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# CONTENT

**Summary**

This issue of the Acta Pruhoniciana Journal presents various methods of landscape changes analyses in the Czech Republic. For the analyses authors have used a large scale of available data sources like: old and present topographic maps at a middle scale, cadastral maps at a large scale, aerial photographs and statistical data sets. The general methodological contributions deal with the landscape changes data sources efficiency and the possibilities of using the geographical information systems for the landscape changes processes evaluation. The specific examples are presented in the landscape-ecological studies of smaller and larger administrative and natural units representing various landscape styles of the Czech Republic. Analyses of long-term landscape changes enable delimitation of the stable landscape elements and recognition of the former landscape structure. This valuable information can thus serve as one of the basis for landscape planning and nature conservation.

**Anotace**

Předkládané číslo časopisu Acta Pruhoniciana je věnováno prezentacím různých metod analýzy krajinných změn v České republice. Pro hodnocení dlouhodobých změn v krajině autoři příspěvků využili celou škálu dostupných zdrojových dat – staré a současné topografické mapy středního měřítka, katastrální mapy velkého měřítka, letecké snímky a statistické datové soubory. Obecné metodické příspěvky se zabývají využitelností zdrojových podkladů pro sledování změn v krajině a možností využití geografických informačních systémů pro hodnocení procesů změn v krajině. Konkrétní příklady jsou prezentovány v krajinně-ekologických studiích menších i velkých administrativních a přírodních celků, reprezentujících různé typy krajin České republiky. Analýza dlouhodobých změn krajiny umožňuje vymezení stabilních prvků krajiny a poznání původní krajinné struktury. Tyto cenné informace pak mohou být využity při krajinném plánování a ochraně přírody.

# LAND USE CATEGORIZATION BASED ON TOPOGRAPHIC MAPS

## KATEGORIZACE VYUŽÍVÁNÍ KRAJINY NA ZÁKLADĚ TOPOGRAFICKÝCH MAP

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**Abstract**

"Land use categorization based on topographic maps" is methodological paper about importance old topographic maps for study of landscape changes. Anthropogenic pressures on more intensively land-use increased during the 20$^{th}$ century. These pressures still continue in the 21$^{st}$ century. The present cultural landscape reflects not only actual activities of the Human society, but also preserves some surfaces from past periods. These stable surfaces (forests, settlements) do not change substantially during the time and form stable basement of the landscape structure. It is useful to study land-use in the past periods for the better understanding of the present-day state of the landscape and prediction of its further development. For this type of studies are very useful medium-scale topographic maps. This type of maps, which covers the whole territory of the present-day Czech Republic, were published in the period 1763–2006. The maps form a base for studies of land-use development in the period 1763–2006 (excluded are maps of the 1$^{st}$ Austrian Military Mapping from years 1763–1768 which are not suitable for georeferencing). Authors use 5 temporal axes (1836–1852, 1876–1880, 1952–1956, 1988–1994 and 2002–2006) and of course use 5 map keys. Map keys include more than 1 240 items (flat, linear and points) without topography. These items were necessary to divide into 10 groups using 358 examples from legends of topographic maps. The resulted land-use types enable quantitative evaluation spatially oriented data in the map series in the scale 1 : 200 000.

**Abstrakt**

„Kategorizace využívání krajiny na základě topografických map" je metodologickým příspěvkem o významu starých topografických map pro studium změn v krajině. V průběhu 20. století postupně sílily tlaky na stále intenzivnější využívání krajiny, které pokračují i nyní. Současná krajina v sobě odráží nejen aktuální působení lidské společnosti, ale zachovává určité plochy z předchozích období. Ty se postupem času podstatně nemění (lesy, sídla) a vytváří stabilní základ krajinné struktury. Pro lepší pochopení aktuálního stavu krajiny a predikování jejího vývoje je vhodné sledovat stav využívání ploch v minulosti. Velmi vhodným podkladem jsou topografické mapy středních měřítek. Pokrývají celé území nynější ČR a vznikaly v období 1763–2006. Podle těchto map lze sledovat vývoj využívání krajiny pro území státu za období 1836–2006 z důvodu nemožnosti georeferencování map I. vojenského mapování z let 1763–1768. Zpracovatelé pracují s pěti časovými osami (1836–1852, 1876–1880, 1952–1956, 1988–1994 a 2002–2006), a tedy pěti mapovými klíči. Mapové klíče obsahují přes 1 240 položek plošných, liniových a bodových bez polopisu, které bylo nutné převést do devíti sledovaných kategorií využívání krajiny prostřednictvím 358 ukázek z položek legend topografických map. Výsledné kategorie umožní kvantitativně vyhodnocovat polohově orientovaná data v mapových sadách měřítka 1 : 200 000.

**Keywords:** topographic map, land use, cultural landscape

## 1 INTRODUCTION

Land-use is one of basic impacts of the Human society in the landscape. Anthropogenic pressures on landscape are more and more intensive and their impacts are influencing its functionality and stability. Experts devote more of their attention to development of land-use in time. Different approaches are applied during studies of long term changes in land-use studies – methods based on elaboration of statistical data, methods using historical data and other sources, land-use maps based on aerial and space images, land-use maps based on medium-scale topographic maps and large-scale cadastral maps.

From statistic data base it is possible to use for instance central evidence of flats incl. their use, historical evidences of properties of individual estates etc. This approach use statistical method especially the group of Ivan Bičík from the Charles University in Prague which posses huge historical database of land-use in cadastral areas of the Czech Republic in periods 1845, 1848 and 1990 (Bičík et al., 2001, 2003).

Methods of land-use studies based on remote sensing (aerial and space images) are time-limited for the period after 1930. Nevertheless, this method is often used for studies of landscape changes, especially due to common renewal of data. Data obtained from the remote sensing sources are sometimes combined with information obtained from historical topographic maps. Unified approach is used during elaboration of maps of Corine Land Cover using as base satellite images in Europe (Feranec, Oťaheľ, 2001, 2003).

Detailed information about the landscape structure in the time of their origin is contained in large-scale maps. The most useful source for evaluation of landscape development in individual cases is the stable cadaster as comparable map work, which covers the whole territory of Bohemia, Moravia and Silesia and its content enables to define landscape structure with a high precision. Saved copies of individual map versions often differ in scale, quality and state of preservation. For the landscape studies are the most suitable so called Stabile Cadastre Obligatory Imperial Prints. These maps are copies of original maps made directly in the field in the scale 1 : 2 880, resp 1 : 1 440 in years 1826–1843 (Bohemia) and 1824–1836 (Moravia and Silesia).

Medium-scale topographic maps enable topographically precise studies of landscape changes from the half of the 19th century. In the Central Europe is common use of Austrian and Hungarian military surveys. Original of these maps are in archives in Vienna and Budapest and are centres of interests of experts for all countries of former Austrian-Hungarian Monarchy. For the landscape studies in the Czech Republic was important publication of maps of the 1st and 2nd Austrian Military Mapping by Laboratory of Geoinformatics of the University of J. E. Purkyně in the town of Most headed by V. Brůna. Later than publication of maps of the 3rd Austrian Military Mapping by State Agency of Nature Conservation and Landscape Protection of the Czech Republic in Brno (Brůna et al., 2002). The advance of the medium-scale maps lays in its use for landscape changes studies of larger land units, e. g. in Germany (Haase et al., 2007), in Great Britain (Swetnam, 2007), in Estonia (Palang et al., 1998), in Hungary (Jordan et al., 2005), in Austria and Italy (Tasser et. al., 2007), in Slovakia (Boltižiar, 2007), in the Czech Republic (Demek et al., 2008; Havlíček, 2008; Mackovčin et al. 2008; Skokanová, 2008; Stránská, Havlíček, 2008).

The research project MSM 6293359101 Research into sources and indicators of biodiversity in cultural landscape in the context of its fragmentation dynamics, is solved by research workers of the department of the landscape ecology and by department of GIS application of The Silva Tarouca institute for landscape and ornamental gardening in Průhonice since 2005. One part of this project is dealing with quantitative changes in landscapes of the Czech Republic. The main objective of the project is the compilation of the complete set of land-use maps of the whole territory of the Czech Republic in five temporal sections 1836–1852, 1876–1880, 1952–1956, 1888–1994 and 2002–2006.

## 2 STUDY AREA

Mapping of land-use for the period 1836–2006 in above mentioned project was carried out on the whole territory of the Czech Republic based on sets of historical and contemporary maps in digital forms archived in Brno branch of The Silva Tarouca Institute for Landscape and Ornamental Gardening, p.r.i. Final maps are compiled in map scheme of the Czech Military Maps in the scale 1 : 25 000. Together the land-use map set will contain 1 059 sheets covering the mean area 83 sq. km each for one temporal section.

## 3 MATERIALS AND METHODS

Base for the Project were military topographic maps compiled on the territory of the present-day Czech Republic by the Austrian Military Geographic Institute in Vienna in the period 1836–1880 (1st, 2nd and 3rd Austrian Military Survey), Czechoslovak Military Geographical Institute in Prague (1952–1955), General Staff of the Czechoslovak People Army and following organisation General Staff of the Army of the Czech Republic (in years 1955–1995) and Czech Office for Surveying, Mapping and Cadastre in Prague (Basic maps of the Czech Republic – digital version ZABAGED 2002–2006).

### 3.1 Types and sources of used data

Maps from the 1st Austrian Military Survey in the territory of the today's Czech Republic were drawn up by imperial officers in periods 1763–1768 (1763 – Silesia 40 sheets, 1764–1767 Bohemia 273 sheets, 1764–1768 Moravia 126 sheets). Experience from the Seven Year's War (1756–1763) and reasons for consistent mapping were explained to the Empress Maria Theresa by count Daun (1764). Daun suggested extending the mapping that was launched in Silesia in 1763 onto the whole empire. The mapping was of purely military character. However, the general concept of work, the geodetic grid for which it was necessary to determine the geographic position of fundamental points distributed across the entire mapped territory as well as the cartographic grid according to a predetermined mode of projection were insufficient. The 1st Austrian Military Survey dwelled on Müller's maps (1 : 367 000), which were magnified and supplemented with objects important for military purposes (Kuchař, 1967; Boguszak, Císař, 1961).

In 1762–1769, cartographer Liesegang constructed a basic cartographic graticule by using locally determined meridian lines (Meridionalline). The meridian line was constructed by military cartographers from astronomical measurements. The proper planimetric mapping was carried out graphically on the plane table or numerically by using the circular instrument – quadrant. Lengths were measured by estimation or by pacing only in cases when the planimetric details in the terrain needed a supplementation. There were 19 and 4 fascicles of descriptions for Bohemia and Moravia, respectively. Distance on the maps and in the military descriptions of the landscape was defined in hours or steps. The scale of 5,000 steps is graphically illustrated on the map margins and represents ½ of Vienna mile (ca. 3.8 km) and the walking time of 1 hour. The mapping drawbacks showed during the war with Prussia (1778–1779) and Emperor Joseph I commanded that an urgent rectification is made but not a new mapping of the northern borderland of the Czech lands. Many sheets were reviewed or newly mapped (30 sheets for Silesia in 1780, 143 sheets for Bohemia in 1778–1781 and 40 sheets for Moravia in 1778–1781). In the original drawings, we find above the upper margin the numbers of column (Col.) and section (Sect.), the names of territories cartographically illustrated in the map, the name of mapping officer, the military unit in which he served and the year of mapping; sporadically inserted are even lines of the triangulation net (Paldus, 1919; Kuchař, 1967; Boguszak, Císař, 1961). The map content is depreciated by coarse geographic orientation and by considerable positional distortions. Therefore, the maps cannot be used for a detailed assessment of land use changes (Brůna et. al., 2002; Cajthaml, Krejčí, 2008).

Maps from the 2nd Austrian Military Survey were drawn up by imperial officers in 1836–1852; 146 sheets for Moravia and

Silesia (1836–1840) and 267 sheets for Bohemia (1842–1852). The mapping was preceded by a military triangulation of Bohemia, Moravia and Silesia in 1806–1811, approved by Emperor Frances I. The plan was worked out by General Mayer of Heldensfeld. A revision mapping was carried out in Bohemia in 1812–1819. Section frames are parallel resp. perpendicular to the image of the Gustenberg meridian.

The map in Moravia and Silesia is based on Vienna Meridian.

Topographic maps were derived from the ensuing maps of stable cadastre (1 : 2 880), which were reduced in size (Paldus, 1919; Kuchař, 1967; Boguszak, Císař, 1961; Brůna et. al., 2002).

Each section contains its number (1–19 from the north to the south) in the column (I. to X. in the western or eastern direction from the Gustenberg), the name of the staff officer who mapped the section, and the year. To the right margin of sections, a list of villages and settlements is attached with the number of houses and stalls, and information how many men and horses can be placed there. The maps are unusually accurate for their time. Hypsography was processed by Lehman's hachure and spot heights only on triangulation points (Cajthaml, Krejčí, 2008). A regular map index was created from which maps of smaller scales could be produced by simple derivation. These maps can be georeferenced by means of adequate tools and represent the oldest middle-scale topographic maps applicable in the assessment of land use changes.

Maps from the 3rd Austrian Military Survey are innovated maps drawn up by the Military Geographical Institute in Vienna in 1874–1880. After the defeat of Austria-Hungary by Prussia at Hradec Králové in 1866 and in the advent of industrial revolution with the development of railways and settlements, a need for new mapping was obvious. With the adoption of decimal system after 1875, the scale 1 : 28 800 was given up and changed to 1 : 25 000 (Kuchař, 1967; Boguszak, Císař, 1961). The mapping was made in a so-called polyhedral projection, in which each sheet on a scale of 1 : 75 000 was projected separately. The division into rectangular or quadratic sections was replaced by the division into fields of geographical net and scale 1 : 25 000, which served to draw up special maps on a scale of 1 : 75 000 (one sheet consisted of 4 sections).

In the creation of new maps, the relief and roads were enhanced. The altitudinal situation was illustrated by spot elevations, hachuring and contour lines by 20 metres, which were not too accurate. After its constitution in 1918, the Czechoslovak state received maps for its national territory, which were taken over by the Military Geographical Institute. Within the framework of revision, the terminology and topography were converted from German and Hungarian languages to Czech and the hachure was replaced by contour lines. In general, the modifications concerned namely the German-speaking borderland and the hinterlands of larger towns (34,000 km$^2$). This mapping was the only map work covering the entire Czech territory of land cover (land use) until 1953. The Third Austrian Military Survey is one of the most valuable sources of information about landscape at the time of industrialization at the end of the 19th century for the entire territory of the state (Kuchař, 1967; Cajthaml, Krejčí, 2008).

**Czechoslovak military mapping**

After World War II, provisional maps were drawn up in 1950–1952 based on the maps from the 3rd Military mapping, Czechoslovak interim mapping and Czechoslovak definitive mapping (Čapek, 1985). Within the coalition of socialist countries in a so-called eastern block, a new topographic mapping was based on Gauss transversal cylindrical map projection and S-52 system of coordinates, which was later adjusted to S-42. The mapping was carried out in 1952–1956 on a scale of 1 : 25 000 (TM25), largely by methods using aerial photographs. These maps served for the derivation of smaller-scale maps (TM50, TM100, TM200). The maps are regularly renewed. A very appropriate starting point for studying landscape development is the first set of maps TM25 from 1952–1956. Similarly useful are data from various stages of renewal, e.g. the 4th renewal from 1988–1995 (Cajthaml, Krejčí, 2008).

**Base maps in the territory of the Czechoslovak Socialist Republic and the Czech Republic**

After 1968, state enterprises increasingly needed to use the map documentation. Most of military maps were confidential. It was desirable to create a set of civil maps from which a precise reading of geographic coordinates would be impossible. A collection of Base Maps of the CSSR (ZM) was created by derivation from the military topographic maps. The basic scale of 1 : 10 000 has been retained until today including the renewal and ZM25, ZM50, ZM100 and ZM200 derivations (Cajthaml, Krejčí, 2008). Raster maps were replaced by a digital vector model of the territory, known today as ZABAGED. At present, the Czech Office for Surveying, Mapping and Cadastre in Prague ensures map renewals. The assessment of land use dwells on the set of data from the period 2002–2006.

### 3.2 Georeferencing of map collections

Maps from the 1st Austrian Military Survey were not georeferenced due to their inaccuracy, which considerably limited their use. A team of workers from the Laboratory of Geoinformatics at the University of J. E. Purkyně in Ústí nad Labem attempted at georeferencing and measured deviations from S-JTSK (JTSK = Integrated cadastral triangulation net) ranging from 400–700 m in dependence on the relief and the time of creation of these maps. Maps from the 2nd and 3rd Austrian Military Survey were georeferenced at the Department of Geomatics, The University of West Bohemia in Plzeň with a planimetric accuracy of 13–30 m, and at the authors' workplace with an accuracy of 10–15 m (Brůna et. al., 2002; Čada, 2005, 2006). Where the planimetric survey error was greater than the above values, a recurrent georeferencing of the source maps was made with the use of tools of the programme ArcGIS version 9.x by means of control points (Skokanová et. al., 2008). The georeferencing of maps from the 2nd and 3rd Austrian Military Survey was carried out in the programme VB150. The georeferencing of maps from the Czechoslovak and Czech military mapping in the periods 1953–1957 and 1988–1995 was made in the programme ArcGIS, version 9.x by means of ground control points and mean planimetric error was 10–15 m. Manually

**Tab. 1 Sets of topographic maps**

| Survey | Topographic map | Area in sq.km | Sheets number | Name of sheet | Dimension of sheet |
|---|---|---|---|---|---|
| 1st Military | 1 : 28 800 approx. | ~209 | 439 | Map layer (Sectio № 3), column (Collone № XII.) | 61,8 × 40,8 cm |
| 2nd Military | 1 : 28 800 | 230 | 413 | Map section (Section № 6), column (Colonne № VIII.) | 52,68 × 52,68 cm |
| 3rd Military | 1 : 25 000 | 242–261 | 604 | 3955/section 3 | 46,54 × 37,81–50,22 × 37,05 cm |
| General staff Czechoslovak people army (1952–1995) | 1 : 25 000 | ~81,28–86,92 | 1736 | M-33-144-D-d | 35,10 × 37,08–37,55 × 37,06 cm |
| Basic map of the Czech Republic | 1 : 10 000 | ~18 | 4572 | 02-32-07 | 38 × 48,38 cm |

**Tab. 2 Content of map symbols and colors of topographic maps**

| Survey | Topographic section | Legend items /map keys | Author catalogue | Colors of map sheets |
|---|---|---|---|---|
| 1st Military | 1 : 28 800 approx. | 31 | 12 | 8 colored fair copy of original |
| 2nd Military | 1 : 28 800 | 75 | 107 | 11 colored drawing |
| 3rd Military | 1 : 25 000 | 308 | 41 | 11 colored |
| General staff of the Czechoslovak People army (1952–1995) | 1 : 25 000 | 316 | 86 | 6 (+1) |
| Basic map of the Czech Republic | 1 : 10 000 | 194 | 26 | 5 (+2 supplementary) |

vectorized were also ZM10 maps in spite of the fact that their digital spatial model exists. The current vector form of maps did not comply with the methodological needs and methods of map processing.

