Lower Badenian gravels and conglomerates and its depressions are filled with Lower Badenian calcareous clays and sands. Dry valleys are formed by deluvio-fluvial sand loam sediments, and deep Chernozem soils, alternating with para-rendzina Cambisols in the carbonate sediments developed there (Mackovčin et al., 2007). From a climatic viewpoint, this area is warm and dry with an average annual temperature of 9.7 °C and mean annual precipitation of 484 mm. Vegetation on the plateaus and gentle slopes is formed by a mosaic of broadleaved dry grasslands, Pannonian loess steppe grasslands, dry herbaceous edges, low xerophillous grassland and also tall mesophillous

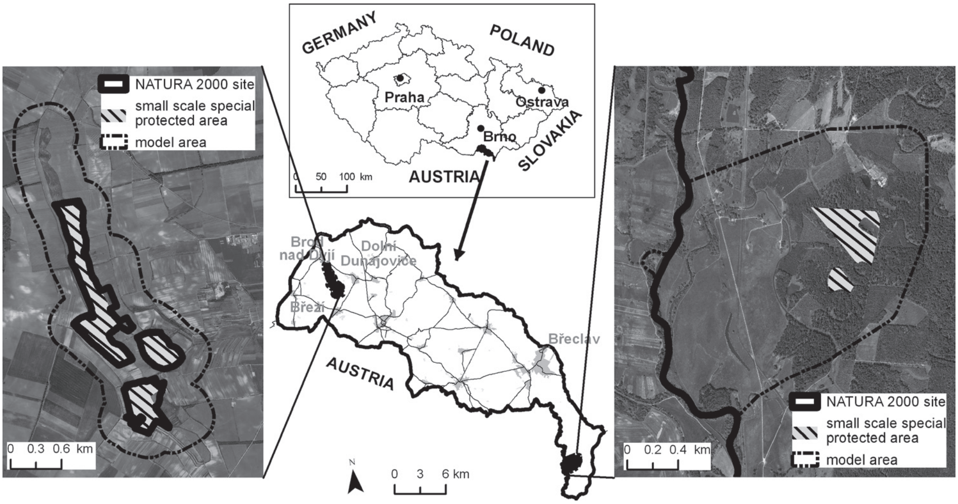

Fig. 1. Delimitation of Dunajovické kopce hills (left) and alluvial plain (right) model areas.

and xerophillous shrubs sheltering numerous specially protected wildlife species. It is possible here, for example, to find the largest Central European population of *Crambe tataria*, several species of *Stipa (Stipa pulcherrima),* and many other steppe plant species. Communities of low xerophillous shrubs are also rich in the critically endangered *Amygdalus nana* species. The adjacent foothills are covered with vineyards and extensive agrarian terraces typical for this area. The surrounding landscape is covered with broad areas of vineyards and fields. The area of Dunajovické kopce hills is one of the most unique areas in the Pannonian part of South Moravia, and this is so widely acknowledged that its middle part was declared a National Nature Monument (NNM) in 1990. Additionally, it has also been classified under the European network of Natura 2000.

The model area of approximately 348 ha **alluvial plain** lies in the alluvia of the Dyje and Morava rivers in the southern part of the South Moravian Region of the Czech Republic (Fig. 1). This locality presents a unique complex of various kinds of forest and non-forest vegetation in an alluvial landscape, which is acknowledged both within the Czech Republic and throughout Central Europe. The current form of these ecosystems characterized by extraordinary species diversity was established due to the influence of natural, and especially fluvial processes, and the long-term human economic activity in this area.