Applicability of vector data thus prepared for the assessment of spatial land use for concrete time lines is very significant. Only in this way, it is possible to acquire comparable data for time lines of the period 1836–2006. The analysis of changes is based on the overlapping of individual vector-processed layers (containing land use polygons) of the respective time periods. Consequently, it is possible to define changes in the respective territories including stable areas and areas with one or more changes.

### 3.3 Principles of vectorization

The authors vectorized areas sized ≥ 0.8 ha. Irrespective of width, watercourses are plotted only as lines in a separate layer of the whole territory of the country. In the vectorization of objects whose interface is formed by linear element (watercourse, road…), the boundary is led in the middle of this linear element. If there are embankments along the watercourse, the spaces between them are not plotted as a polygon. Polygons larger then 0.8 ha have to be of cartographically appropriately selected shape based on the principle of generalization. At places where more polygons below 0.8 ha concentrated, a compact polygon of sufficient size could be created regardless of the actual boundaries of initial elements.

Each polygon was delineated unambiguously and on the boundary of the map sheet it had to link with the polygon in the neighbouring map sheet (in this case, the area of polygon in the map sheet could be even considerably smaller than 0.8 ha; it was necessary to ensure that in the sum with adjacent plots of neighbouring map sheets its area would be equal or larger than 0.8 ha). Each polygon has a code marking for land use and calculated area.

Topographic maps are very valuable source of information of temporal land-use changes. Problem causes the large gap between the 3rd Austrian Military Survey (1876–1880) and the Czechoslovak Military Mapping (1952–1956), where the time interval is 80 years (twice in comparison with the 1st and 2nd Austrian Military mapping). The reason is the lack of the complete map set for the whole territory of the Czech Republic.

### 3.4 Definitions of individual land use categories

For unequivocal inclusion of individual polygons on topographic maps from the period 1763–2006 in to land use categories author defined individual categories of land-use.

*1. Arable land*

Arable land can be generally defined as land used mainly for agricultural production (bothprimary and secondary). In the map, the authors include also buildings and other structures relating to the growing of cereals, legumes, oil crops, root crops and technical crops.

*2. Permanent grassland*

This category includes lands with dominant grass and herbs and areas whose grass cover was modified by human society into meadows or pastures. The category also contains meadows with dispersed tree and shrub vegetation.

### *3. Garden and orchard*

This category includes gardens, orchards, tree nurseries and ornamental gardens. Tree growing and seed producing nurseries and glasshouses are included in this category, too. Within settlements, they are categorized as the Built-up area. As an independent category, the gardens and orchards are mapped outside the built-up area. In the case that there are 1–2 houses in gardens and orchards outside the built-up area on the map, the authors classified the territory in this (3) category. On the maps from the period of the 2nd Austrian Military Survey, this category includes also vegetable and other gardens.

### *4. Vineyard and hop field*

Vineyards are plots on which grapes are grown for the production of wines. Hop fields are important landscape elements with a typical structure (hop poles, wire structures). The category of vineyards and hop fields includes also related objects outside the intravillan of municipalities (e.g. wine cellars inside vineyards or on their margins). In the case that a built-up area links up with a large area of vineyards or hop fields, the authors classified it this category.

### *5. Forest*

Forests are ecosystems constituted primarily by trees grown for purposes including production of timber and other wood-based products. Forest areas have a canopy of ≥10% and contain trees used for the production of stems and other wood-based products; they affect climate and water. In this category, the authors included also structures and buildings directly related to forest management (e.g. hunting lodges, gamekeeper's houses, timber yards etc.). The category also includes windbreaks (distinctly linear strips plotted in green), which occur in map collections after World War II and are more than 40 m wide.

### *6. Water area*

This category includes rivers, brooks, canals and other linear water bodies such as oxbows permanently or temporarily filled with water, lakes, fishponds and other water reservoirs outside the intravillan of residential areas (e.g. fire protection reservoirs or swimming pools), water-filled extraction shafts of quarries, gravel pits and mines. It also includes wetlands with water surface on the ground surface, close to the ground surface or above the terrain level for a significant part of the year. In this they differ from other categories in which the water surface has to be larger than 0.8 ha.

### *7. Built-up area*

#### *i) Built-up area urban*

Residential area used for the construction of dwelling houses and other anthropogenic structures together with the land adjoining the buildings which its use immediately relates to (e.g. squares, parking lots, house gardens etc.).

The authors included also cemeteries in the urban landscape. In the maps of land use, built-up area is plotted as a continuous line of compact developments and against the surrounding landscape it is demarcated as a continuum. In the conditions of the Czech Republic, settlements include also agricultural, industrial and other production sites, areas with facilities providing services, commercial premises and transport terminals adjoining the continuous development. For the classification of a polygons in the category of built-up area, a criterion has to be met of at least 3 houses with the garden (area > 1 ha). If the criterion is not met, the polygon is classified in Category 3 – Garden and orchard.

#### *ii) Built-up area rural*

Small settlement located in a country area and surrounded of arable land. Small settlements show typical sites developing during livestock and poultry rearing. Frequently occurring are village ponds, built usually on village green.

Note. *Due to technical reasons the categories 7 i) and 7ii) are on final maps 1 : 200 000 mapped together as built up areas.*

### *8. Recreational area*

Areas used mainly for recreation and tourism. Regarding the fact that there are various types of recreation, the category is defined in the first place according to the type of use. The authors included in the recreational landscape sports grounds (playgrounds) and recreational facilities outside the intravillan. This is why the category contains both anthropogenic objects (spa resorts, sports stadiums) and areas with the prevailing greenery (e.g. cottage sites and garden colonies, golf greens, zoological gardens etc.).

The category does not include house gardens. They are delineated at places with the concentration of smaller construction works. The size of construction works plotted in the map is 2 × 2.5 mm against the background of orchards or gardens. They are often indicated in the map as a cottage, and the objects have been appearing on maps from the 1970s.

### *0. Other*

This category includes unused land (it may be permanently non-productive, formerly used and now abandoned, mining sites, open-cast and underground mining of minerals and rocks). In open-cast mining, the soil is entirely removed, on the other hand, there are various types of landfills in the territory. The authors include in this category brickworks with attached buildings, loam-, sand- and gravel pits, limekilns with quarries and other mining premises.

This category also includes peat-mining sites, devastated areas outside the intravillan, hydraulic engineering works (pumping objects, distribution reservoirs and water towers etc.), earth embankments of large dam lakes and waste dumps.

## 4 RESULTS

In the first phase of the project were published studies of landscapes changes in the period 1763–2006 based on land-use changes in selected typical regions of the Czech Republic. Mackovčin, Demek, Havlíček and Slavík (2006, 2007) published landscape changes in two contrasted regions – in the Rychlebské hory Mts. and in adjacent Vidnavská nížina Lowland ( 30 sq. km – Mackovčin et al., 2006; Demek et al., 2007). Development of the landscape of Brno agglomeration was studied by Demek et al., 2007 and Mackovčin et al., 877 sq. km (2007, 2008). The study based on changes of land use has shown the high dynamics of Brno suburban landscape. The development of urban landscapes in the Southern Moravia has shown studies of Demek et al. (2008 – 510.28 sq. km) and Havlíček (2008 – 470 sq. km). Especially large dynamics of landscape change was proved in floodplains. The landscape changes in relation to ecological nets and natural condition are presented in studies from Ivančice region (Stránská, 2008), the town of Kuřim (Drobilová, 2007 – 77.11 sq. km), industrial towns of Rosice and Oslavany (Skokanová, Stránská, 2008 – 193 sq. km), in the surroundings of the village Dambořice (Stránská et al., 2008 – 23.21 sq. km) and in the vicinity of the town Chotěboř (Eremiášová, Stránská, 2008 – 13.38 sq. km). Studies of land-use changes in flodplains of rivers Svratka, Dyje and Jihlava have documented the large sensitivity of floodplains and disturbances of ecological connectivity and equilibrium due to training of rivers (Havlíček, 2008 – 84.96 sq. km, Skokanová, 2008 – 430.27 sq. km, Demek et al., 2008 – 80 sq. km). Landscape development in naturally very valuable areas based on topographic maps were studied in National park Podyjí (Skokanová, 2009 – 430.27 sq. km), Protected landscape area Šumava (Eremiášová et al., 2007 – 20 sq. km, Eremiášová, Skokanová, 2008; Lacina et al., 2008 – 15 sq. km). Examples of landcape changes from devastated mining areas in the NW Czechia (Bílina, Tušimice) brings the study of Drobilová (in this issue of the Journal Acta Pruhoniciana – 30 sq. km, 329.36 sq. km).

In the second phase of the project were compiled medium scale land use maps 1 : 200 000. These land use maps is possible to use for evaluation of ecological state of the landscape and its elements incl. territorial systems of ecological stability (Stránská, 2007; Stránská, Eremiášová, 2008). Two maps in the scale 1 : 200 000 were compiled a prepared for printing (sheets M-33-XXIX a M-33-XXXV of total area 4,794.4 sq. km. Totally the area of compiled land use maps of the Czech Republic is 5,444.84 sq. km.

In the third phase will be compiled digital landscape maps in the scale 1 : 200 000.

## 5 DISCUSSION

Content of topographic maps compiled in the period 1763–2006 for military and private use is comparatively rich. Author obtained topographic maps from the University od J. E. Purkyně in the town of Ústí nad Labem, Branch in Most (Dr. Brůna), map collection of the Charles University in Prague (Dr. Jánský), Archive of the Czech Office for Surveying, Mapping and Cadastre in Prague (Dr. Kronus) and Military Geographical and Hydrometeorological Office in Dobruška (Ing. Schubert). Unfortunately some sets were incomplete and for the cover of the whole territory of state it was necessary to obtain missing sheets from other sources (e.g. from Austrian military historical archive in Vienna).

The richness of content of topographic map is the result of map keys content. Authors evaluated number of aflat, point and linear symbols contained in map keys or legend of individual map sheets and prepared its transformation into 10 mapped types of land use. Due to a military reason of maps are many items (e.g. information about constructions, roads, etc.) contained not only on maps but also in explanations, which were in maps of the 1st Military Survey and were used up to beginning of the 20th century (World War I.). The legend to the maps of the 1st Austrian Military Survey was very simplified. Authors prepared from maps of the 1st Austrian Military Survey several examples of map symbols interpretation into 10 mapped types of land-use. These were used in some model areas only. The 2nd Austrian Military Survey used already more map symbols. Authors prepared more than 107 model examples enabling inclusion into types of land-use. Third Austrian Military Survey changed not only character of expression, but also used map key which includes more than 300 flat, point and linear symbols. During mapping many point or supplementary objects were not included into land-use categories due to their small dimensions or unimportance. As already mentioned above some map sets were incomplete and it was necessary to obtain missing sheets from other sources. The boundaries of the new Czechoslovak state (1918) differed from previous historical lands Bohemia, Moravia and Silesia in the frame of Austrian-Hungarian Monarchy. Czechoslovak map set compiled in fifties of the 20th century obtains in map key 316 items, which were changed in following map restorations (1952–1996). Content of these military maps is printed in 6 basic colors. The objection of chosen colors is to receive the best legibility of maps (e.g. of horizontals). The map key of the state map set Basic map of the Czech Republic in the scale 1: 10 000 used by civil sector obtained together 194 items in 1993. The number of item is changed due to number of new objects in the landscape. The map set use 5 basic colors and 2 supplementary. The selection of certain type approaches to order selected flats of map sets into 10 chosen categories was necessary for unified approach in mapping the whole state territory.

## 6 CONCLUSIONS

Use of map keys that were chosen for compilation of land use maps based on military and civil maps from 1763–2006 is not simple. The determination of unequivocality of land-use type and inclusion into certain category of landscape use was the only way in approach to evaluation of 9 mapped units. The amount of map keys was growing up to 316 items without topography (Czechoslovak Military Mapping 1952–1956). Authors have chosen from 1,240 flats, points and linear elements in map keys and legends together 358 types which combined into 9 selected categories of landscape use.

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**Other sources**

1st Austrian Military Survey in the scale 1 : 28 800 (1763), Section No. 39 Mähren, Olomouc and surroundings (Fig. 1).
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# APPLICATION OF METHODOLOGICAL PRINCIPLES FOR ASSESSMENT OF LAND USE CHANGES TRAJECTORIES AND PROCESSES IN SOUTH-EASTERN MORAVIA FOR THE PERIOD 1836–2006

# APLIKACE METODOLOGICKÝCH PRINCIPŮ HODNOCENÍ TRAJEKTORIÍ ZMĚN VYUŽITÍ KRAJINY A PROCESŮ NA JIHOVÝCHODNÍ MORAVĚ PRO OBDOBÍ 1836–2006

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**Abstract**

The article presents several approaches how to assess land use changes in the Czech Republic in the period 1836–2006. Land use changes are studied on the basis of old topographic maps from five time steps. The first approach uses six groups of change trajectories that are calculated on the basis of three indices – turnover, diversity and similarity. Second approach distinguishes seven processes, which occurred between studied time steps. Finally, third approach studies land use changes according to their intensity of landscape exploitation. These approaches are tested on a part of southeast Moravia with different types of landscape and natural conditions. More than 50% of the region was marked as stable with the prevailing stable categories of arable land and forest. The second most common change trajectory was a stepped one and the third quasi stable. Dynamic changes and changes with no clear trend compose only about 10% and are concentrated mainly in the floodplain. Agricultural intensification was most pronounced at the end of the 19th century, with the exception of upland where it peaked in the 1950s. Urbanization occurred along big towns in the floodplain and was most significant in the second half of the 20th century. Afforestation concentrated in areas with poor quality soils in the floodplain and was most common in the second half of the 19th century. Concerning intensity of land use changes, intensification bound to the floodplain and flat areas prevailed, while extensification was less pronounced and was bound to poor quality soils (similarly as afforestation) and steeper areas.

**Abstrakt**

Článek představuje několik přístupů, jak hodnotit změny využívání krajiny České republiky v období 1836–2006. Změny využití krajiny jsou studovány na základě starých topografických map z pěti časových horizontů. První přístup vymezuje šest skupin trajektorií změn, které jsou vypočítány na základě tří indexů – index změny, diverzity a podobnosti. Druhý přístup rozlišuje sedm procesů, které se objevily mezi dvěma časovými kroky. Konečně třetí přístup studuje změny využití krajiny vzhledem k jejich intenzitě využívání krajiny. Tyto přístupy jsou testovány na části jihovýchodní Moravy, ve které jsou rozlišeny různé typy krajiny s různými přírodními podmínkami. Více než 50 % oblasti bylo označeno jako stabilní s převažujícími stabilními kategoriemi orné půdy a lesa. Druhou nejčastější trajektorií změny byla stupňovitá změna a třetí kvazi-stabilní. Dynamické změny a změny bez jasného trendu tvoří pouze 10 % celkového území a jsou koncentrovány především v nivě. Zemědělská intenzifikace byla nejvýraznější na konci 19. století s výjimkou vrchoviny, kde vyvrcholila v padesátých letech 20. století. Urbanizace se objevila v okolí velkých měst v nivě a byla nejvýznamnější ve druhé polovině 20. století. Zalesňování se soustředilo na plochy s půdami s malou kvalitou v nivě a bylo nejčastější ve druhé polovině 19. století. Co se týče intenzity změn využití krajiny, převažovala intenzifikace vázána na nivu a ploché oblasti, zatímco extenzifikace byla méně výrazná a objevovala se v oblastech s nízkou kvalitou půdy (podobně jako v případě zalesňování) a v oblastech s větším sklonem.

**Keywords:** land use, trajectories of change, land use trends, old maps, GIS

## 1 INTRODUCTION

Landscapes can be understood as dynamic and open systems where biophysical, social and economic factors interact and are structured in heterogeneous patterns in different space and time frameworks (Haase et al., 2007; Petek and Urbanc, 2004; Petek, 2002).

Today's cultural landscapes reflect their historic appearance (Petek and Urbanc, 2004). Generally, European landscapes, especially in Central Europe, attained their highest level of ecological and land use diversity during the preindustrial period of mid-19th century (Roweck, 1995 in Bender et al., 2005b). A dramatic change of these landscapes occurred during the second part of the 20th century (Bastian and Bernhardt, 1993; Fjellstad and Dramstad, 1999). These rapid landscape transformations were and still are caused by intensified use of agricultural land and increasing abandonment of marginal areas (Haines-Young et al., 2003 in Hamre et al., 2007). Thus, exact knowledge of historical landscape conditions and of landscape change over time could facilitate and improve predictions about the current and future state of the landscape as well as enable scenarios for future conditions (Marcucci, 2000).

Landscape development and changes can be studied in terms of land use. We can say that land use reflects the close relation between man and nature (Petek and Urbanc, 2004; Bičík and

Chromý, 2006) and its study yields insight in pattern-process relations at landscape level (Zhang et al., 2004). Land use changes also represent one of few quantifiable information about landscape development in a longer period (Bičík and Chromý, 2006). Most outcomes of change analyses are presented as landscape pattern maps or land use/land cover change statistics (see e.g. Demek et al., 2007; Bičík et al., 1996).

The landscape development dynamics can be studied by identification and analysis of trajectories of land use changes (e.g. Swetnam, 2007; Käyhkö and Skånes, 2006; Crews-Meyer, 2004). The focus of land use change trajectory analysis on change as a dynamic process is different from an approach where landscape patterns, i.e. states of a landscape, are observed and measured at any one moment in time. That is why the change trajectories cannot be determined without spatial intersection of data and at least three time steps are needed in order to build a change trajectory (Käyhkö and Skånes, 2006).

Another way to analyse land use changes is to focus on trends and processes that change the landscape only between two time steps (e.g. Bender et al., 2005a; Petek, 2002; Poudevigne et al., 1997; Bender et al., 2005b; Lipský, 1994).

It is also possible to research intensity of land use changes by assigning pre-defined indices to individual land use categories or trends, as was applied by e.g. Olah et al. (2006) or Petek (2002).

The aim of this article is to apply above mentioned methodological principles, mainly those of Swetnam (2007), Olah et al. (2006) and Petek (2002), on the land use data that are being derived from old topographical maps within a research project MSM 6293359101 Research into sources and indicators of biodiversity in cultural landscape in the context of its fragmentation dynamics. Examples here presented cover a part of southeast Moravia, represented by the map sheet M-33-119 (Fig. 1). Other examples of assessment of land use change trajectories and their integration into further landscape studies are discussed in articles from Stránská, Eremiášová published in this issue or Eremiášová and Skokanová (2009) (in review). Intensity of land use changes is also mentioned in the article from Havlíček et al. published in this issue as well.