The altitude throughout this study area varies by approximately 150 m. Tertiary sediments of the Vienna basin in the substrate of the alluvial plain are superimposed with fluvial gravel-sands and sandy flood loams, while the oxbow lakes are filled with sapropel organic sediments. The soil cover is represented by gley- and typical Fluvisols (Mackovčin et al., 2007). The continental climate with average annual precipitation of 501 mm and average annual temperature of 10 °C is similar to that of the Dunajovické kopce hills. The dominant types of landscape structure here are extensive areas of hardwood alluvial floodplain forest, fragmentally complemented with softwood alluvial floodplain forest on long-term waterlogged localities. There is also a significant proportion of extensively used meadows, mainly with continental inundated features, and these biotopes are complemented in extensive areas by numerous water and wetland biotopes. These comprise mainly macrophytic vegetation in stagnant to flowing water and also reeds and tall sedges. Drier vegetation types occur to a small extent on elevations of former alluvia. These types are specific for this area and they include forest vegetation characteristic of Pannonian oak-hornbeam woods and non-forest vegetation which is typical of dry acidophilous grassland. This entire alluvial floodplain model area has a high level of ecological stability, and it is mostly covered by highly representative forest stands unique within the Czech Republic for their extent and quality. Part of this area forms the Cahnov–Soutok National Nature Reserve (NNR) which was proclaimed in 1949. The main conservation objectives therein relate to biotopes of floodplain forest with primeval character, and this entire model area lies within the European network of Natura 2000.

Results

Dunajovické kopce hills

Historical development and current state

The Dunajovické kopce hills model area is a landscape with stable long-term intensive agricultural use, a high proportion of vineyards, and a low degree of industrialization. A significant portion is represented by arable land, and permanent grasslands currently in the form of steppe barrens (Table 2). It also has a low proportion covered by forests and marginal areas of other land use/land cover categories. The **vineyards** form relatively stable complexes covering more than half of the model area, and their extent did not change significantly during the period under consideration. They were most widespread at the end of the 19th century, but their relative percentage was at its lowest in the 1960s as a result of the expulsion of the local German population who took their viticultural expertise with them. **Permanent grassland** recorded a significant decrease after the second half of the 19th century and that trend continued until the 1930s, when the vast majority of the model area was covered by vineyards and small agricultural fields with scattered fruit trees. Remnants of those old vineyards, uncultivated fields and orchards are still visible on these terraces. Many areas, especially on the western slopes, were left derelict following World War II, the expulsion of the autochthonous German population and the collectivization of agriculture. Subsequently, succession stages with grassy herbaceous vegetation and rare communities developed on the steppe barrens within a few decades. The proportion of permanent grassland has grown gradually since the end of the 1960s, and these grasslands have been preserved to the present day due to currently improved management. A small proportion of the area is traditionally covered by **forest and non-forest woody vegetation,** due to long-term agricultural utilization of the area. The percentage of forest has been increasing slightly since the 1990s, and a part of the area has become overgrown with woody vegetation due to the lack of management. A large portion of the grassy herbaceous vegetation is therefore at risk of being overgrown by shrubs and by naturally-seeding woody vegetation. This situation is especially manifested in the northern part of the model area, where the black locust is invasive.

In terms of the landscape's spatial structure, the most obvious changes occurred in vineyards, arable land, and permanent grasslands, all of which varied during the period in number, shape and patch size. Narrow areas of vineyards alternating with areas of arable land and irregularly shaped permanent grassland used to be typical. Scattered fruit trees formerly composed a considerable proportion of the patches in this model area, and they created the characteristic landscape mosaic here in this model area. The landscape started to change from the second half of the 20th century and the original mosaic of patches of arable land was replaced by more extensive and united blocks of vineyards, and arable land in simple shapes. This was reflected in the smaller number of patches in these categories. Meanwhile, the number of irregularly shaped forested areas increased with natural succession.

T a b l e 2. Percentages of individual land use categories during historical development (authors' own calculations).

	1821/1841		1875/1876		1933/1944		1959/1960		1993/1994		2004/2005		2009	
	DK	L	DK	L	DK	L	DK	L	DK	L	DK	L	DK	L
Arable land	27.7	-	28.6	-	56.0	-	42.0	-	25.2	-	18.4	0.2	14.3	-
Permanent grassland	16.4	43.7	8.9	46.5	0.5	52.0	23.2	44.4	24.8	48.8	20.0	40.8	24.1	39.6
Orchard	-	-	-	-	-	-	-	-	0.3	-	0.5	-	0.5	-
Vineyard and hop field	55.8	-	62.5	-	43.0	-	34.5	-	47.9	-	55.3	-	52.4	-
Forest	-	49.0	-	47.9	0.6	45.0	0.2	50.5	1.8	45.5	5.8	53.4	8.5	54.6
Water area	-	7.4	-	5.6	-	2.4	-	4.1	-	4.9	-	5.1		5.0
Built-up area	-		-		-	0.6	-	1.0	0.0	0.8	0.0	0.5	0.0	0.6

Symbol "-" indicates the category was absent in the period. DK – Dunajovické kopce hills, L – alluvial plain.

The lowest diversity of landscape within the individual time horizons was recorded in the 1930s. The largest number of areas with irregular or complicated shapes and their lowest average extent were concurrently recorded in this same period. The landscape now displays its largest diversity today. A more or less regular distribution of areas, and especially those of vineyards and arable land, is typical of the landscape in the second half of the 19th century.

Analysis of the current state of secondary landscape structure

Individual elements of the current secondary landscape structure were classified on the basis of field mapping carried out in 2009 and on the mapping source of the Natura 2000 biotopes according to the classification key for natural habitats (Chytrý et al., 2001). A total of 19 landscape elements were specified and levels of ecological stability were assigned to the individual segments.

Communities with low ecological stability in level 2 are spatially most extensive with 54.2% area coverage. These are followed by communities of medium ecological stability in level 3, covering 26.7%, and those of very low ecological stability in level 1 covering 16.1%. Meanwhile, communities with a high level of ecological stability in level 4 cover only 4% of the area.

High and medium ecological stability levels were recorded for permanent grassland communities in landscape element Group 2, while Group 5 forest and non-forest woody vegetation recorded level 3 medium ecological stability, although their extent is less due to the area's character.

Ecologically more stable communities are apparent in the central part of this model area while less stable communities occur on the slopes in the north-west, south-west and east (see Fig. 2a).