## 2 STUDY AREA

The study area is located at the southeast Moravia on the border with Slovakia and covers the map sheet M-33-119. Its area is 706.7 km$^2$. It can be divided into four geomorfological units – the Kyjovská pahorkatina hilly land in the northwest and north, the Vizovická vrchovina highland in the east, the Bílé Karpaty mountains in the southeast and the Dolnomoravský úval graben in the centre. We can therefore distinguish two types of relief – flat floodplain in the centre that are surrounded by hilly areas (see Fig. 1). The highest point is situated in the Bílé Karpaty mountains in the southeast with 580 m a.s.l. while the lowest point can be found in the floodplain on the Morava river in the southwest with 153 m a.s.l. The main river that drains the region is the Morava river, going in the northeast – southwest direction with its main tributaries the Kyjovka river (right tributary), Velička river and Svodnice river (both left tributaries).

From the geological point of view, the study area is part of the Alpine-Carpathian foredeep and intermontane basins, the Bohemian Massif and Outer Carpathian and Klippen zone. The Bohemian Massif can be found in the southeast and is represented by variation in gravel, sand and clay of tertiary origin. Tertiary flysh, i.e. variation in sandstones and claystones, is typical for Outer Carpathian and Klippen zone. Alpine-Carpathian foredeep is filled mainly by tertiary clay, sand, gravel and lignite, which are covered by quaternary aeolian sands and floodplain sediments. The prevailing soil type is chernozem and its varieties. The floodplains are covered by gleyic fluvisols or fluvi-gleyic phaeozems, the western part of the Dolnomoravský úval graben by arenosols. Luvisols are located in the Vizovická vrchovina highland in the northeast and cambisols in the Bílé Karpaty mountains in the south. The climate is from west to east very warm to mildly warm with mean annual temperature between 8–11 °C and mean annual precipitation ranging from 450 mm to 800 mm.

Potential vegetation is represented by alluvial woodlands, sub-continental thermophilous oak woodlands in the west, pine-oak woodlands in the centre, Pannonian oak-hornbeam forests and subacidophilous Central-European thermophilous oak woodlands in the east (Neuhäuslová et al., 2001). Special protected area Bílé Karpaty, which is also a biosphere reserve, partly occupies the southeast and there are 15 small scaled protected areas distributed more or less evenly throughout the study region.

## 3 MATERIALS AND METHODS

The analysis of land use changes, or generally of cultural landscape changes, is based on a variety of sources, including topographic and old (historical) maps, aerial and satellite photographs, land registers with geodetic survey maps and land plot records as well as various statistical and archival data (Bender et al., 2005b). The advantages and disadvantages of these sources were pointed by the author elsewhere (e.g. Skokanová et al., 2007; Skokanová et al., 2009).

Five map datasets in medium to large scale; from mainly military surveys were used for the derivation of land use data. They represent periods of 1830s, 1880s, 1950s, 1990s and 2000s. Their overview together with their positional error is stated in Tab 1.

All topographic military maps were scanned. Maps from the first two periods were rectified in a MATCART program (Brůna et al., 2002; Čada, 2006); maps from 1950s and 1990s were rectified according to control points represented by corners of map sheets created for the military topographic survey. Topographic base maps were obtained in their digital form. Czechoslovak topographic base maps from the 1990s were used as a complimentary source of the military topographic maps as these significantly underestimate area of permanent grassland.

On the basis of legends to these datasets, nine land use

**Tab. 1 Map sources and their characteristics**

| Period | Name | Date of creation | Scale | Positional error |
|---|---|---|---|---|
| 1830s | 2nd Austrian Military Survey | 1836–1852 | 1 : 28 800 | 11–30 m |
| 1880s | 3rd Austrian Military Survey | 1876–1880 | 1 : 25 000 | 13–30 m |
| 1950s | Czechoslovak military topographic maps | 1952–1955 | 1 : 25 000 | 10–15 m |
| 1990s | Czechoslovak military topographic maps | 1988–1995 | 1 : 25 000 | 10–15 m |
| | Czechoslovak topographic base maps (ZABAGED 2) | 1982–1996 | 1 : 10 000 | 5–10 m |
| 2000s | Czech topographic base maps (ZABAGED) | 2002–2006 | 1 : 10 000 | 5–10 m |

categories were distinguished: 1 – arable land, 2 – permanent grassland, 3 – orchard, 4 – vineyard and hop-field, 5 – forest, 6 – water area, 7 – built-up area, 8 – recreational area and 0 – other area. These categories are defined as follows:

1) Arable land is represented by cultivated fields with crops, technical crops, root-crops, corn, legumen, oilseeds etc.
2) Meadows and pastures with wetlands, scattered green, steppes, heath, moor and reed are included in permanent grassland.
3) Orchards are vectorized as a separate category mainly outside the residential area. However, they are also distinguished in the case when they border with built-up area but the length of this border is smaller than length of the side which stretches into the landscape. Also if one or two buildings are surrounded by large garden, they belong to this category. Furthermore, vegetable gardens distinguished on the 1830s maps are a part of orchards.
4) Vineyards and hop-fields include related objects outside residential area (e.g. wine cells within or at the edges of the vineyards).
5) Forests include besides coniferous, deciduous and mixed forests dwarf pines, arboreta, game parks and parks outside built-up area, continuous shrub vegetation adjacent to forests, wind-breaks with width larger than 40 m and their occurrence during at least two following time steps, pheasantries and forest management facilities.
6) Water area is represented by ponds, lakes, reservoirs outside built-up area, quarries and gravel pits filled with water and oxbow lakes.
7) Built-up area incorporates residential area, gardens, or water areas surrounded by residential area, industrial and agricultural complexes, air fields, train stations, petrol stations, large interchanges, military objects, castles, fortresses, power stations, chateaus, graveyards, glass houses, medical institutions and parking slots.
8) In recreational area, there are swimming pools with facilities, sports areas and stadiums, race and golf courses, baths, zoos, playgrounds, garden colonies and second houses.
9) Finally, other area includes ruins, quarries, gravel pits, brickworks, waste deposits and large bulk dams.

The maps were manually vectorized in the ArcGIS software. Only areas larger than 0.8 ha and wider than 40 m were vectorized regarding the output scale, which is 1 : 200 000. Vector data, which were derived from the maps, were overlaid. As a result, GIS database for further analyses was created. However, this database had to be adjusted first because by overlaying the vector data sliver polygons were produced. These polygons might distort mainly visual results whereas quantitative results could be modified only up to 3% of one map sheet in the scale 1 : 25 000, depending upon complexity of the landscape (see also Skokanová, 2008). This number can be considered rather insignificant with respect to the output scale. Nevertheless, the sliver polygons were eliminated with the use of tools in the ArcGIS software according to the predefined criteria (the area is less than 5 000 m and the width is less than 10 m). These criteria were chosen on the basis of series of tests conducted at author's workplace.

To analyse land use changes dynamics by change trajectories, a method called stability mapping was used. This process systematically identifies those areas which have been most prone to land use change and is based on calculation of three indices that altogether distinguish six classes of land use change trajectories (Swetnam, 2007).

The three indices identifying class of land use change trajectory are similarity, turnover and diversity. Similarity captures information about the dominance of any one category at a particular location throughout the period. Turnover records how many changes occurred between adjacent pairs of years. And diversity is simply the number of different categories recorded for the five time steps (Swetnam, 2007). The six land use change trajectory classes derived from the combination of these indices are: stable, quasi-stable, stepped, cyclical, dynamic and no constant trend (NCT) (Tab. 2).

Stable class records the same land use category in each of time steps. Quasi-stable class reflects the dominant trend with only one change of category. Stepped class indicates those locations where there had been one point of change between two dominant categories. Frequent change between just two categories indicates cyclical class, while frequent change among more than three categories is classified as dynamic class. The last class with no constant trend (NCT) means that the land use categories changed several times during the researched period but this change has been variable.

By comparing land use changes between two adjacent time steps, six types of processes were distinguished: afforestation – changes of land use categories into forest; grassing over

**Tab. 2 Combination of the three spatial indices (turnover, diversity and similarity) in order to derive the change trajectory classes**

| Turnover | Diversity | Similarity | Class | Example |
|---|---|---|---|---|
| 0 | 1 | 5 | Stable | AAAAA |
| 1, 2 | 2 | 4 | Quasi-stable | ABAAA |
| 1 | 2 | 3 | Stepped | AABBB |
| 2, 3, 4 | 2 | 2, 3 | Cyclical | ABABA |
| 3, 4 | 3, 4, 5 | 1, 2 | Dynamic | CABBA |
| 2, 3 | 2, 3 | 3 | NCT | ABBBA |

– changes of land use categories into permanent grassland; agricultural intensification – land use categories change into arable land, orchard or vineyard and hop-field; urbanization – changes of land use categories into built-up area, recreational area or other area; water regime optimalization – land use categories change into water area; steady trend – occurs when there is change between categories in the intensification or urbanization processes; and stable areas – there has been no change during the two time steps. The first four types of processes correspond to some extent with those distinguished by Medved 1970 (in Petek, 2002).

To assess intensity of land use changes, a modified method from Olah et al. (2006) was used. It consists of several steps. Firstly, the land use categories were grouped according to their intensity of landscape exploitation and were assigned coefficients: Built-up area and other area representing the most exploited categories were assigned the highest number (5), then arable land (4), orchard, vineyard and recreational area (3), permanent grassland and water area (2), and forest (1). Secondly, relative intensity of land use changes between adjacent time steps was calculated by extracting coefficients from older to newer time step. Finally, all derived changes were summed up. The polygons with negative intensity of land use change represent the areas with land use extensification; polygons with positive intensity represent the areas with intensification of land use (Olah et al., 2006). Polygons where intensity was calculated as zero and that do not correspond with stable areas were marked as "balanced".

## 4 RESULTS

Trajectories of change, processes as well as intensity of land use changes were assessed for the study region as a whole and within its three parts – hilly land in the west, floodplain in the centre and upland in the east.

More than 50% of the study region has been stably used, i.e. the use did not change, during the last 170 years. Stable categories are mainly those of arable land (26.9%) and forest (14.9%) but also of permanent grassland and built-up area, with some traces of vineyards, orchards and water areas. Concerning the three parts, both hilly land and upland have the proportion of stably used areas higher than the whole region (61.3% and 62.2% respectively), while stably used areas in the floodplain covers only 45.0%. In this part, the main stable categories are forests (51.8%), represented by large complexes in the centre and southwest, and arable land (38.4%), with smaller extent of permanent grassland and built-up area. On the contrary, in the hilly land and upland the prevailing stably used category is arable land, which in the case of the hilly land reaches up to 82.5% of the area of the stable category; in the case of upland it is 69.7%. The second most widespread stable category in both regions is forest with 9.4% for the hilly land and 17.5% for the upland respectively. Trajectories of change and their proportion are shown in Tab. 3, their spatial distribution in Fig. 2.

Stepped change, recording a clear change between one land use class and another, is the second most common change trajectory in all parts of the study area, with dominance in the floodplain, and also in the whole region. It is associated predominantly with changing farm management, mainly switch between arable land and permanent grassland, but also with urbanization. Changing farm management prevails in the floodplain, especially along the Morava and Kyjovka rivers, while urbanization occurs around towns situated on the edges of the floodplain, which mainly fall into the upland. The exception is urbanization in the surroundings of Hodonín town that is located in the floodplain.

The third most common change trajectory is quasi-stable, meaning that the change occurred at the beginning or the end of the researched period. This class also dominates in

**Tab. 3 Trajectories of change and their proportion (%) in the study region and its parts**

| Trajectory | Floodplain | Hilly land | Upland | Whole region |
|---|---|---|---|---|
| Stable | 45.0 | 61.3 | 62.2 | 52.8 |
| Quasi-stable | 15.7 | 9.1 | 11.4 | 13.4 |
| Stepped | 21.3 | 15.1 | 13.0 | 17.8 |
| Cyclical | 5.3 | 7.8 | 6.3 | 6.0 |
| Dynamic | 1.7 | 0.8 | 1.0 | 1.3 |
| NCT | 11.1 | 5.8 | 6.1 | 8.8 |

the floodplain where larger areas change mainly into forest (in the centre of the part) and into arable land (southwest of Hodonín town and in the north). In the upland, the larger areas change mainly into arable land; and the hilly land shows only small areas that are associated with this type of trajectory.

Cyclical change trajectory is typical for hilly land and upland and is bound mainly to agricultural fields on slopes. It reflects a mixed farming profile, which includes switches between arable land and permanent grassland or arable land and vineyards. Dynamic change trajectory combines elements of high turnover with high diversity and is rather scarce as is clear from the Tab. 3. It occurs especially along the Morava and Kyjovka rivers in the floodplain.

Finally no clear trend (NCT) trajectory shows those areas that have experienced some turnover but not as frequently as the dynamic areas. If we sum up the dynamic and NCT classes, we can clearly see that floodplain has been the most dynamic part of the study region. The changes occurred mainly between permanent grassland, forests and arable land in the vicinity of municipalities.

Processes that were detected in the whole region and its parts were assessed for four periods corresponding with data from five time steps – second half of the 19$^{th}$ century, first half of the 20$^{th}$ century, second half of the 20$^{th}$ century and the turn of the 20$^{th}$ and 21$^{st}$ century. If we consider stable areas, their proportions are bigger than those of stable areas derived from change trajectories. This fact itself shows to some extent the dynamics of the landscape and means that it is necessary to look not only on a research period as a whole but also to study changes and processes within this period.

The most dynamic period appears to be the first half of the 20$^{th}$ century as only 75,7% (for floodplain) to 84,8% (for upland) of the respective area was stable. On the other hand, the turn of the 20$^{th}$ and 21$^{st}$ century shows proportion of stable areas bigger than 90%.

Agricultural intensification was most pronounced process in the second half of the 19$^{th}$ century, which corresponds with the general trend of agricultural intensification in the Czech Republic (Bičík et. al., 2001). It occurred mainly along rivers and afflicted mainly the floodplain. In this part the proportion of areas where agricultural intensification was detected changed very little until the 1990s and then decreased. Concerning the spatial distribution of these areas, it was different in all four periods as can be seen in Fig. 3. While in the hilly land the intensification prevailed until 1950s (when it reached its peak) and then the proportion of areas with this process significantly dropped, the upland showed steady decrease during the whole research period.

Afforestation was most common in the floodplain in the second half of the 19$^{th}$ century and was bound to the poor quality soils in this part. In the following period this process spread southward. Afforestation in the hilly land and upland played less important role than in the floodplain. Both parts have been intensively agriculturally used, as can be clear from the proportion of stable category of arable land (see above), due to the favourite natural conditions. However, it does not mean that the upland did not have any forests at all as there was quite a large stable forest complex in the southern part. The proportion of areas affected by afforestation gradually decreased to the minimum at the turn of 20$^{th}$ and 21$^{st}$ century. It was typical for all parts of the study region. Generally we can say that afforestation occurred on the plots adjacent to the steady forested areas.

Urbanization took part mainly in the 20$^{th}$ century and was most intensive in its second half. It was bound especially to the towns located on the Morava river – Hodonín, Strážnice, Veselí nad Moravou and Uherský Ostroh. This process corresponds with industrial development of these towns and state policy practiced in the period in question.

Changes within agricultural intensification and urbanization were marked as a steady trend. The first group prevails, while the second group is of a lesser extent. This is logical due to the agricultural character of the study region. The trend was typical mainly for both hilly land and upland and was most pronounced in the second half of the 20$^{th}$ century when large-scale vineyards and orchards were established on arable land.

Concerning water balance optimalization, it was not a very significant trend and occurred especially in the floodplain. It included restoration of ponds that were dried at the end of the 19$^{th}$ century, mainly along the Kyjovka river.

The intensity of land use changes to some extent indicates the rate of landscape exploitation. As can be seen from the Tab. 4 and Fig. 4, intensification prevails in all three parts. It dominates in the floodplain but also in the upland. Intensively used areas are concentrated along the rivers and in the vicinity of settlements.

The extensively used areas in the floodplain and hilly land are mostly connected with poor quality soils while in the upland it is with steeper slopes in the southern part. Balanced areas have the biggest proportion in the hilly land. They can be found in the south, northwest of Mutěnice and Svatobořice villages, and north of Vracov and Bzenec towns in this part, in the south and east of the upland, and along the Kyjovka between Hodonín and Dubňany towns in the floodplain.

**Tab. 4 Relative land use change intensity (%) in the study region as a whole and its three parts**

| Intensity | Floodplain | Hilly land | Upland | Whole region |
|---|---|---|---|---|
| Intensification | 32,0 | 18,4 | 21,1 | 26,6 |
| Extensification | 16,0 | 12,1 | 9,4 | 13,4 |
| Balanced areas | 7,0 | 8,1 | 7,3 | 7,2 |
| Stable areas | 45,0 | 61,3 | 62,2 | 52,8 |

## 5 DISCUSSION

The big proportion of stable categories of arable land and forest is not an exception as it was found elsewhere in the Czech Republic, especially in South Moravia (e.g. Demek et al., 2007; Skokanová et. al., 2009). However, the situation, when stable forests dominate in the floodplain and not in the hilly land or the upland, is somewhat different from the above mentioned regions. Here it clearly reflects relation between land use and natural conditions: forest complexes in the floodplain are bond mainly to poor quality soils (arenosols and gleyic fluvisols) that can be found only in this part, whereas hilly land and upland are covered by soils with better quality.

As for other change trajectories, findings concerning stepped change trajectory correspond with those of Swetnam (2007) who also found stepped change associated with changing farm management in the lowlands of England and also cyclical change in the hilly land and upland reflecting mixed farming profile is similar to the results from this author recorded for site 1 (a lowland grassland landscape in the south-western England). On the other hand, other her findings concerning association of cyclical change with forestry were not found here.

Although quasi stable change trajectory is the third most common trajectory in the region, it must be stressed out that this change class is strongly restricted by the research period because if the beginning or the end of the period is shifted, the class can change into a stepped change trajectory.

If we assess processes between two adjacent periods we must be careful with handling the results. It is because the four periods differ in their length and especially the first half of the 20th century is the longest one while the turn of the 20th and 21st century is the shortest. This is prominent when evaluating stable trend and intensification. Unfortunately the availability of land use data based on medium scale map sources prohibits eventful division of the time periods.

Spatial distribution of intensively and extensively used landscape in the study region is not surprising as it to some extent follows a von Thünen theory of spatial distribution of different land uses according to the distance, and thus economic yields, from a settlement (see e.g. Olah, 2003; Hoover and Giarratani, 1999).

## 6 CONCLUSIONS

Studying land use and its changes on the basis of old topographic maps and/or remote sensing data enables detection of spatial distribution of these categories as well as their processes. It is different from summary statistics that conceals the amount of dynamism within a site.

The article shows that here presented approaches, especially those concerning land use change trajectories and processes, can reveal processes that occurred during a longer period and also implies that these processes can act contradictorily during the time. It is clear from the results that the land use changes depend not only on socio-economic driving forces but also on natural conditions, which play an important role especially in agricultural landscapes. It is necessary to emphasise that the results from analyses are still only approximations and generalisation of a complex reality as was already pointed out by Käyhkö and Skånes (2006). Nevertheless, with studying driving forces that are behind these processes, these results can help to some extent predict future land use changes at specific sites. Another significant use of these approaches can be in the field of restoration ecology and/or landscape planning.