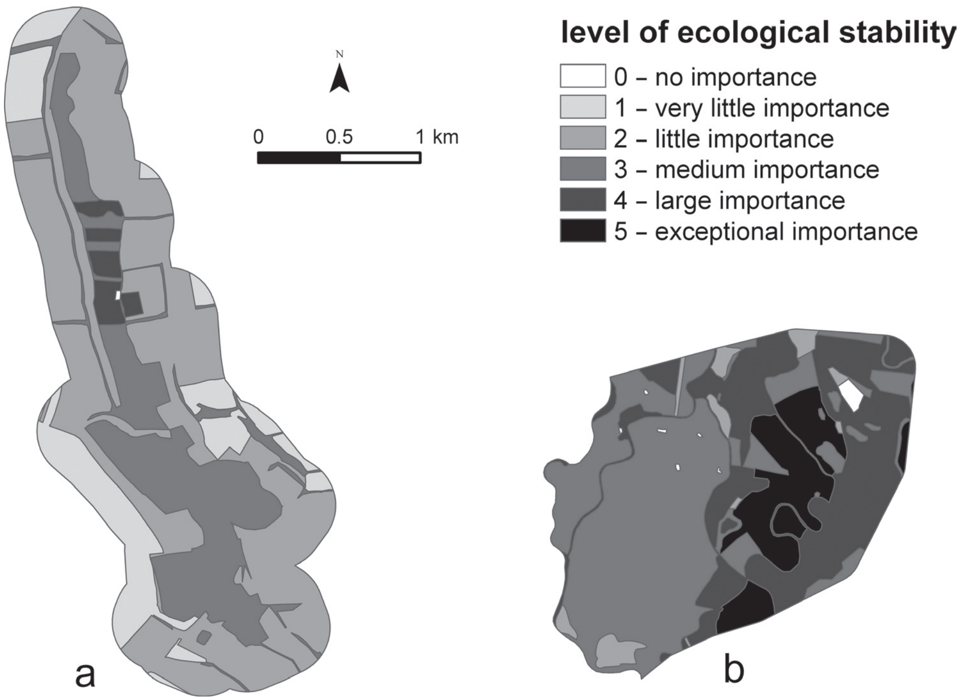

Fig. 2. Ecological stability of biotopes in model areas of Dunajovické kopce hills (a) and alluvial plain (b).

Comparison of current landscape ecological stability and that of historical land use/land cover

Analysis shows that there are no patches in the model area concurrently characterized by both high ecological stability and land use/land cover stability. Although the most stable land use/land cover areas are vineyards and arable land, these landscape element groups have very low and low ecological stability, and they account for 4.8% and 2.0% of the total area, respectively. These areas are mainly found in the north and south-west and on the eastern slopes in the central part of the area close to the NNM. Changes in land use/land cover for these areas were recorded in the 1930s, 1990s, and also today.

Element groups with high and medium ecological stability exhibit either dynamic changes, or changes with an ambiguous trend, caused by frequent rotation of individual land use/land cover categories, which mainly occurred in the 1960s and 1990s.

The correlation between ecological stability and changes in land use/land cover in the NNM from the time directly predating its declaration in the 1960s and onwards shows areas with high and medium ecological stability in conjunction with areas with land use/land cover stability. Their areas cover 1.5% and 7.5%, respectively, of the total model area.

Alluvial plain

Historical development

With only four alternating categories, the alluvial plain territory is characterized by a relatively uniform landscape with respect to land use/land cover. A long-term high proportion of forests and permanent grasslands are characteristic, as is their mutually stable proportion. Water areas were also recorded. These are represented mainly by streams of the Dyje and Kyjovka rivers and forest irrigation canals, with watercourses in this area vectorized as polygons. This category also contains abandoned meanders of these watercourses and water pools, which mostly dried up during the 1930s. Other categories of land use/land cover in this area are represented by built-up areas alone, although these occur only marginally in the northern and north-eastern parts. The extent and location of forests and permanent grasslands did not change significantly during this period. Forests always used to occupy the eastern part of this area, and their extent today has increased slightly to 54.6% compared with their 1821 percentage (Table 2). Permanent grasslands are mainly found in the western part of this area and their extent today has decreased slightly to 39.6, in favour of forests, compared to their share at the beginning of the studied period in 1821.

The model area is characterized by a relatively simple landscape structure with a greater mean patch size, which is typical mainly for permanent grasslands and forests. More or less continuous complexes of forests and permanent grassland are intersected by watercourses and other water areas. The number of these aquatic areas increased over the studied period, causing increased fragmentation of these land-cover categories and a decrease in the mean patch size.

More or less equal values, ranging between 0.82 and 0.90, were calculated for landscape diversity. This landscape displayed its lowest diversity in the 1930s and its largest in the mid-19th century. Equal values were also observed in area-weighted mean patch fractal dimension, with values ranging from 1.31 to 1.34,, and this alluvial plain landscape can therefore be specified as relatively simple. The highest number of patches together with their smallest mean size was recorded for the present day. In contrast, the least number of patches with large extent were typical at the end of the 19th century.

Current state of the secondary landscape structure

The digital layer of biotope mapping for Natura 2000 and field mapping carried out in spring 2010 served as references for specifying current secondary landscape structure. Four groups of landscape elements, with a total of 25 landscape element types from the current secondary landscape structure, were identified and assigned levels of ecological stability.

Communities with medium to high ecological stability in levels 3 and 4, were the most extensive spatially, covering 48.1% and 32.8% of the total area, respectively. While communities with medium stability are the most widespread in the western part of this area and are connected primarily to permanent grassland, in the eastern part, communities with high stability are connected with forest complexes. The third most widespread communities are those in level 5, which have very high levels of ecological stability. They occur mainly in the central part of the model area, and these are also connected to forest complexes. They cover 14.6% of the total area with a significant proportion lying in the Cahnov–Soutok NNR (Fig. 2b).

Less than 4% of the landscape elements are included in communities with low levels of ecological stability. Those elements are mainly permanent grassland which are either intensively used or have many ruderal species. They are mainly situated in the northern part of the model area, while the forest landscape element with black locust also shows low ecological stability and it is widespread in the southern part.

Landscape elements with zero ecological stability represent anthropogenic landscape elements and these comprise drilling towers and buildings in the northern part covering approximately 0.6% of the total model area.

Comparison of current landscape ecological stability and historical land use/land cover

Patches of forest group elements recorded high or very high ecological stability, with concurrent zero change in land use/land cover, and these form nearly a quarter of the model area, occurring especially in its eastern half.

The most widespread are areas without change in land use/land cover with medium ecological stability (33.4%) which are connected to permanent grasslands in the western half of the model area.

Meanwhile, the most widespread areas with low ecological stability are areas that went through one change in land use/land cover either in the 1960s or at the beginning of the 21st century.

Discussion

The results elucidated the following:

The most stable areas in terms of land use/land cover within the Dunajovické kopce hills area of interest are connected with vineyards and arable land, while in the alluvial plain these are the permanent grasslands and forests. Analysis showed that 6.8% of the Dunajovické kopce hills area had stable land use/land cover during the study period while the alluvial plain had an eight times higher percentage at 58.7%. This is entirely due to different landscapes characteristics and utilization. While the Dunajovické kopce hills represent an intensively cultivated agricultural landscape orientated towards grape growing, the alluvial plain is an example of a Czech Republic pristine locality in the "iron curtain zone" where no admittance was allowed after 1948. These conclusions correspond with those of other case studies in the Czech Republic (e.g. Bičík, Chromý, 2006; Skaloš, Engstová, 2010) and result from the fact that all the surveyed areas were influenced by similar socio-economic factors. These factors included: agricultural collectivization in the 1950s which caused the subsequent simplification in landscape structure (Lipský, 1995); post-war expulsion of the

German population; abandonment of areas for military reasons and defensive creation of the iron curtain along the southern and western borders of the Czech Republic; and finally, the abandonment of peripheral areas.

The simplification of the secondary landscape structure recorded for the Dunajovické kopce hills corresponds with the general trend in the Czech Republic and throughout Europe (Lipský, 1995; Antrop, 2000; Haase, et al., 2007).

The landscape's character and localization also determine the ecological stability of these model areas. Landscape elements in the Dunajovické kopce hills with medium and high ecological stability compose a significant minority, and they are mainly located in the area of the NNM. On the other hand, these elements prevail in the alluvial plain, and they are evenly distributed throughout the entire model area. Additionally, there are even landscape elements with very high ecological stability located there.

Spearman's rank correlation coefficient confirmed a relationship between changes in land use/land cover and ecological stability. Although this relationship is quite weak at values ranging between 0.08 and 0.22, it is statistically significant.

Strong correlations were found between ecological stability and indices describing landscape structure in the mean shape index (MSI), and this corresponds with Fu et al's results in 2006. However, the correlation was statistically significant at the 0.05 level only for the Dunajovické kopce hills elements.

Conclusion

Ecological stability, or more specifically its level, in relationship to past land use/land cover is very difficult to establish. While it is possible to assume that landscape in the past possessed higher ecological stability because human influences in energy and material input was not so intensive then. On the other hand, since the assessment of ecological stability level presented here includes species composition and nativity, the historical assessment based on the abovementioned presumption is more suitable for assessing hemeroby and not ecological stability.