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# LANDSCAPE CHANGES IN THE DYJSKO-SVRATECKÝ ÚVAL GRABEN AND DOLNOMORAVSKÝ ÚVAL GRABEN IN THE PERIOD 1764–2009 (CZECH REPUBLIC)

# ZMĚNY KRAJINY DYJSKOSVRATECKÉHO A DOLNOMORAVSKÉHO ÚVALU V OBDOBÍ 1764–2009

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**Abstract**

Authors deal in the paper with the analysis and assessment of landscape changes in Grabens Dyjsko-svratecký úval and Dolnomoravský úval on the border among Czechia, Slovakia and Austria. A source of information for studying changes of cultural landscapes in the period 1764–2009 was the computer aided analysis of historical and current topographic maps on scales 1 : 28 800, 1 : 25 000 and 1 : 10 000 from 1764–2006 combined with the study of aerial photographs and field research. The method used for studying landscape changes by means of studying land use changes makes it possible to quantify the landscape changes in the period studied, to establish the number of changes, to characterize stable elements in the landscape and to characterize trends in landscape development.

**Abstrakt**

Autoři se v tomto příspěvku zabývají analýzami a hodnocením změn krajiny v Dyjsko-svrateckém a Dolnomoravském úvalu, které leží při hranicích mezi Českou republikou, Slovenskem a Rakouskem. Zdrojem pro informace o studiu změn v kulturní krajině v období 1764–2009 byly počítačově podporované analýzy starých a současných topografických map v měřítku 1 : 28 800, 1 : 25 000 a 1 : 10 000 z let 1764–2006 v kombinaci se studiem leteckých snímků a terénním šetřením. Metody použité pro sledování změn v krajině pomocí studia změn využití ploch umožňují kvantifikovat změny v krajině pro jednotlivá období, stanovit počet změn ve využití ploch, charakterizovat stabilní prvky v krajině a zjistit trendy ve vývoji krajiny.

**Keywords:** Czech Republic, changes of cultural landscapes, computer aided land-use analysis, land-use maps, Dyjsko-svratecký úval Graben, Dolnomoravský úval Graben

## 1 INTRODUCTION

The current interest of scientists and general public in landscape follows out both from the rapid changes of the European cultural landscape in the last centuries and from the development of landscape ecology as a scientific discipline on the boundary between geographic and biological disciplines. Contribution to progress in learning the landscape development was the boom of methods for landscape visualization by means of computer technique, especially methods of geographic information systems (GIS). In the article, the authors deal with the analysis and assessment of changes in the old lowland residential landscapes of the Dyjsko-svratecký úval Graben and Dolnomoravský úval Graben on the border among the Czech Republic, Slovakia and Austria. The Dyjsko-svratecký úval Graben was colonized by mammoth hunters 25,000 years B.C. The Neolithic agricultural revolution that started ca. 5,300 years B.C. represented the first historical milestone in the development of the South-Moravian cultural landscape. In the 9$^{th}$ century, the two Grabens constituted a core of the Great Moravian Empire. However, the most profound landscape changes occurred in the 20$^{th}$ century due to the sprawl of residential landscapes and industrialization of agriculture.

The target of the paper is to quantitatively evaluate landscape development in two large Central European landscape ecological units in the borderland among Czechia, Slovakia and Austria based on computer-aided analysis of large-scale historical topographic maps in the 19$^{th}$ and 20$^{th}$ centuries. The digital quantitative cartographic and explanatory description methods of study of land-use changes were used for this aim. However, in contrary to the most other Czech landscape-ecological studies, authors present digital quantitative analyses of large landscape ecological units, dynamics of cultural landscape changes in several time sections and trajectories of landscape changes.

Different approaches are applied during studies of long term changes in land-use studies – method based on elaboration of statistical data, method using historical data and other sources, land-use maps based on aerial and space images, land-use maps based on medium-scale topographic maps and large-scale cadastral maps.

From statistic data base it is possible to use for instance central evidence of flats incl. their use, historical evidences of properties of individual estates etc. This approach use statistical method especially the group of Ivan Bičík from the Charles University in Prague which posses huge historical database of land-use in cadastral areas of the Czech Republic in periods 1845, 1848 and 1990 (Bičík et al., 2001, 2003). In Germany for instance used statistical method Bender, Boehmer, Doren, Schumacher (Bender at al., 2005), in

Slovenia Petek, Gabrovec, Kladnik (Petek, 2002; Gabrovec, Kladnik, 1997), in Poland Lowicki (Lowicki, 2008).

Methods of land-use studies based on remote sensing (aerial and space images) are time-limited for the period after 1930. Nevertheless, this method is often used for studies of landscape changes, especially due to common renewal of data (Alberti et al., 2004; Groom et al., 2006; Milanova et al., 1999; Guth, Kučera, 1997; Cardille, Foley, 2003). Data obtained from the remote sensing sources are sometimes combined with information obtained from historical topographic maps. Unified approach is used during elaboration of maps of Corine Land Cover using as base satellite images in Europe (Feranec, Oťaheľ, 2001, 2003).

Detailed information about the landscape structure in the time of their origin is contained in large-scale topographic maps. The most useful source for evaluation of landscape development in individual cases is the stable cadaster as comparable map work, which covers the whole territory of Bohemia, Moravia and Silesia and its content enables to define landscape structure with a high precision. The problem is, that saved copies of individual map versions often differ in scale, quality and state of preservation. For the landscape studies are the most suitable so called Stabile Cadastre Obligatory Imperial Prints. These maps are copies of original maps made directly in the field in the scale 1 : 2 880, resp 1 : 1 440 in years 1826–1843 (Bohemia) and 1824–1836 (Moravia and Silesia).

Computer aided analysis of medium-scale topographic maps enable topographically precise studies of landscape changes from the half of the 19th century. In the Central Europe is common use of Austrian and Hungarian military surveys. The advance of analysis of the medium-scale maps lays first in its use for landscape changes studies of larger or middle land units and second in possibility to study landscape development in several temporal sections (Haase et al., 2007; Swetnam, 2007; Palang et al., 1998; Jordan et al., 2005; Tasser et. al., 2007; Boltižiar, 2007; Demek et al., 2008; Jurnečková, Kolejka, 1999; Kilianová, 2001; Lipský, 1999, 2007; Pucherová et al., 2007; Skokanová, Stránská, Malach, 2007).

The research project MSM 6293359101 Research into sources and indicators of biodiversity in cultural landscape in the context of its fragmentation dynamics, is solved by research workers of the Department of the Landscape Ecology and by Department of GIS Application of The Silva Tarouca Institute for Landscape and Ornamental Gardening, Pub. Res. Inst., in Průhonice since 2005. One part of this project is dealing with quantitative changes in landscapes of the Czech Republic. The main objective of the project is the compilation of the complete set of land-use maps of the whole territory of the Czech Republic in five temporal sections 1836–1852, 1876–1880, 1952–1956, 1888–1994 and 2002–2006.

## 2 STUDY AREA

The Dyjsko-svratecký Graben represents the westernmost part of the Carpathian Foredeep in the Czech territory at the border with Austria. The N-S and W-E axes of the Dyjsko-svratecký Graben are formed by the Dyjsko-svratecká niva Floodplain of the Dyje (Thaya) R. and Svratka R. The floodplain is flanked by low hilly lands composed of Neogene and Quaternary sediments (Fig. 1). In the Southeast, there is the Věstonická brána Gateway, connecting the depression of the Dyjsko-svratecký úval Graben with the Dolnomoravský úval Graben. The Dolnomoravský úval Graben is a northern spur of the Vienna Basin. The axis of the Dolnomoravský úval Graben is formed by the broad Dyjsko-moravská niva Floodplain of Dyje and Morava Rivers. The Dyjsko-moravská niva Floodplain is flanked by low hilly lands on Neogene and Quaternary sediments, too. In the northern section of the Dyjsko-svratecký úval Graben, there is a city of Brno agglomeration with urban landscape considerably changed by anthropogenic activities. Historic settlements occur in the Dolnomoravský úval Graben, too (Uherské Hradiště, Hodonín and Břeclav). Although the two Grabens show predominantly the landscape of agricultural character, the Dolnomoravský úval Graben features extensive forest areas (both in low hilly lands and in the Dyjsko-svratecká niva Floodplain – Fig. 6). Between the town of Valtice and village of Lednice, there is a scenic reserve of the Lednice-Valtice Area with the landscape composition including a system of fishponds and historical structures. The southern section of the Dolnomoravský úval Graben is reached by the Pálava Protected Landscape Area (Pálava PLA) and by the Biosphere Reserve of Dolní Morava (Lower Morava R.). The studied territory occupies an area of 2,417 km$^2$ – the Dyjsko-svratecký úval Graben 1,454 km$^2$ and the Dolnomoravský úval Graben 963 km$^2$.

## 3 MATERIALS AND METHODS

A total of 9 basic land use categories were monitored: 1 – arable land, 2 – permanent grassland, 3 – garden and orchard, 4 – vineyard and hop field, 5 – forest, 6 – water area, 7 – built-up area, 8 – recreational area, 0 – other area. A primary source of information for studying landscape changes in 1764–2009 was the analysis of historical and current topographic maps on scales 1 : 28 800, 1 : 25 000 and 1 : 10 000 from 1764–2006 combined with the study of aerial photographs and field research. Maps from the 1st Austrian Military Survey were assessed manually. Starting with maps from the 2nd Austrian Military Survey, all other maps were assessed quantitatively by means of computer-aided analysis in GIS environment using software ArcGIS 9.1 and ArcView 3.3. Based on these groundworks, digital maps of land use were created for 1836, 1876, 1955, 1995 and 2006. The analysis lies in overlaying vectorial maps and in calculation of the number of land use changes for the whole researched period. Scale of the changes ranges from 0 (no change) up to 4 (maximum possible change), when analyzing five maps. By superimposing all the five land use mapping datasets, we obtained a five-point code which indicates the overall type of land use changes. Synthetic maps for the first time i) quantitatively show dynamics of landscape changes, ii) stable plots in the landscape, iii) enables to find out trends in the landscape development in the area under study in the period 1836–2006. The information obtained from the historical topographic maps was further complemented with literary data. Explanatory description method was used for reasoning of landscape evolution.

# 4 RESULTS

### 4.1 Land use changes in the Dolnomoravský and Dyjsko-svratecký Grabens in the period 1836–2006

Maps from the 1st Austrian Military Survey of Moravia in 1764–1768 provide on a scale of 1 : 28 800 a unique image of landscape at the beginning of agricultural revolution and before changes induced by industrial revolution. Maps from the 1st Austrian Military Survey were assessed manually.

Landscape structure and situation in the landscape of the first half of the 19th century are well depicted in topographic maps from the 2nd Austrian Military Survey on a scale 1 : 28 800, which was carried out in Moravia in 1836–1841. The maps had already the triangulation network and can be georeferenced and further computer-processed. Results from the quantitative assessment of land use are presented in Tab. 1 and Fig. 2.

In the assessment of landscape structure and landscape development in the second half of the 19th century, the authors made use of maps from the 3rd Austrian Military Survey, which was carried out in Moravia in 1875–1877 on a scale 1 : 25 000. The period between the Second and Third Military Survey was the period of a very rapid development of the cultural landscape, which experienced far-reaching changes. Size of areas in which the land use changed was 18.12% in the Dyjsko-svratecký úval Graben and 20.37% in the Dolnomoravský úval Graben (Tab. 1 and Fig. 3).

No integral set of large-scale topographic maps exists for the first half of the 20th century that would make it possible to follow the landscape development continually. In this relatively long period of landscape development (1875–1953), the size of land use changes amounted to 18.26% of area in the Dyjsko-svratecký úval Graben and 22.53% of area in the Dolnomoravský úval Graben (Tab. 1 and Fig. 4).

Czechoslovak military maps from 1991–1992 document the growing urban landscape in Brno and suburban landscape in the town's surroundings with the increasing size of built-up areas in the floodplains (Tab. 1 and Fig. 5). Land use and landscape changes were more pronounced in the Dolnomoravský úval Graben where the size of area with land use changes in a relatively short period 1953–1992 was 23.09%, Dyjsko-svratecký úval Graben only 16.67%.

Maps of the Czech Republic scaled 1 : 10 000 – the detailed maps show a rapidly increasing built-up area, which reached its historical maximum (Tab. 1 and Fig. 6). The landscape changes were once again more intensive in the Dolnomoravský úval Graben than in the Dyjsko-svratecký úval Graben.

### 4.2 Total number of landscape changes

Comparison of all 5 map sets has shown that in the Dolnomoravský úval Graben the land-use changed on 51.99% of the territory (Fig. 7), on 32.34% plots changed land-use 1 time, on 14.02 % changed twice, on 4.90% changed three times and on 0.72% plots changed four times. In the Dyjsko-svratecký úval changed land-use on 39.01%, that is 13% less than in Dolnomoravský úval Graben (22.32 % only one change, 12.10% twice, 3.89% three times, 0.70% four times). The result is that the landscape of the Dyjsko-svratecký úval Graben is more stable than the landscape of Dolnomoravský úval Graben.

### 4.3 Trajectories (trends) of changes

The applied GIS method enables to found trends of changes. The most common trend in the Dolnomoravský úval Graben is connected with intensification of agriculture – code 22211 – ploughing up of meadows in the periods 1953–1955 and 1991–1992 (4.80% of the total area). In the Dyjsko-svratecký úval Graben the trend was the same, but the processes occurred earlier among 1836–1841 to 1875–876 (code 21111 on 4.67% of the territory). Next trends of changes in the Dolnomoravský úval Graben: code 25555 process of forestation (2,77% of the total area), code 11177 urbanisation (1,62% of the total area) and code 11777 urbanisation (1,15% of the total area). Next trends of changes in the Dyjsko-svratecký úval Graben: code 11177 urbanisation (2,09% of the territory), code 11117 urbanisation (0,52% of the territory), process of deforestation code 51111 (0,97% of the territory).

### 4.4 Stable plots

In the Dolnomoravský úval Graben 48.01% of the territory shows stable use (Fig. 8). The most stable category of land-use is arable land. Stable plots in the Dolnomoravský úval Graben: arable land (25,285 ha), forest (16,616 ha), built-up area (1,831 ha), permanent grassland (1,786 ha), water area (462 ha), vineyard and hop field (228 ha), orchard (14 ha). Dyjsko-svratecký úval Graben 60.99% of the territory was stable, also mostly arable land. Stable plots in the Dyjsko-svratecký úval Graben: arable land (83,652 ha), forest (2,276 ha), built-up area (2,274 ha), vineyard and hopfield (332 ha), permanent grassland (177 ha), orchard (7 ha) water area (3 ha). The detail digital large scale maps of stable plots are very important renewal ("restauration") landscape ecology.

# 5 DISCUSSION

### 5.1 Landscape structure in the 18th century

Maps from the 1st Austrian Military Survey of Moravia in 1764–1768 provide on a scale of 1 : 28 800 a unique image of landscape at the beginning of agricultural revolution and before changes induced by industrial revolution. In these maps, Brno is illustrated as a baroque fortified place enclosed in massive ramparts. Similarly, Uherské Hradiště in the Dolnomoravský úval Graben is plotted as a fortified town in the Dolnomoravská niva Floodplain (a part of the Dyjsko-moravská niva Floodplain) embanked between the channels of the Morava River, its tributary Olšava R. and water-filled ditches.

In the floodplains, rivers flanked by floodplain forests, meadows and ponds freely meandered and anastomosed. Typical was a considerably high number of fishponds including fishpond systems. In the Dyjsko-svratecký úval Graben, the systems of fishponds occurred namely near the town of Pohořelice, at Měnín and in the Dunávka River valley. In the Dolnomoravský úval Graben south of the town

**Tab. 1 Land use changes in the Dolnomoravský and Dyjsko-svratecký Grabens in the period 1836–2006**

| **Dolnomoravský úval Graben** | | | | | | |
|---|---|---|---|---|---|---|
| | | **1836–1841** | **1875–1876** | **1953–1955** | **1991–1992** | **2002–2006** |
| 1 | Arable land | 38.06 | 46.46 | 49.61 | 49.26 | 49.52 |
| 2 | Permanent grassland | 32.00 | 22.96 | 14.95 | 6.92 | 5.70 |
| 3 | Garden and orchard | 0.67 | 0.50 | 0.87 | 1.44 | 1.78 |
| 4 | Vineyard and hop field | 1.62 | 1.24 | 1.26 | 2.83 | 2.36 |
| 5 | Forest | 23.86 | 25.42 | 26.46 | 26.51 | 27.09 |
| 6 | Water surface | 1.42 | 0.74 | 1.21 | 3.41 | 3.57 |
| 7 | Built-up area | 2.35 | 2.67 | 5.42 | 9.14 | 9.47 |
| 8 | Recreational area | 0.00 | 0.00 | 0.03 | 0.26 | 0.31 |
| 0 | Other areas | 0.01 | 0.01 | 0.19 | 0.23 | 0.18 |
| TOTAL | | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| **Dyjsko-svratecký úval Graben** | | | | | | |
| | | **1836–1841** | **1875–1876** | **1953–1955** | **1991–1992** | **2002–2006** |
| 1 | Arable land | 74.08 | 81.57 | 82.05 | 77.10 | 75.86 |
| 2 | Permanent grassland | 14.43 | 7.76 | 2.82 | 1.00 | 1.55 |
| 3 | Garden and orchard | 0.46 | 0.60 | 1.60 | 2.02 | 1.75 |
| 4 | Vineyard and hop field | 3.75 | 3.16 | 1.80 | 2.76 | 2.55 |
| 5 | Forest | 4.85 | 4.35 | 6.15 | 6.34 | 7.18 |
| 6 | Water surface | 0.21 | 0.03 | 0.58 | 1.96 | 1.89 |
| 7 | Bulit-up area | 2.21 | 2.52 | 4.85 | 8.19 | 8.50 |
| 8 | Recreational area | 0.00 | 0.00 | 0.06 | 0.39 | 0.39 |
| 0 | Other areas | 0.00 | 0.01 | 0.09 | 0.25 | 0.33 |
| TOTAL | | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

**Tab. 2 River bed length changes (km) in the studied area in the course of time**

| **River** | **1836** | **1876** | **1944** | **1954** | **1991** | **2007[3)]** |
|---|---|---|---|---|---|---|
| Svratka | 52.50 | 44.62 | 40.25 | 40.21 | 35.33 | 36.75 |
| Cézava | 28.24 | 26.48 | -----[4)] | 24.46 | 24.41 | 24.48 |
| Jihlava | 26.32 | 25.20 | 25.36 | 25.55 | 24.52 | 24.97 |
| Dyje | 68.39 | 67.14 | -------[4)] | 61.46 | 59.11 | 60.15 |
| Jevišovka | 31.82 | 32.36 | -------[4)] | 31.79 | 31.46 | 31.49 |
| Morava[1)] | 145.53 | 144.51 | -------[4)] | 112.12 | 97.292) | -------[4)] |

[1)] from Napajedla up to the confluence with the Dyje River (Kilianová, 2001)
[2)] 1999 (Kilianová, 2001)
[3)] mapping scale 1 : 10 000
[4)] --------- data not available

of Uherské Hradiště, there were two large fishponds. Large fishponds in the Dolnomoravská niva Floodplain occurred also near towns of Ostroh, Strážnice and south of Hodonín. A fishpond system existed near Lednice, too. Fishpond systems occurred also in the Kyjovka River valley.