The assessment of the relationship between historical land use development and ecological stability represents just one approach to landscape assessment. It has both advantages and disadvantages. The advantages can be seen in the use of old maps and orthophotos which specify the spatial relationship of landscape elements, the relative simplicity of the defined landscape elements and the relative simplicity of the levels of ecological stability. Meanwhile, the disadvantages mainly centre on the availability, accuracy and interpretation of old maps, which in the case of older maps can be very difficult. Another disadvantage concerns the assignment of ecological stability levels, and although this is based on expert judgement, it is always possible that this judgement is subjective.

When we consider the connection of present ecological stability with changes in land use/land cover, it is clear that the results presented here confirm the correlation between these two variables. We also confirm the findings of other authors who have reported that old maps present a suitable foundation for nature conservation, landscape protection and their management.

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References

Antrop, M., 2000: Changing patterns in the urbanized countryside of Western Europe. Landsc. Ecol., 15: 257–270.

Bender, O., Boehmer, H.J., Jens, D., Schumacher, K., 2005: Analysis of land use change in a sector of Upper Franconia (Bavaria, Germany) since 1850 using land register records. Landsc. Ecol., 20: 149–163.

Bičík, I., Chromý, P., 2006: Land use changes in selected model areas in Czechia (in Czech). In Šimůnek, R. (ed.), Historická geografie. Suppl. I. Historický ústav, Praha, p. 189–204.

Brůna, V., Buchta, I., Uhlířová, L., 2002: Identification of historical network of the landscape stability elements on the military survey maps (in Czech). Acta Universitatis Purkynianae - Studia Geoinformatica II, 46 pp.

Chytrý, M., Kučera, T., Kočí, M. (eds), 2001: Catalogue of biotopes of the Czech Republic (in Czech). Agentura ochrany přírody a krajiny ČR, Praha, 307 pp.

Čada, V., 2006: Assessment of the positional and geometric accurracy of the elements of the 2nd Austrian military survey localized in the S-JTSK coordinate system (in Czech). In Šimůnek, R. (ed.), Historická geografie. Suppl. I. Historický ústav, Praha, p. 82–105.

European Commission, 1992: Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31992L0043:EN:NOT (accessed on 10th June 2010)

Fu, B.J., Hu, C.X., Chen, L.D., Honnay, O., Gulinck, H., 2006: Evaluating change in agricultural landscape pattern between 1980 and 2000 in the Loess hilly region of Ansai County, China. Agric. Ecosyst. Environ., 114: 387–396.

Guth, J., 2002: Methodologies of the biotope mapping of the NATURA 2000 and SMARAGD networks (in Czech). AOPK, Praha, 47 pp.

Haase, D., Walz, U., Neubert, M., Rosenberg, M., 2007: Changes to Central European landscapes - analysing historical maps to approach current environmental issues, examples form Saxony, Central Germany. Land Use Policy, 24: 248–263.

Haines-Young, R., Barr, C.J., Firbank, L.G., Furse, M., Howard, D.C., McGowan, G., Petit, S., Smart, S.M., Watkins, J.W., 2003: Changing landscapes, habitats and vegetation diversity across Great Britain. J. Environ. Manag., 67: 267–281.

Hamre, L.N., Domaas, S.T., Austad, I., Rydgren, K., 2007: Land-cover and structural changes in a western Norwegian cultural landscape since 1865, based on an old cadastral map and field survey. Landsc. Ecol., 22: 1563–1574.

Jančura, P., 1998: Present and historic landscape structures in the landscape creation (in Slovak). Život. Prostr., 32: 236–240.

Lipský, Z., 1995: The changing face of the Czech rural landscape. Landsc. Urban Plan., 31: 39–45.

Mackovčin, P. (ed.), 2007: Brno region. Protected areas of the Czech Republic (in Czech). Vol. IX. AOPK ČR a Ekocentrum Brno, Praha, 932 pp.