The low hilly lands typically featured rural landscapes dominated by fields, vineyards and agricultural settlements. The landscape to the south of Bzenec (Dúbrava in older maps, Doubrava in current maps) still featured freely moving sand dunes.

Rivers, their floodplains and adjacent low hilly lands were mutually linked in the landscape.

Regarding the fact that the maps from the 1st Austrian Military Survey did not have a triangulation network, quantitative assessment of landscape structure and plotting of detailed land use maps with using GIS tools was impossible. This is why the maps were assessed manually.

## 5.2 Landscape structure in the first half of the 19th century

Landscape structure and situation in the landscape of the first half of the 19th century are well depicted in topographic maps from the 2nd Austrian Military Survey on a scale 1 : 28 800, which was carried out in Moravia in 1836–1841. The agricultural landscape still dominated in the area under study. The historical core of Brno was still bastioned. It is however obvious that demolition of town walls and backfilling of moats had already begun. The area of suburbanized landscape around the historical core began to sprawl. Town walls of Uherské Hradiště were already taken down and orchards were established in their place. The river pattern experienced considerable changes. The main channel of the Olšava R. did not lead any longer in the direction of Uherské Hradiště but instead to the west of town of Kunovice, and then meandered in a Yazoo contact to the south parallel with the Morava River channel. Thus, the Olšava R. opened into the Morava R. only in town of Ostroh. To the south of town of Hodonín, the Morava River braided. Although its main channel continued meandering, a system of braiding river arms developed in the Dolnomoravská niva Floodplain. The Kyjovka R. flanked the western margin of the Dolnomoravská niva Floodplain and opened into the Dyje River. A tangle of river arms developed in the floodplain south of Lanžhot between the rivers Dyje, Kyjovka and Morava. The degree of connectivity, both longitudinal and lateral, was still considerable in the mapped territory. A number of other fishponds were drained. In the Středodyjská niva (Middle Dyje R. Floodplain), regulation works were launched on the Dyje R. between Jaroslavice and Nový Přerov along the current state border between the Czech Republic and Austria. The Zámecký fishpond near the village Jaroslavice was drained and its floor started to be used as arable land. In 1823, afforestation was started of drift sands in the area south of Bzenec (Dúbrava, Doubrava – Vitásek, 1942, p. 1).

### 5.3 Landscape structure in the second half of the 19th century

In the assessment of landscape structure and landscape development in the second half of the 19th century, the authors made use of maps from the 3rd Austrian Military Survey, which was carried out in Moravia in 1875–1877 on a scale 1 : 25 000. The period between the Second and Third Military Survey was the period of a very rapid development of the cultural landscape, which experienced far-reaching changes. Size of areas in which the land use changed was 18.12% in the Dyjsko-svratecký úval Graben and 20.37% in the Dolnomoravský úval Graben. The rate of landscape changes began to accelerate already in 1840–1850. Agricultural revolution leading to the increased intensity of agricultural production was responsible for the fact that the proportion of arable land increased in the agricultural landscape of both Grabens (Tab. 1 and Fig. 3), namely at the cost of permanent grasslands. The process is particularly conspicuous in the Dyjsko-svratecký úval Graben (Tab. 1 – grassland area decreased by half). The floodplains showed a reduced share of floodplain forests, too, and arable land sprawled from the adjacent hilly lands into the floodplains. The number of fishponds in the landscape was dramatically reduced, especially in the Dyjsko-svratecký úval Graben (from 0.21% to 0.03% – see Tab. 1). The maps from the 3rd Military Survey show a rapid sprawl of the urban landscape of Brno (Fig. 3) following a total demolition of town walls in 1858–1863. The urban landscape sprawled namely along the flat terrain of the Svitavsko-svratecká niva (Svitava – Svratka Floodplain) and across the river terraces of the Šlapanická pahorkatina Hilly land. In the floodplain, industrial landscape developed along the Svitava River (streets Cejl, Křenová, Dornych). The development called for the regulation of Svratka and Svitava river channels, which was launched in 1848. The original hydrological junction on the confluence of Svratka R. and Svitava R. was moved by Man from Horní Heršpice southwards to the village of Přízřenice. A new deep and dyked channel was dug out between Brno in the north and the village of Vojkovice in the south. The deep man-made channels and dykes retained the flood water and disturbed the connectivity of valley slopes, floodplains and water stream channels. The regulation of rivers resulted in a fragmentation of the Dyjsko-svratecká niva Floodplain, changing also the length of watercourses and the index of sinuosity. The Dyje River channel was further regulated in 1887–1890. In spite of the fact, the floodplains were flooded at higher water levels especially in the spring. The construction of railway network started in the mapped territory after 1839, in which the railway from Vienna to Brno was put into operation. Railways gradually took over the long-distance transport of passengers and goods. In 1850, the construction was completed of a network of imperial-royal roads (Musil, 1987, p. 175), which – together with the railway network – essentially contributed to the landscape fragmentation.

The map (Fig. 3) shows that the western part of drift sands (Dúbrava, Doubrava) south of Bzenec was already covered by forest.

The construction of transport networks and extension of settlements asked for the mining of building materials. Gravel and sand pits were coming to existence in the floodplains and raw materials for brick making (namely loess and clay) were extracted in the adjacent hilly lands.

The structure of agricultural landscape was affected by the Austrian agricultural reform (so-called raabization), which led to the allocation of a greater part of seigniorial and church farms to serfs and to the foundation of new settlements (Nekuda, 1982, p. 207).

### 5.4 Landscape structure in the first half of the 20th century

No integral set of large-scale topographic maps exists for the first half of the 20th century that would make it possible to follow the landscape development continually. Only the maps from the 3rd Austrian Military Survey were gradually revised. In this relatively long period of landscape development (1875–1953), the size of land use changes amounted to 18.26% of area in the Dyjsko-svratecký úval Graben and 22.53% of area in the Dolnomoravský úval Graben.

The first Czechoslovak agricultural reform after World War I led to the reduction of large estates, to the division of land to small farmers and to a more conspicuous mosaic of small fields in the rural landscape in the two Grabens. By contrast to the Dyjsko-svratecký úval Graben, the Morava River in the Dolnomoravský úval Graben was regulated as late as in the 20th century. At the beginning of the century, the river regulation started between towns of Napajedla and Lanžhot. Due to the regulation, the Morava R. channel was shortened by 17 km in the river section between Napajedla and Strážnice and by 30 km (from the original 82 km to 52 km) in the section from Strážnice up to the confluence with the Dyje R.

at Lanžhot (Kilianová, 2000, p. 30 – Tab. 2). The topographic map 1 : 75 000 from about 1930 shows the Morava River flow regulation and cut-off free meanders between towns of Napajedla and Spytihněv. Regulated were also river sections around the town of Uherské Hradiště. A straight channel of the Olšava River between Kunovice and Kostelany nad Moravou came to existence through a cut-off. The map already shows a new navigation canal named Morávka (so-called Bata's canal) excavated between the town of Veselí nad Moravou and Vnorovy. In the above mentioned map, we shall also find a conspicuous, straight regulated channel of the Syrovinka River in the western part of the floodplain. The regulation of the Morava River affected first of all river sections near towns of Strážnice and Hodonín. Regulated was also the channel of Kyjovka (Stupava) R. in the western part of the floodplain that runs parallel to the main channel of the Morava R. The area of drift sands in Doubrava south of Bzenec was already fully covered by forests.

Intravillans of settlements were sprawling and the share of urban landscape was increasing. The growth of settlements in the floodplains accelerated due to the regulation of rivers.

### 5.5 Landscape structure in the second half of the 20th century

In the second half of the 20th century, the cultural landscape in the studied territory experienced essential changes. After a long break of about 75 years, another integrated set of military topographic maps was published in 1952–1955 (S52). Land use and landscape changes were more pronounced in the Dolnomoravský úval Graben where the size of area with land use changes in a relatively short period 1953–1992 was 23.09% (Dyjsko-svratecký Graben only 16.67% – Fig. 4).

The period after World War II saw the second Czechoslovak agricultural reform. Industrialization and collectivization of agriculture were launched after 1955. The structure of agricultural landscape changed due to the consolidation of lands. The mosaic of small fields was gradually replaced by extensive cooperative fields, which further grew during the 1970s in the following wave of land consolidation. A larger part of dispersed greenery disappeared from the landscape due to the consolidation. Agrochemical inputs into the farmland markedly decreased after 1989.

In the floodplains of Dyje and Morava Rivers, the regulation of watercourses continued, which resulted in disturbed connectivity. Nevertheless, the regulation of the Morava River and its tributaries did not prevent inundation of the entire floodplain during the great flood of 1997.

In that period, the built-up area began to grow (Tab. 1 – Fig. 4). Unfortunately, residential landscapes in the floodplains were sprawling, too. Renewed Czechoslovak military maps from 1991–1992 document the growing urban landscape in Brno and suburban landscape in the town's surroundings with the increasing size of built-up areas in the floodplains (Fig. 5). We can see the increasing area of recreational landscapes, too. The maps also depict landscape fragmentation due to the construction of freeways D1 and D2. A transport junction came to existence south of city of Brno. Drawback of the above maps is that they underestimated the size of permanent grasslands in the landscape. Lowland water reservoirs of Nové Mlýny were constructed in the Dyje-Svratka and Dyje-Morava floodplains (Fig. 5). Towards the end of the century, the regulation was accomplished of the Morava River, which started to resemble a sewer, namely below the town of Hodonín. Floodplain forests were maintained in the biosphere reserve of Dolní Morava.

In the Dyjsko-moravská pahorkatina Hilly land, the loss of arable land through rainwash was increasing. On the other hand, many fishponds (such as the Pohořelice fishpond system) were restored (Fig. 5).

### 5.6 Landscape structures at the beginning of the 21st century

The present landscape structure is shown on the grid Base Maps of the Czech Republic scaled 1 : 10 000 as well as on aerial and satellite photographs. The detailed maps show a rapidly increasing built-up area, which reached its historical maximum (Fig. 6). The landscape changes were once again more intensive in the Dolnomoravský úval Graben than in the Dyjsko-svratecký úval Graben. Agricultural landscapes represent a typical mosaic of arable land and vineyards, specific in the Czech Republic. New landscape elements are large shopping parks with extensive asphalt surfaces (hardscape) in the vicinity of towns and important traffic veins (e.g. Olympia Shopping Park in the town of Modřice on the speedway D2).

### 5.7 General evaluation of landscape changes and processes in the Czech landscape

The paper for the first time brings quantitative assessment of landscape changes in two large landscape-ecological units in the borderland among Czechia, Slovakia and Austria based on quantitative digital analyses of old topographic maps and literature data. The advance of the medium-scale maps lays in its use for landscape changes studies of larger or middle landscape-ecological units. Both studied landscape- ecological units exhibit similar natural condition, but in the landscape structure, land-use development and trajectories (Swetnam, 2007) authors found large differences. The period under study (1764–2009) includes the coming into existence and further development of modern Central-European cultural landscape with substantial land-use changes. Cartographic method used for studying landscape changes by means of quantitative studying land use changes makes it possible to quantify the landscape changes in the period studied (Tab. 1 and 2), to establish the number of changes (Fig. 7), to characterize stable elements in the landscape (Fig. 8) and establish landscape trajectories changes. In the period of the 1st military mapping, the European economy was of mainly agricultural character. Agriculture was the largest landscape user and played a main role in the formation of the cultural landscape. However, this was also a period of significant technological and socio-economic changes in the agricultural landscapes. The first changes in the agricultural landscape were induced by the Austrian agricultural reform (raabization) in the second half of the 18th century, which changed the structure of the agricultural landscape. At the beginning of the 19th century, it was followed by the first stage of scientific and technical revolution in agriculture, which resulted in the increased intensity of agricultural production. Technical revolution in the period of the 2nd military mapping manifested itself in the demolition of town walls, building of new industrial facilities in thus released towns, and in about the mid-19th century, it led to the rapid growth of urban landscapes (Fig. 2). The 1st Czechoslovak agricultural reform after World War I markedly reflected in the character of agricultural landscapes. The disproportion between the size of urban and agricultural landscapes became considerably smaller in the second half of the 20th century due to the 2nd Czechoslovak agricultural reform after World War II, the following industrialization, collectivization of agriculture and urban processes proceeding from towns to rural settlements. In spite of all these facts, the agricultural landscape in the area under study features a relatively high stability (Fig. 8). Unstable due to suburbanization are city outskirts and floodplain landscapes.

## 6 CONCLUSIONS

A detailed computer-aided analysis of land use changes based on detailed topographic maps from the period 1836–2006 revealed landscape development differences between the Dyjsko-svratecký úval Graben and the Dolnomoravský úval Graben (Fig. 2–6). Changes in the Dyjsko-svratecký úval Graben started earlier and reflected in the regulation of rivers already in the first half of the 19th century, in the more intensive use of arable land and in the changes of forest stands. Nevertheless, about 61% of the landscape could be considered stable (Fig. 8). The extensive Brno residential agglomeration was developing in the northern part of the graben especially after coming to existence of Czechoslovakia in 1918 (Fig. 4–6). Landscape changes in the Dolnomoravský úval Graben began later and the Morava River channel was regulated practically as late as in the 20th century. The greatest changes in land use occurred in the period 1953–1992 but only 48% of the landscape could be considered stable. The detailed topographic maps from 1836–2006 represent a valuable source of information on cultural landscape changes in the studied lowlands. In comparison with earlier landscape ecological studies authors analyzed in detail large landscape-ecological units in the borderland among Czechia, Slovakia and Austria.

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# LONG-TERM CHANGES IN LAND USE IN THE LITAVA RIVER BASIN

## DLOUHODOBÉ ZMĚNY VE VYUŽITÍ KRAJINY V POVODÍ ŘEKY LITAVY

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**Abstract**

In the present study, we evaluated changes in land use in the Litava River basin. We used topographic maps at scales 1 : 28 800, 1 : 25 000 and 1 : 10 000 from the years 1836–1841, 1875–1876, 1953–1955, 1991–1992 and 2002–2006 for our research. Altogether, we explored 9 categories of land use – arable land, permanent grassland, garden and orchard, vineyard and hop field, forest, water area, built-up area, recreation area, other land. Using environment of geographic information systems we quantified the shares of the individual areas of land use, specified land used permanently and unstably, quantified the changes in the landscape and the main types of these changes, described the processes of the changes in the landscape and evaluated the intensity of these changes in the landscape. In terms of land use, the Litava River basin can be considered a relatively stable area where 71.1% of the areas remained unchanged in all the five map collections. In the process, we took into account the regional differences within the Litava River basin. The heaviest intensification of the landscape was seen in the Dyjsko-svratecký úval Graben (20.63% of the area) and Vyškovská brána Gateway (19.08%).

**Abstrakt**

V příspěvku jsou hodnoceny změny ve využití krajiny povodí řeky Litavy. Pro vytvoření map využití ploch byly použity topografické mapy v měřítku 1 : 28 800, 1 : 25 000 a 1 : 10 000 z let 1836–1841, 1875–1876, 1953–1955, 1991–1992, 2002–2006. Sledováno bylo celkem 9 kategorií využití ploch – orná půda, trvalý travní porost, zahrada a sad, vinice a chmelnice, les, vodní plocha, zastavěná plocha, rekreační plocha, ostatní plocha. Za pomoci prostředí geografických informačních systémů byly kvantifikovány podíly jednotlivých ploch využití krajiny, vymezena stabilně a nestabilně využívaná území, zjištěny počty změn v krajině a hlavní typy těchto změn, popsány procesy změn v krajině a zhodnocena intenzita změn v krajině. Z hlediska využívání krajiny lze povodí Litavy považovat za relativně stabilní území. Přibližně 71 % ploch zůstalo na všech pěti mapových sadách beze změny. Při hodnocení území bylo přihlédnuto k regionálním odlišnostem v rámci povodí řeky Litavy. Intenzifikace krajiny se projevila nejvíce v Dyjsko-svrateckém úvalu (20,63 % území) a Vyškovské bráně (19,08 %).

**Keywords:** land use, changes in the landscape, old topographic maps, Litava River basin

## 1 INTRODUCTION

Long-term changes in the landscape are caused by both natural and anthropogenic processes. The intensity of anthropogenic processes is increasing and their impact on the landscape is seen in its functionality and stability. The primary structure of the landscape is its natural foundation independent on human impact; it consists of geological and geomorphological structures, superimposed drainage, soils and the potential natural vegetation cover. The secondary structure of the landscape is seen in the way the landscape is used by man (Lipský, 2000). Although the primary landscape structures (e.g. relief, soil) predestine the secondary structure of the landscape, anthropogenic activities have suppressed this link to the original natural conditions. The memory of the landscape may be the constant structures, which consist of a natural and a cultural component. The natural component of the landscape memory is dependent on the relief, climate, substrate, soil, network of watercourses and water bodies. The cultural component of the landscape memory is dependent on the presence and condition of man-made historical landscape structures. The more changes in the structure of the landscape take place and we fail to preserve at least the most important and most valuable structures, the more will our landscape be impoverished of the cultural and natural heritage of the past (Němec, Pojer et. al., 2007).

At the present time, changes in the landscape are the subject of interest of experts and working groups in a number of countries. There is a considerable quantity of articles and studies on this topic and various approaches and methods of solution are applied. The recent development of information technologies, availability of digital data, dynamic development in the area of geographic information systems have led to their massive exploitation in the area of monitoring the changes in the landscape.

Statistical data and surveys, old maps, aerial photos and satellite images are used to explore the long-term changes in the landscape. The statistical methods are based on comparisons of data on land use which have been historically recorded namely in land registration, demesne property, agricultural books and other historical documents. In a number of countries at the present time available electronic databases can be used which register the types of land or how the land is used. In the Czech Republic, statistical methods are used particularly by the working group of Ivan Bičík from Charles University which possesses a vast historical database on land use in the cadastres of the Czech Republic in 1845, 1948 and 1990 (Bičík et. al., 2001, 2003).