Mackovčin, P., 2009: Land use categorization based on topographic maps. Acta Pruhoniciana, 91: 5–13.

McGarigal, K., Marks, B.J., 1995: FRAGSTATS: spatial pattern analysis program for quantifying landscape structure. USDA For. Serv. Gen. Tech. Rep. PNW-351.

Míchal, I., 1994: Ecological stability (in Czech). Veronica, Brno, 275 pp.
Miklós, L., 1989: The general ecological model of the Slovak Socialist Republic – Methodology and contents. Landsc. Ecol., 3: 43–51.
Naveh, Z., Liebermann, A., 1984: Landscape ecology – theory and application. Springer-Verlag, Berlin and New York, 360 pp.
Olsson, E.G.A., Austrheim, G., Grenne, S.N., 2000: Landscape change patterns in mountains, land use and environmental diversity, Mid-Norway 1960–1993. Landsc. Ecol., 15: 155–170.
Pellantová, J. (ed.), 1994: Methodology of the landscape mapping for the needs of the nature conservation management in the sense of the Act No. 114/92 Col. (in Czech). ČÚOP Praha – Výzkumné a monitorovací pracoviště v Brně.
Petrovič, F., 2005: Landscape assessment in the area of the population in Pohronský Inovec and Tribeč (in Slovak). Ústav krajinnej ekológie SAV, pobočka Nitra, Bratislava, 209 pp.
Pucherová, Z. (ed.), 2007: Secondary landscape structure (Methodology for mapping) (in Slovak). UKF v Nitre, Nitra, 124 pp.
Rennetzeder, C., Schindler, S., Peterseil, J., Prinz, M.A., Mücher, S., Wrbka, T., 2010: Can we measure ecological sustainability? Landscape pattern as an indicator for naturalness and land use intensity at regional, national and European level. Ecological Indicators, 10: 39–48.
Ružička, M., Miklós, L., 1988: Ecological planning of the landscape, methodological principles and framework procedure (in Slovak). ÚEBE CBEV SAV, Bratislava, 110 pp.
Skaloš, J., Engstová, B., 2010: Methodology for mapping non-forest wood elements using historic cadastral maps and aerial photographs as a basis for management. J. Environ. Manag., 91: 831–843.
Skokanová, H., 2008: GIS methods in the land use changes assessment (in Czech). In Kubíček, P., Foltýnová, D. (eds), Geoinformatika ve veřejné správě. CD-ROM. MSD, Brno.
Steinhardt, U., Herzog, F., Lausch, A., Müller, E., Lehman, S., 1999: Hemeroby index for landscape monitoring and evaluation. In Pykh, Y.A., Hyatt, D.E., Lenz, R.J. (eds), Environmental Indices – System Analysis Approach. Oxford, EOLSS Publ., p. 237–254.
Stránská T., Havlíček M., 2008: Ecological asessment of landscape development and changes in the Ivančice microregion (Czech Republic). Moravian Geographical Reports, 16: 26–36.
Špulerová, J., 2008: Land use changes in the Veselovianka river catchment in the Horná Orava region. Ekológia (Bratislava), 27: 326–337.
Vondrušková, H. (ed.), 1994: Methodology of the landscape mapping (in Czech). SMS Hradec Králové, Praha, 55 pp.
Wozniak, M., Leuven, R.S.E. W., Lenders, H.J.R., Chmielewski, T.J., Geerling, G.W., Smits, A.J.M., 2009: Assessing landscape change and biodiversity values of the Middle Vistula river valley, Poland, using BIO-SAFE. Landsc. Urban Plan., 92: 210–219.
Wrbka, T., Erb, K.-H., Schulz, N.B., Petersteil, J., Hahn, C., Haberl, H., 2004: Linking pattern and process in cultural landscapes. An empirical study based on spatially explicit indicators. Land Use Policy, 21: 289–306.