In order to study long-term changes in land use available old topographic maps are frequently used. In Central Europe old Austrian and Hungarian military maps are used in great abundance. Original copies of these maps are deposited in Vienna and Budapest and are the subject of interest of experts in all the succession countries of the former Austrian-Hungarian Empire. An important undertaking, which has enabled to explore the changes in the landscape in the Czech Republic was the release of maps of the 1st and 2nd Austrian Military Survey by the Laboratory for Geoinformatics of the UJEP University in Most headed by Vladimír Brůna and making accessible maps of the 3rd Austrian military Survey survey in co-operation with the Czech Agency for Nature Conservation and Landscape Protection (AOPK ČR) in Brno (Brůna et. al., 2002).

Since the mid-19th century, topographic maps have allowed detailed and accurate monitoring of changes in the landscape. By contrast, the methods based on remote sensing of the earth and on aerial photographs have limited usability only from the 1930's and/or 1950's. Naturally, the advantage is that these methods can be used at the present time because the renewal of aerial photographs and satellite images is much quicker than the renewal of national medium-scale maps. In Europe, the integrated method used to compile land cover maps is the Corine Land Cover project which uses satellite images (Heymann et. al., 1994; Feranec, Oťaheľ, 2001, 2003).

In the Czech Republic, a number of authors have explored changes in the landscape on a long-term basis: Zdeněk Lipský (Lipský, 2000, 2002,) Jaromír Kolejka (Kolejka, Trnka, 2008), Jaromír Demek (Demek et. al., 2007, 2008), Leoš Jeleček, Pavel Chromý (Jeleček, Chromý et. al., 2008) and others. In Slovakia it is for example Florian Žigrai (Žigrai, 2001), Ján Feranec, Ján Oťaheľ (Feranec, Oťaheľ, 2001, 2003), Vladimír Falťan (Falťan et. al., 2008; Falťan, Bánovský, 2008), Branislav Olah (Olah, 2003) and Martin Boltižiar (Olah, Boltižiar et. al., 2006). Thanks to the availability of the maps and to the development of GIS, the focus of a number of working teams at universities and research institutes in the Czech Republic is on this topic.

In their research activities the department of GIS applications and department of landscape ecology of The Silva Tarouca Research Institute for the Landscape and Ornamental Gardening in Brno are exploring the changes in the landscape on the basis of old topographic maps (Demek et. al., 2007, 2008; Havlíček, 2008; Mackovčin et. al., 2006; Skokanová et. al., 2007, 2008; Stránská, 2008).

## 2 STUDY AREA

The Litava River basin lies in south Moravia, east of the city Brno. The Litava River rises in the Chřiby Upland at an altitude of 495 m, 2 km south of Cetechovice and runs into the Svratka River in the town Židlochovice at an altitude of 178.4 m. The river is 58.6 km long and the area of the river basin is 788.4 km$^2$. Leaving the Chřiby Upland headwaters Litava runs westwards; its longest section flows through the Litenčická pahorkatina Hilly Land, from Slavkov u Brna the river flows through the Dyjsko-svratecký úval Graben. The most important towns on the Litava River are Bučovice, Slavkov u Brna and Židlochovice. The shape of the Litava River basin is asymmetric; left-hand tributaries descending from the Ždánický les Upland are relatively short (cca 10 km); right-hand tributaries which begin in the Drahanská vrchovina Upland are much longer (Říčka 38.9 km, Rakovec 36.5 km).

A total of 9 geomorphological units extend into the Litava River basin: three uplands – Chřiby, Drahanská vrchovina and the Ždánický les; one hilly land – Litenčická pahorkatina; two lowlands – Dyjsko-svratecký úval Graben and Vyškovská brána Gateway. The major part of the Litava River basin is agricultural land, only the Drahanská vrchovina Upland, the Chřiby Upland and some parts of the Ždánický les Upland and Litenčická pahorkatina Hilly Land are forests. In the northern part of the river basin, in the Drahanská vrchovina Upland, is the Protected Landscape Area (PLA) of Moravian Karst, nature park Říčky, nature park Rakovecké údolí Valley; in the southern part we see valuable natural sites in the nature park Ždánický les Upland; in the Litava River headwaters is the nature park Chřiby Upland and where it flows into the Svratka River is the nature park Výhon.

## 3 MATERIALS AND METHODS

In the present study, the focus was on the change of the landscape in the Litava River basin. Changes in the landscape were evaluated on the basis of available old and contemporary topographic maps at scales 1 : 28 800, 1 : 25 000 and 1 : 10 000. Maps, which were the sources for the analyses, were following: maps from 2nd Austrian Military Survey in the scale 1 : 28 000 from the period 1836–1841, maps from 3rd Austrian Military Survey in the scale 1 : 25 000 from the period 1875–1876, Czechoslovak military topographic maps in the scale 1 : 25 000 from 1953–1955 and 1991–1992s, and Czech topographic base maps in the scale 1 : 10 000 from 2002–2006. A total of 9 basic land use categories were monitored: 1 – arable land, 2 – permanent grassland, 3 – garden and orchard, 4 – vineyard and hop field, 5 – forest, 6 – water area, 7 – built-up area, 8 – recreational area, 0 – other area. Using the geographic information systems (Arc GIS 9.x), we quantified the share of the individual areas of landscape use, specified the permanently and unstably used land, described the processes of the change in the landscape and evaluated their intensity.

The analysis lies in overlaying vectorial maps and in calculation of the number of land use changes for the whole researched period. Scale of the changes ranges from 0 (no change) up to 4 (maximum possible change), when analyzing five maps. By superimposing all the five land use mapping datasets, we obtained a five-point code which indicates the overall type of land use changes.

Another indicator completing the characteristics of changes in the landscape is the overall intensity of changes in land use which had been used in a similar way in studies of Olah, Boltižiar, Petrovič (Olah, Boltižiar et. al., 2006) and Skokanová (see article in this copy). The value respecting the intensity of landscape use by human society was assigned to the individual categories of land use. The highest value 5 was assigned to built-up areas and to other areas formed by human activities; value 4 was assigned to the category arable land; value 3 to orchards, vineyards recreation areas with the focus on hobby-gardening communities; value 2 to water surfaces and permanent grasslands; and value 1 to forests. The total intensity of landscape use equals the sum of differences in intensities between the individual mapped periods I= ($I^{1875}$-$I^{1836}$) + ($I^{1953}$-$I^{1875}$) + ($I^{1991}$-$I^{1953}$) + ($I^{2006}$-$I^{1991}$). The resulting values range between -4 and 4. Positive figures 1 to 4 indicate a more intensive method of landscape use with a maximal pressure on the landscape in the case of value 4. Negative figures from -4 to -1 indicate extensive exploitation of the landscape by the human society. Value 0 characterises balanced use of the landscape, which includes areas not used permanently and on top of that areas where interventions leading to intensification in land use were counterbalanced by a converse intervention – extensification.

## 4 RESULTS

To compile the first of the five land use maps we took maps of the 2nd Austrian Military Survey scale 1 : 28 800 from 1836–1841. Most of the land of the Litava River basin was arable land (60.26%) and was concentrated in the lowlands in the area of the Dyjsko-svratecký úval Graben and Vyškovská brána Gateway (over 80 %), in the lower locations of the Litenčická pahorkatina Hilly Land (69.5%) and the Ždánický les Upland (59.5%). The second most frequent category of land use was forests (24.62%). The largest areas of forests lie in the Chřiby and Drahanská vrchovina Uplands (cca 80%). Larger areas of forests are seen in the top parts of the Ždánický les Upland. By contrast, the fewest forests are in the Vyškovská brána Gateway (0.3%) and the Dyjsko-svratecký úval Graben (1.6%). In the above period the permanent grasslands reached their maximum (11.38%) and were concentrated in the immediate vicinity of the Litava River and its tributaries; most of them in the Dyjsko-svratecký úval Graben and Litenčická pahorkatina Hilly Land (13.5%). The built-up area in this period occupied 2.49%, vineyards 0.43%, gardens and orchards 0.41% and water areas 0.40 %. Of all the 5 mapping periods water bodies occupied the major part (318 ha), i.e. particularly in the lower sections of the rivers in the Dyjsko-svratecký úval Graben, specifically Litava, Říčka and Dunávka.

The next map of land use was compiled on the basis of the 3rd Austrian Military Survey at scale 1 : 25 000 from 1875–1876. Compared to the previous period 14.89% of the territory was changed. The main change was agricultural intensification – almost 4,800 ha of permanent grassland were ploughed up (particularly in the vicinity of water courses), cca 1,300 ha of forests were cut down and were turned into arable land, the largest ponds of a total area of 270 ha were dried up. Against these processes in various places the situation was the opposite; i.e. extensification of the land (ca 2,300 ha of land was grassed over). Most of all the intensification process hit the Dyjsko-svratecký úval Graben and the Vyškovská brána Gateway; these processes were also monitored to a great extent in the Litenčická pahorkatina Hilly Land. Forestation was recorded in the Chřiby Upland. In the entire Litava River basin the share of arable land increased to 65.67%; in terms of the other categories the proportion of permanent grassland and forests decreased to 7.36% and 23.80%, respectively; the proportion of water bodies actually decreased to 0.03%. The water bodies occupied only 26 ha and compared to the other mapping datasets reached their minimum.

The third mapping dataset was compiled on the basis of military topographic maps at scale 1 : 25 000 from 1953–1955. Already 80 years had passed from the last complete mapping of our lands, but comparisons of the land use maps from the Litava River basin revealed that only 14.23% of land had changed, i.e. approximately much like the previous 40-year period. Agricultural intensification in the area continued – 5,150 ha of permanent grassland disappeared, of which 4,300 ha were converted into arable land. Some of the meadows and pastures were built-up (not quite 400 ha). At this period the urbanisation process began to play an important role – the built-up area increased by 1,500 ha and the bulk was on arable land (ca 1,100 ha). Out of the total proportions of categories of land use, it is obvious that in the 1950's the area of arable land increased (68.86 %) and reached its maximum of the five monitored periods. In the Dyjsko-svratecký úval Graben and Vyškovská brána Gateway the proportion of arable land reached 90%. In contrast permanent grasslands in this period were at their minimum (0.82 %), from the original 8,970 ha of permanent grasslands in 1836–1841 only 648 ha remained in the Litava River basin. The area of gardens and orchards increased considerably (1.42% share, increase by 880 ha). The forest areas remained virtually the same (24.11%). In this period for the first time recreational areas were specified.

The fourth set of land use maps was compiled using the military topographic maps at scale 1 : 25 000 from 1991–1992. Approximately 40 years had passed from the previous interpreted mapping dataset; comparisons of the maps revealed that land use had changed on 9.60% of the area of the Litava River basin. The main process in this period was urbanisation – growth of the built-up town areas and rural settlements accompanied by increased industrial areas, particularly near the towns Bučovice, Slavkov u Brna and Rousínov. In total the built-up area increased by 2,250 ha, the absolute majority by taking up arable land. In this period forestation was recorded; approximately 500 ha of new forests appeared primarily in the area of the Ždánický les and the Drahanská vrchovina Uplands.

The last fifth dataset of land use was based on the basic map of the Czech Republic at scale 1 : 10 000 from 2002–2006. Although there is only a 10-year gap between the individual mapping datasets, changes in landscape use appeared on 6.63 % of the area of the Litava River basin. The main processes in this period were extensification (approximately 800 ha of arable land was grassed), expanding sub-urbanisation (550 ha of arable land was built-up) and forestation (about 300 ha of new forests emerged). Grassing was carried out particularly on sloping areas of the Litenčická pahorkatina Hilly Land and the Drahanská vrchovina Upland. In this period forestation was conducted namely in the Litenčická pahorkatina Hilly Land and the Dyjsko-svratecký úval Graben. Sub-urbanisation was seen in the neighbourhood of Slavkov u Brna, Bučovice and in the wide hinterland of Brno in the western part of the Litava River basin. In 2002–2006 the proportion of arable land in the Litava River basin area was 62.23%, i.e. about by 1,300 ha less than in 1991–1992. Thanks to grassing the proportion of permanent grassland increased to 2.25%, but it is still only one fifth of the proportion of 1836–1841. The proportion of recreation areas, in this area particularly hobby-gardening communities and weekend cottages, increased to 0.61%. The development of the other categories of areas was more dynamic and was based on human activities (waste disposal sites, quarries etc.). Their proportion increased to 0.79%.

By comparing the five mapping datasets we discovered that land use in the Litava River basin changed on 28.29% of the area; 15.17% of areas underwent 1 change, 9.73% underwent 2 changes, 2.83% had 3 changes and 0.55% of areas underwent 4 changes (Fig. 2). Compared to other already explored areas of South Moravia (e.g. the Dyjsko-svratecký úval Graben, Dolnomoravský úval Graben, district Hodonín, surroundings of Brno) we can consider the Litava River basin as a relatively stably used area. However, the differences in landscape changes in the Litava River basin are regional. Most of these land use changes are bound to the immediate surroundings of the rivers, particularly to their alluvial sections, and/or to the surroundings of larger settlements – Slavkov u Brna, Židlochovice, Bučovice, Rousínov and Šlapanice. Most changes in land use occurred in the Dyjsko-svratecký úval Graben (32.45% of the area was changed) and in the Vyškovská brána Gateway (30.27% of the area was changed). In the Litenčická pahorkatina Hilly Land 29.08% of the area was changed. The proportion of changes was roughly the same in the Ždánický les Upland (24.86%) and Drahanská vrchovina Upland (24.54%). The fewest changes in landscape use were monitored in the Chřiby Upland (16.41%).

**Tab. 1 Categories of land use in the Litava River basin in 1836–2006 (proportion in %)**

| Code | Category of land use | 1836–1841 | 1875–1876 | 1953–1955 | 1991–1992 | 2002–2006 |
|---|---|---|---|---|---|---|
| 1 | arable land | 60.26 | 65.67 | 68.86 | 63.89 | 62.23 |
| 2 | permanent grassland | 11.38 | 7.36 | 0.82 | 1.20 | 2.25 |
| 3 | garden and orchard | 0.41 | 0.31 | 1.42 | 1.48 | 1.46 |
| 4 | vineyard | 0.43 | 0.29 | 0.33 | 0.52 | 0.34 |
| 5 | forest | 24.62 | 23.80 | 24.11 | 24.75 | 25.24 |
| 6 | water area | 0.40 | 0.03 | 0.04 | 0.15 | 0.17 |
| 7 | built-up area | 2.49 | 2.43 | 4.35 | 7.21 | 6.91 |
| 8 | recreational area | 0.00 | 0.00 | 0.01 | 0.56 | 0.61 |
| 0 | other area | 0.00 | 0.11 | 0.05 | 0.24 | 0.79 |
| Sum | | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

By superimposing all the five land use mapping datasets, we obtained a five-point code which indicates the overall type of land use changes. In the Litava River basin the changes were predominantly changes connected with the processes of intensification of agriculture – code 21111 (4.14% of the total area of the river basin); these are areas where the permanent grasslands were ploughed in some time between 1836–1841 and 1875–1876 and up to the present time have been used as arable land. On 2.16% of the area of the entire basin, the type of changes was under code 22111; permanent grasslands were ploughed between 1875–1876 and 1953–1955. Changes of this type can be seen particularly in the Dyjsko-svratecký úval Graben, Litenčická pahorkatina Hilly Land and Vyškovská brána Gateway. The other most frequent changes under code 12111 (1.66% of the entire area of the river basin) are temporary extensification (grassing) between the years 1836–1841 and 1875–1876 and the following process of intensification (ploughing permanent grasslands). These are mostly areas of the Ždánický les Upland and Dyjsko-svratecký úval Graben. Other frequent types of changes under 11177 (1.30%) and 11777 (0.81%) is the increasing growth of built-up areas connected with urbanisation. Among frequent types of changes, we may classify the combination of arable land and forests which indicate the expansion or extinction of forest areas. An unexpected type of change is type 11112 indicating the process of grassing of arable land once used as agricultural land on a long-term basis (0.48% of the area) – especially in the Litenčická pahorkatina Hilly Land and Drahanská vrchovina Upland. What has however confirmed is the assumption that the new permanent grasslands very often did not follow the original location in the river floodplains but were established on sloping less fertile soils. The process of agricultural extensification of the past years is closely connected with the economic results of the agricultural subjects.

Since permanently used areas prevail in the Litava River basin (71.71%), it is necessary to focus on the structure (Fig. 3 ). The most frequent category of permanently used areas is arable land (38,753 ha). The permanently used areas of arable land make up almost one-half of the total area of the river basin (49.16%). The largest areas are concentrated in the Dyjsko-svratecký úval Graben and Vyškovská brána Gateway (65% proportion), Litenčická pahorkatina Hilly Land (58%) and Ždánický les Upland (50%). Forest areas in the entire Litava River basin amount to 16,405 ha and were recorded in all the five mapping datasets. Most of the forests are located in the Chřiby Upland and the Drahanská vrchovina Upland, i.e. proportion of 79% and 68%, respectively. Other permanently used forest areas are located in the hilltops of the Ždánický les Upland and Litenčická pahorkatina Upland. In the Dyjsko-svratecký úval Graben and the Vyškovská brána Gateway, only respectively 27 and 5 ha of forest were exploited permanently. Among the permanently exploited areas, we also rank the original housing developments of the towns and communities, in the Litava River basin amounting to 1,293 ha. However, very alarming are the results of the following categories of land use which have a great effect on the ecological stability of the area – since 1836 the permanent grasslands have been exploited on only 63 ha and water surfaces on 10 ha. Orchards and vineyards are generally seen to relocate within the framework of cadastres and only small areas are used permanently.

Another indicator completing the characteristics of changes in the landscape is the overall intensity of changes in land use. The value respecting the intensity of landscape use by human society was assigned to the individual categories of land use. The resulting values range between -4 and 4. Positive figures 1 to 4 indicate a more intensive method of landscape use with a maximal pressure on the landscape in the case of value 4. Negative figures from -4 to -1 indicate extensive exploitation of the landscape by the human society. Value 0 characterises balanced use of the landscape, which includes areas not used permanently and on top of that areas where interventions leading to intensification in land use were counterbalanced by a converse intervention – extensification. The largest proportion of the Litava River basin was the total intensity of changes in the landscape ranked as value 0 (78.86%); no changes in land use were detected on 71.71 % of the area, in the remaining 7.15% of the area the changes in the intensity were mutually compensated and we can say that exploitation of the landscape was balanced. In the Litava River basin intensification of the changes in the landscape prevailed over extensification (15.59%); intensification degree 1 was reported for 4.77% of the area, the higher degree 2 for 7.74% of the area, degree 3 for 2.76% of the area and the highest degree 4 for 0.32% of the area.

**Tab. 2 Permanently used area of the Litava River basin in 1836–2006**

| Code | Category of land use | Acreage in ha | Proportion of the entire area of the Litava R. basin in % |
|---|---|---|---|
| 1 | arable land | 38,753 | 49.16 |
| 2 | permanent grassland | 63 | 0.08 |
| 3 | garden and orchard | 3 | 0.01 |
| 4 | vineyard | 1 | 0.01 |
| 5 | forest | 16,405 | 20.81 |
| 6 | water area | 10 | 0.01 |
| 7 | built-up area | 1,293 | 1.64 |
| | Stable areas in total | 56,526 | 71.71 |

Particularly the river floodplains, surroundings of towns and regions connected with limestone extraction in Mokrá and other areas considerably changed by human activities were exploited more intensively. The heaviest intensification of the landscape was seen in the Dyjsko-svratecký úval Graben (20.63% of the area) and Vyškovská brána Gateway (19.08%). Intensification was slightly above-average in the Litenčická pahorkatina Hilly Land (16.7%) and below-average in the Ždánický les Upland (11.13%), Drahanská vrchovina Upland (10.69%) and was the lowest in the Chřiby Upland (4.11%).

In the Litava River basin, extensification of landscape changes was seen on 5.54% of the area; value -1 on 3.14% of the area, -2 on 1.06% of the area, -3 on 1.32% of the area, and -4 on 0.02% of the area. Above-average areas where extensification changes in the landscape were monitored were observed in the Litenčická pahorkatina Hilly Land (6.20%) and the Chřiby Upland (10.23%). The Chřiby Upland was the only area where extensification in the landscape prevailed over intensification (Fig. 4).

## 5 DISCUSSION

The significance of changes in land use discovered on the basis of studies of old topographic maps is essential if we are to get to know the present and historical landscape structures (Haase et. al., 2007; Swetnam, 2007; Palang et. al., 1998). Usability of the compiled mapping documents, analyses of changes in the landscape, stabile areas and intensity of the changes in the landscape correspond to the details in which the old and present topographic maps were compiled. The used topographic maps at scales 1 : 28 800, 1 : 25 000 and 1 : 10 000 are suitable for evaluations of larger territories, for instance for administratively delimited territories of districts, regions and naturally delimited territories, too – hydrologic river basins, geomorphological units etc. It is not possible to discover the exact structure of the land from the maps, which detailed aerial photographs and/or cadastral maps provide. All the same, the data from these maps capture the basic processes of landscape changes; in contrast to statistical data the topographical maps show their location, their standardisation can be conducted, relations to the natural environment can be compared. The obtained data can be used in a general way; for planning in the landscape, for regeneration of ecological functions in the landscape; they may serve as a lesson from unsuitable interventions in the landscape, for monitoring and regulation of sub-urbanisation processes etc. We must realise that we are not monitoring the changes in a continual development, but only in five time horizons with 10 to 80-year intervals in between. That means that some changes in the landscape, which might have taken place in the interval and then have been returned to the original type of land use, need not be detected at all. The mapping datasets can be completed with other time horizons – for instance the 1970's and 1980's or for parts of the Czech Republic by maps from the 1920's and 1930's. The final outcome would naturally be that we would see more changes in the landscape. Unfortunately, for the Litava River basin no revised maps from the 1920's and 1930's are available, which are sometimes used for landscape changes.

In 1836–1841 the landscape, land use and its settlement were relatively harmonious and in terms of economic and ecologic relationships relatively balanced. Agriculture was still functioning without additional energy and artificial fertilisers. In agricultural landscape we see secondary differentiation into three functional zones – intensive (always as arable land), extensive (always as meadows and pastureland) and reserve (used according to immediate demands). Due to the stabilisation of plot boundaries and development in land cultivation, erosion was more intensive and sedimentation occurred. Counter-measures to these phenomena were balks and refuge islands, which could also be used for grazing.

The industrial revolution and its consequences also hit the typical agricultural landscape of the Litava River basin. Agricultural crops were specialised for industrial production. Improvement in technologies for the sugar industry at that period forwarded the expansion of sugar beet production. The expansion of potato production into the less fertile areas resulted in gradual growth of the population. In the last quarter of the 19$^{th}$ century alongside the intensification of rotating farming new information in plant nutrition appeared and organic and inorganic fertilisers became more widely used. The availability of agricultural commodities improved particularly due to the development of railway transport.

The introduction of perennial fodder crops radically increased the production of roughage and this gradually reduced the importance of meadows and pastures. After 1948 agricultural production underwent significant changes. Collectivisation resulted in the liquidation of personal property, ploughing up of balks and refuge islands, intensification of erosion processes, depersonalisation and unification of the cultural agricultural landscape. The process of intensification continued – mechanisation, changes in the housing of cattle, excessive use of mineral fertilisers.

Until 1989, socialistic agriculture in the Litava River basin had been subordinated in the first place to achieving maximal yields at the expense of excessive fertilisation and chemical pest control. Consolidation of land and concentration of production into agricultural centres resulted in the growth of field plots (10 to 15 ha in 1980 compared to 0.23 ha in 1948). After 1989, the agricultural enterprises were gradually transformed and land was restituted.

## 6 CONCLUSIONS

A total of 9 basic land use categories were monitored: arable land, permanent grassland, garden and orchard, vineyard and hop field, forest, water area, built-up area, recreational area, other area. In terms of land use, the Litava River basin can be considered a relatively stable area where 71.1% of the areas remained unchanged in all the five map collections. However, in terms of the ecological function of the landscape, in the studied period from 1836 to 2006 we see as particularly alarming the reduction of permanent grasslands, which 170 years ago had been abundant in river floodplains. In the framework of the Litava River basin, we saw regional differences in the landscape changes; most of the forests are located in the Dyjsko-svratecký úval Graben, Vyškovská brána Gateway and Litenčická pahorkatins Hilly Land. While the permanently exploited areas in the Dyjsko-svratecký úval Graben, Vyškovská brána Gateway and Litenčická pahorkatina Hilly Land are predominantly arable land, in the area of the Chřiby Upland and Drahanská vrchovina Upland there are forests. In terms of permanent grasslands and water surfaces which have a positive effect on the ecological stability of this cultural agricultural landscape, only a minimum of permanently used areas has been preserved. The most intensive landscape changes were monitored in the Dyjsko-svratecký úval Graben and Vyškovská brána Gateway and were connected with the processes of agricultural intensification, urbanisation and in general with intensive human activities in the landscape.

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# CHANGES OF STREAMS IN THE LITAVA RIVER BASIN FROM THE SECOND HALF OF THE 18TH CENTURY UNTIL THE PRESENT (1763–2006) BASED ON THE STUDY OF OLD MAPS

# ZMĚNY NA VODNÍCH TOCÍCH V POVODÍ ŘEKY LITAVY OD DRUHÉ POLOVINY 18. STOLETÍ PO SOUČASNOST (1763–2006) NA ZÁKLADĚ STUDIA STARÝCH MAP

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**Abstract**

The paper brings assessment of hydrographic changes recorded on ten selected streams in the Litava River catchment. Within the framework of analyses, the most significant modifications and changes are described, captured in six sets of old maps from years 1763–1783, 1836–1852, 1876–1880, 1952–1955, 1988–1995 and 2002–2006. An additional numerical analysis of changes in the mainstream length, length of its side channels and main stream sinuosity changes was carried out for the three longest streams. Data for the analysis were harvested through vectorization in ArcGIS environment over the raster maps. More recent map sets were processed by using available vector data. All surveyed streams showed significant anthropogenically conditioned hydrographic changes, namely in middle and lower reaches, of which some originated from the period before year 1763. There are four types of processes that participated in the stream changes: (1) foundation and abandonment of water reservoirs, (2) straightening of the originally sinuous, and meandering streams, (3) extinction of side channels, and (4) changes in the location of headwaters and spring area.

**Abstrakt**

V příspěvku byly vyhodnoceny hydrografické změny deseti vybraných vodních toků z povodí řeky Litavy. V rámci analýzy byly popsány nejvýznamnější úpravy a změny zachycené v šesti sadách starých map z let 1763–1783, 1836–1852, 1876–1880, 1952–1955, 1988–1995 a 2002–2006. U třech nejdelších toků byla provedena také numerická analýza změn délky hlavního toku, změn délky jeho vedlejších úseků a změn křivolakosti hlavního toku. Data pro analýzu byla získána v prostředí ArcGIS vektorizací nad mapovými podklady, u novějších mapových sad byla využita dostupná vektorová data. Na všech analyzovaných tocích byly zjištěny významné antropogenně podmíněné hydrografické změny, zejména na středních a dolních úsecích, z nichž některé byly provedeny již před rokem 1763. Na změnách toků se podílely čtyři typy procesů: (1) zakládání a rušení vodních nádrží, (2) napřimování původně zvlněných až meandrujících toků, (3) zánik vedlejších úseků toku a (4) změny pramenných úseků a polohy prameniště.

**Keywords:** river network, hydrographic changes, old maps, GIS environment

## 1 INTRODUCTION

River network is one of important landscape constituents. Landscape changes reflect in many cases also in streams because their alluvia are as a rule very dynamically used. Therefore, studying the state and changes of streams should be and often is an important complement to any analysis of landscape changes and use (e. g. Hooke et Redmond, 1992; Winterbottom, 2000; Waburton et al., 2002; Jones et al., 2003; Kusimi, 2008; Demek et al., 2008; Stäuble et al., 2008; and others).

The use of rivers and their floodplains by man usually leads to more or less extensive modifications of their natural state (e. g. Fortuné, 1988; Gilvear et Winterbottom, 1992; Mossa et McLean, 1997; Langhammer, 2003; Matoušková, 2004; and others). Main objectives of river training are usually intensification of land use and flood protection. Although the mild and extensive regulations may even have a positive effect on landscape diversity, they often include extensive changes that are reflected in reduced diversity of riverine landscape and in impaired multipurpose potential of the landscape. Third objective of the stream and its floodplain regulation has recently become their revitalization and restoration of their impaired multipurpose potential (Just et al., 2005). Analyses of the historic development of anthropogenic changes of streams may be contributing especially to the above-mentioned river and floodplain training.

The most obvious consequences of river regulations are stream length changes (both of the main stream and its side channels) and channel straightening along with the development and extinction of reservoirs on the stream. A basic source of information for studying these processes (especially if analyses of entire streams are concerned from the headwater to the mouth) are sets of old maps (e.g. Hooke et Redmont, 1989b; Hauser et al., 2004; Kukla, 2007; Stäuble et al., 2008). In spite of the fact that individual map sets, namely older ones, are not always comparable (due to different scales, projection and/or approach of the surveyor or different planimetric accuracy), they may provide, if properly processed, data sufficient for the analysis of the above processes.

This paper focuses on the backbone network of streams in the Litava River basin and aims at a description and evaluation of changes of some streams of this network, captured in the sets of old maps from the 1st Austrian (Joseph's) Military Survey in the second half of the 18th century until present.

## 2 STUDY AREA

The Litava River basin lies in south Moravia, east of the city Brno (Fig. 1, basic watershed is divided according to ČHMÚ, 2006). A total of 9 geomorphological units reach into the Litava River basin: three uplands (Chřiby, Drahanská vrchovina and the Ždánický les Forest), one hilly land (Litenčická pahorkatina), and two lowlands (Dyjsko-svratecký úval Graben and Vyškovská brána Gateway). The major part of the Litava River basin is agricultural land, large forested areas are localised only in hilly parts of the river basin (the Drahanská vrchovina Upland, the Chřiby Upland and some parts of the Ždánický les Forest or Litenčická pahorkatina Hilly Land).

In the northern part of the river basin, in the Drahanská vrchovina Upland, the Protected Landscape Area (PLA) Moravian Karst, nature park Říčky, and nature park Rakovecké údolí are situated. Other valuable natural sites can be found in the southern part of the river basin (nature park Ždánický les Forest), in the Litava River headwaters (nature park Chřiby Upland), and also at the mouth of the Litava River (nature park Výhon).

The shape of the Litava River basin is asymmetric. Left tributaries descending from the Ždánický les Forest are relatively short, to about 13 km, right tributaries, which begin in the Drahanská vrchovina Upland, are much longer, to about 39 km (see also below).

The Litava R. catchment has an area of about 788.4 km$^2$, elevation ranging from 178.4 to 571.8 m a. s. l. and a greater part of the territory (c. 68%) is situated at 200–350 m a. s. l. (Linhartová et Zbořil, 2006). Localities of higher altitudes can be found in the Litava R. spring area and particularly in the northern spur of the basin (upper reach of the Říčka R. and spring area of the Rakovec R.).

In the current catchment of the Litava River, there are c. 805 km of streams, which are classified as piedmont, hilly land country and lowland types. The piedmont type occurs very sporadically (total length 9 km, 1%, brooks only). The hilly country type of streams is represented most (677 km, 84%) of which brooks total 512 km (76%), small rivers 124 km (18%) and rivers 41 km (6%). The lowland type of streams (119 km, 15%) is represented also mainly by brooks, the total length of which is 76 km (64%) and to a lesser extent by rivers (29 km, 24%) and small rivers (14 km, 12%).

The river network consists of 527 streams of which a majority (518) do not exceed the length of 10 km. The backbone network of the catchment (i. e. the backbone streams of the 4th order catchment) consists of 43 streams of which only 9 are longer than 10 km (Litava R. and its right-bank tributaries Říčka, Rakovec, Dunávka, Hvězdlička plus Roketnice as a left-bank tributary of Říčka, and the left-bank tributaries of the Litava R.: Milešovický potok Brook, Moutnický potok Brook and its left-bank tributary Šitbořický potok Brook). The current state of the backbone network is shown in Fig. 14.

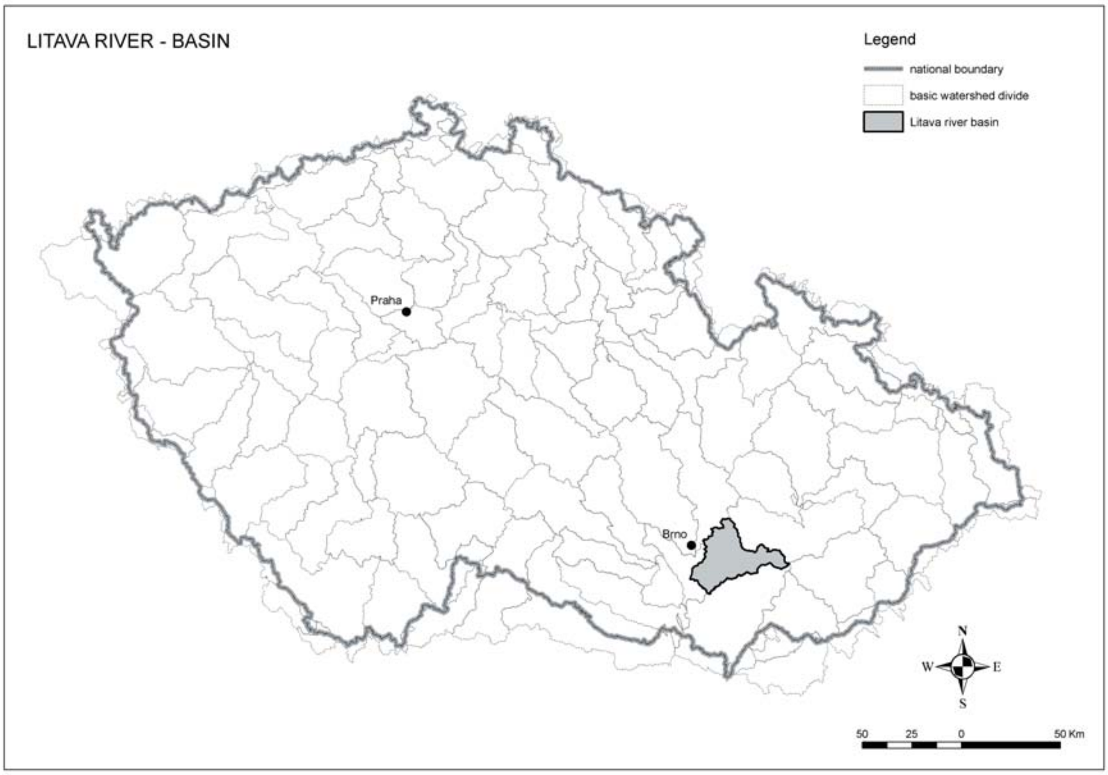


**Fig. 1 Study area**

## 3 MATERIALS AND METHODS

It has been selected and analyzed 10 longest backbone streams in the Litava River catchment of the 4th order – Litava, Říčka, Rakovec, Dunávka, Hvězdlička, Roketnice, Moutnický, Milešovický, Šitbořický and Žlebový brooks. All significant changes and regulations of these streams captured in the used maps (see below) were described. Three longest streams – Litava, Říčka and Rakovec – were subjected to a numerical analysis of mainstream length changes, length changes of side channels (without any distinction between man made side channels and natural branches) and mainstream sinuosity changes. This analysis was made both for the entire stream and for its main sections (upper and lower, in some cases also middle stream, defined with respect to the river stream typology worked out for the Ministry of the Environment and available at www.ochranavod.cz).

Data for the assessment and for numerical analyses were obtained from 6 sets of old maps, i. e. 1st Austrian Military (Joseph's) Survey from 1763–1783 (1 : 28 800), 2nd Austrian (Frances's) Military Survey from 1836–1852 (1 : 28 800), 3rd Austrian Military Survey from 1876–1880 (1 : 25 000), Czechoslovak (or Czech) military topographic maps from 1952–1955 and 1988–1995 (both map sets at a scale of 1 : 25 000), and the current base map (ZABAGED) from 2002–2006 (1 : 10 000, more info on the scale see below).

The analyzed streams were vectorized over the individual map sets with respect to their current course (i. e. with respect to the course of streams in layers A01 and/or A03 of the Digital Water Data Base (DIBAVOD) from 2006) in order to ensure the linkage of changes for the whole period and in the case of older maps (especially black and white ones) also to distinguish the particular stream from other linear elements in the floodplain (this concerning namely upper reaches). In the more recent map sets (from the 1990s), were used modified, already existing vector data (DMÚ 25 and ZABAGED; the latest vector data at a scale 1 : 25 000 were not available at the time of preparing documentation for this paper).

For each numerically analyzed stream or its section, total length of the stream was calculated as well as direct distance of initial and end nodal points. The two values were used to calculate sinuosity rate (Lehotský et Grešková, 2004). Calculated were also total lengths of their side channels and their sections. The behaviour of all three indicators for the period from 1836 to the present is illustrated in Fig. 2–11 and a survey of total changes for that period is presented in Tab. 1.

The numerical analysis did not include the oldest map set of the 1st Austrian Military Mapping from 1763–1783, which did not make it possible to provide comparable vector data (and hence comparable numerical data) with respect to missing geodetic basis and hence resulting frequent topographic errors (see Discussion). Stream names and basic numerical characteristics of the current river network presented in the text correspond with the Digital Water Data Base (DIBAVOD) from 2006 (provided no other data source is cited).

## 4 RESULTS

### 4.1 Evaluation of changes and results from the numerical analysis of the Litava R., Říčka R. and Rakovec R.

#### *4.1.1 Litava R.*

The river springs in Chřiby, at a distance of c. 5 km from the village of Střílky. It is a left-bank tributary of the Svratka R. into which it flows near Židlochovice on its 23.4 river km. Total length of the stream is 58.6 km. The upper reach is c. 12.3 km long and near Brankovice (from about the confluence with the Litenčický Brook), it passes into the middle reach (c. 25.8 km), which ends at the confluence with the Rakovec R. near the village of Hrušky, from where the lower reach continues for more c. 20.5 km. Except for the first half of the upper reach and some shorter sections of the middle reach, the river floodplain is rather broad.

The flow of the Litava R. was affected by the development and extinction of large reservoirs (of both through-flow and by-pass types) with the process occurring already before 1763. Most affected is the lower part of the middle reach (namely near Slavkov where 3 relatively large, likely through-flow reservoirs used to be) and a greater part of the lower reach where several large through-flow and by-passed reservoirs developed and were dried out of which the largest one was the by-passed Měnínský rybník pond (see Fig. 15 and 16). The extinction of reservoirs usually led to the stream straightening but also to an increased number of side channels (mostly drainage channels), many of which became later gradually extinct. Distinct stream straightening in the area of extinct reservoirs can be explained by the restoration of main stream not in its historic channel (commonly sinuous or meandering) but in the modified (straightened) channel with the aim to enhance the effective drainage of the area and thus also enhance its further exploitation. Stream straightening occurred also outside the areas of the former reservoirs (e. g. on the boundary between the middle and lower reaches below the village of Hrušky). Some side channels in the upper and middle reaches served as mill races, some mills were built below the reservoirs (at the beginning of the surveyed period there were 13 water mills on the river).

Major part of the process of stream straightening dates back to the mid-20th century (see Fig. 2) and later the stream recorded hardly any changes. The change of the length of side channels had a similar course as sinuosity changes with a greater part of side channels becoming extinct before the mid-20th century. Differences between the upper, middle and lower streams (see Fig. 3–5 and Tab. 1) more or less correspond to the character of river and its floodplain in those reaches. Most conspicuous changes are in the lower reach; the different behaviour of changes in the length of side channels in the upper reach (slight increase in the mid-20th century) resulted from regulation works between the Chvalnovský potok Brook and Litavka R. where the mainstream was replaced into a new channel while the original channel remained preserved and became extinct later. A slight increase in sinuosity in the upper stream in the last surveyed period was affected by the difference in the scale of the map set (see Chapter 3 and below).

### *4.1.2 Říčka R.*

The river springs in a forest valley, some 2 km northwest of Račice-Pístovice. It is a right-bank tributary of the Litava R., into which it flows below Měnín on its 7.2 river km. Total length of the stream is 38.9 km. The upper reach is about 28.3 km long and the lower reach of 10.6 km starts near Ponětovice (below the confluence with the Roketnice R.). The upper reach floodplain is narrow with the stream incised into the valley and with the middle part flowing through a karst area. The lower reach passes through a broader floodplain mostly only in the mildly undulating landscape.

Changes of the stream are relatively inconspicuous. The main process affecting the stream was straightening, namely in the lower reach; the development and extinction of reservoirs did not play an important role. Although there were some reservoirs developing and disappearing in the upper reach, they were relatively small and did not induce any increase of side channels in the narrow floodplain. Larger reservoirs were built only later (a cascade of reservoirs between Muchova bouda Hut and Kadlecův mlýn Mill in the last section of the upper reach). In the lower reach, there used to be 2 large by-pass reservoirs near Kobylnice, which gradually became extinct. The number and length of side channels were not particularly affected by the process (reason being apparently the by-pass character of the reservoirs). However, a number of side channels developed along the main river stream (namely in its upper reach), which served as millraces (there were about 12 water mills on the stream at the beginning of the assessed period), of which some gradually disappeared or stopped being operated. Worth mentioning is the anastomosis of the Říčka with the Dunávka (water supply from the Dunávka) at Sokolnice, which is partly apparent already in the oldest analyzed maps from 1763–1783 (probably, the anastomosis was interrupted in the following period or it ceased).

Stream straightening was processed from the end of the 19th century to the end of the 20th century (see Fig. 6). Increased sinuosity in the last period results from the difference in the scale of the map set (see Chapter 3), which has a somewhat more pronounced impact here than in the case of the Litava R. This is given by the character of the upper reach (the course of the stream – at many places richly sinuous to meandering in the narrow floodplain was apparently generalized in older map sets of smaller scale). Thus, it can be assumed that results from the analysis of the lower stream are affected only negligibly (see Fig. 7 and 8, Tab. 1). The extinction (shortening of total length) of side channels is the least conspicuous of all three rivers subjected to detail survey. On the other hand, the length of side channels markedly increased in the mid-20th century, which resulted from the restoration of a relatively long canal in the space of the former by-pass reservoir below Měnín and due to its extension up to the village of Blučina. Nevertheless, the disappearance of side channels further continued at other places of the reach (e. g. above Sokolnice and near Telnice).

### *4.1.3 Rakovec R.*

The river springs about 3 km to the southeast of Jedovnice. It is a right-bank tributary of the Litava R. into which it flows near the village of Hrušky on its 20.4 river km. Total length of the stream is 36.5 km. The upper reach is 24 km long and passes into the lower reach of 12.5 km in length near Rousínov at the confluence with the Vážanský potok Brook. The alluvium of the Rakovec resembles in its character more the Litava R. floodplain than the floodplain of the Říčka R. In the upper reach, it is somewhat broader than that of the Říčka because the valley is of different character (it constitutes a graben).

During the period of survey, the stream was changing due to straightening. Another important impact was multiple rechanneling of the main stream (namely in the site of former reservoirs in the lower reach, to a lesser extent also in the upper reach). Larger reservoirs (generally through-flow) developed both in the middle section of the upper reach and in the middle section of the lower reach where most of them disappeared before 1763 and were never restored again (likely due to processes similar to those occurring on the Litava R. below Slavkov). It seems that the only water reservoir that did not change much in the surveyed period was the through-flow Pístovický pond situated at about mid-upper stream near Račice-Pístovice. On this stream, too, a number of water mills were built (about 15 at the beginning of the surveyed period), some of which near water reservoirs.

The process of stream straightening happened in the period until the mid-20th century, similarly as in the case of the Litava R. (see Fig. 9), more continually in the lower reach than in the upper reach where main changes of sinuosity were found for the period from the end of the 19th century to the mid-20th century (see Fig. 10 and 11 and Tab. 1). What was stated about increased sinuosity in the upper stream of the Říčka R. during the last period of survey holds for the Rakovec R. too (see Chapter 4.1.2 above). The extinction (shortening of total length) of side channels does not have such a pronounced course as in the Litava R., and the course of this process is similar in the upper and lower reaches.

## 4.2 Assessment of changes of other selected streams

### *Dunávka R.*

At present, the river springs c. 0.5 km north of the village Dvorska. It is the last right-bank tributary of Litava R., into which it flows below the village Blučina on its km 2.3. Total length of the stream is 15.2 km. The Dunávka R. floodplain is rather broad and the stream flows through only a mildly undulating landscape.

The most important process affecting the stream course was development and extinction of water reservoirs. At the beginning of the study period, there was a system of 9 relatively large water reservoirs in the middle reach of the stream and one small reservoir was in head water area, too. At that time, the last reservoir was likely connected with the reservoir upstream Rajhradice, which was fed from the Svratka R. Most of these reservoirs disappeared in the following periods. Drainage channels, which later became extinct, developed in the place of some former reservoirs. The interconnection with the Říčka R. near Sokolnice was mentioned above (see Chapter 4.1.2); in the second half of the 20th century, irrigation canals were constructed at this place of the river reach (some of them apparently restored), radiating from the restored reservoir along both sides of the stream. The process of straightening was more pronounced in the last section, below the last of the former reservoirs. There was no water mill built on the stream. At the beginning of the surveyed period, the river apparently sprang some 1.6 km above its today's spring, which occurred in the current location already in the mid-20th century. The process might have been related with water losses in the landscape due to intense cultivation after deforestation (which happened before 1763), see also below (Žlebový potok Brook).

*Hvězdlička R.*

The stream head lies c. 3.4 km to the northeast of village Hvězdlice. The stream is a right-bank tributary of the Litava R. into which it flows at the village Nesovice on its km 42.5. Total length of the stream is 12.5 km. The floodplain of the Hvězdlička R. is rather narrow (stream flowing through a hilly terrain) and somewhat broader only before the confluence with the Chvalkovický potok Brook.

Its course it not too much affected by regulation. There are only a few water reservoirs that were built, dried out or restored, of which the most important one is Uhřický pond situated in the widened section of the floodplain at the confluence with the Chvalkovický Brook (it was originally a through-flow reservoir, which was later changed into a by-pass reservoir). Straightening was made only at a small scale, similarly as changes on a few side channels. Several water mills were built usually below the reservoirs.

*Roketnice R.*

At present, the Roketnice R. springs cca 1 km to the east of the lower end of Hostěnice village and it is a left-bank tributary of Říčka R., which it joins near Ponětovice village at its km 10.6. Total length of the stream is 12.4 km. The floodplain of the Roketnice is rather narrow but sporadically widening.

The stream was affected by the development and extinction of two smaller water reservoirs, by the straightening of low extent (especially within the space of settlements) and possibly also by changes and later extinction of side channels (two mill races and stretches at the places of reservoirs). During the study period, the spring area location (which used to be lower below Hostěnice) was changing, which may relate to the fact that the headwater lies in the karst area.

*Moutnický potok Brook*

The stream springs in the area of Borovany village and is a left-bank tributary of the Litava R. into which it flows below Měnín village on its km 5.6. Total length of the stream amounts to 12.4 km. The floodplain is rather broad and the stream flows mainly through a mildly undulating landscape, which passes into lowland in its lower reach. Near Těšany village, below about the first third of its length, the Moutnický Brook splits now into two arms of which the first one is recorded in the Digital Water Data Base (DIBAVOD) as a self-contained Hranečnický potok Brook.

The stream was affected by development and abolishment of water reservoirs (incl. the Měnínský pond on the Litava R., into which the Moutnický Brook originally flew). A specific situation here is the above mentioned stream division into two branches near Těšany. The original state cannot be plausibly reconstructed from the used map collections. The oldest map collection captures a similar situation on this stream also below the village of Těšany above Moutnice village where another branch singles out from the Moutnický Brook in the direction of Nesvačilka village. The branching does not exist any longer and the branch is an independent stream springing above Nesvačilka. Thus, it could have been an artificial interconnection aimed at enhancing water stage of this stream by water from the Moutnický Brook. A similar hydrotechnical measure could have been made near Těšany in the direction of the currently existing Hranečnický potok Brook (here it related to the construction of a water reservoir and water mill, from which both arms emptied) where the interconnection remained preserved (after an interruption in about the mid-19th century) even after the reservoir ceased to exist.

*Milešovický potok Brook*

The Milešovický Brook springs cca 3.1 km to the southeast of the village Kobeřice and it is a left-bank tributary of the Litava R., into which it flows near Šaratice willage on its km 16.2. Total length of the stream is 11.9 km. The floodplain is rather narrow at first (the stream flows through a hilly landscape) and in the second half it gradually widens (landscape is only mildly undulating there).

Similarly as the Moutnický Brook, the Milešovický Brook is affected by the development, destruction or restoration of water reservoirs, which counted ten in total. They were not too large, only one of them, situated in the lower reach, had a water mill below. The process was more intense in the upper half of the reach, which is likely to relate to favourable conditions of the floodplain.

*Šitbořický potok Brook*

The stream springs near the village Šitbořice and it is a left-bank tributary of the Moutnický Brook, into which it flows near the former Měnínský pond (at one of its former dykes). Total length of the stream is 10.3 km. The floodplain is rather broad, the stream flows through only a mildly undulating to flat landscape.

The water course and namely its lower reach was affected by the development and destruction of water reservoirs; the stream originally flew into the Měnínský pond. Upstream (at about the middle of the stream), there used to be only two smaller water reservoirs at the beginning of the surveyed period. With their destruction a significant change likely occurred in the stream course (displacement into another channel with the original channel running through the reservoirs dried out).

*Žlebový potok Brook*

The shortest of the surveyed streams is only 9.7 km long and springs at the present about 0.5 km to the northeast of Bohaté Málkovice village. It is a right-bank tributary of the Litava R., which it joins at Marefy village on its km 32.1. The floodplain is of variable width and the stream flows through a hilly country.

The course of this stream was affected by the development and destruction of water reservoirs, too, because conditions for them were very favourable in the floodplain of variable width. There were four water reservoirs that were gradually built and dried out on this short stream and water mills occurred below two of them. Another distinct process on the stream (in relation to its length) concerned headwater changes. The spring of the Žlebový Brook was originally situated some 700–800 m to the north of Bohaté Málkovice (see Fig. 17). Later, this headwater disappeared and was followed by disappearance of the first right-bank tributary of comparable length. At present, the headwater is represented by the former first left-bank tributary (see Fig. 18). Should we abstract from the errors and different approaches of map preparation and processing (or significant differences in precipitation amounts in periods of field survey), we could consider the process as a manifestation of gradual drainage of a formerly (before 1763) forested landscape rich in water (see also development on the Dunávka R.).

## 5 DISCUSSION

Hydrographic changes of streams can be analyzed at various levels and in various time horizons, depending on requirements imposed on the analysis and/or depending on what period is covered in the studied area by applicable (and comparable)

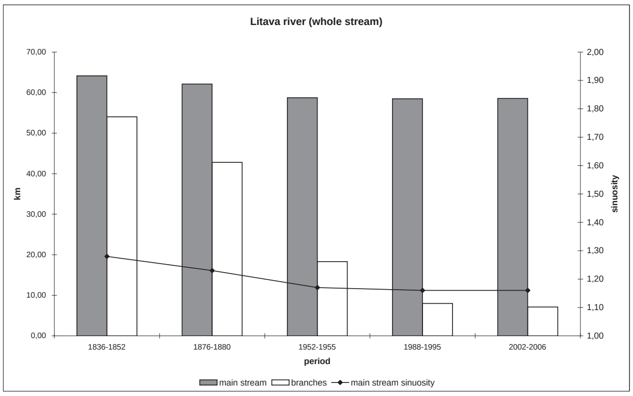


**Fig. 2 Litava R. (whole stream) – changes in the length of the mainstream and side channels, changes in the mainstream sinuosity**

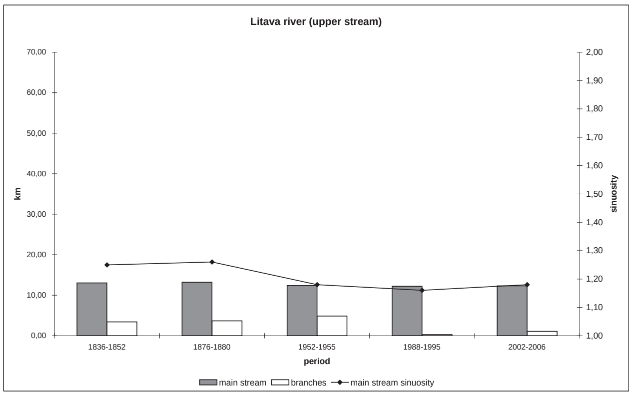


**Fig. 3 Litava R. (upper stream) – changes in the length of the mainstream and side channels, changes in the mainstream sinuosity**

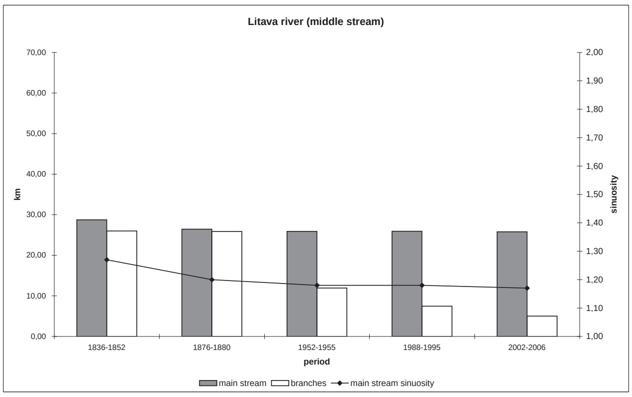


**Fig. 4 Litava R. (middle stream) – changes in the length of the mainstream and side channels, changes in the mainstream sinuosity**

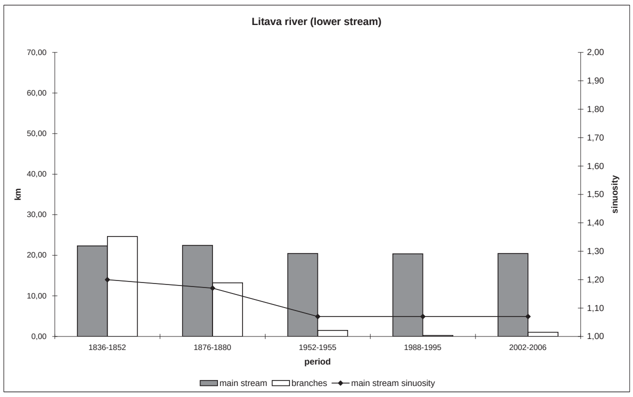


**Fig. 5 Litava R. (lower stream) – changes in the length of the mainstream and side channels, changes in the mainstream sinuosity**

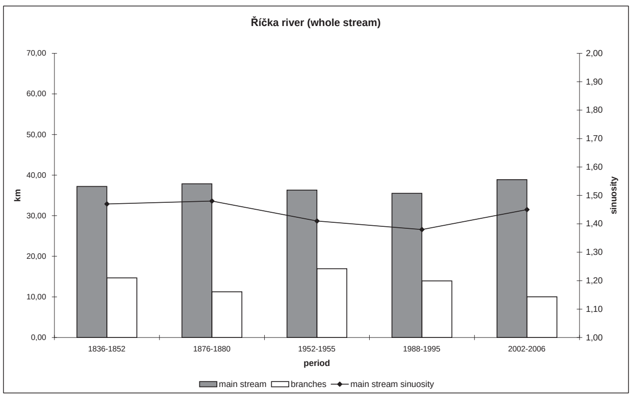


**Fig. 6 Říčka R. (whole stream) – changes in the length of the mainstream and side channels, changes in the mainstream sinuosity**

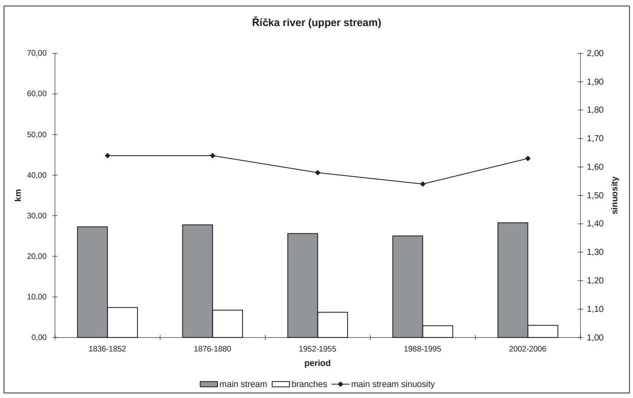


**Fig. 7 Říčka R. (upper stream) – changes in the length of the mainstream and side channels, changes in the mainstream sinuosity**

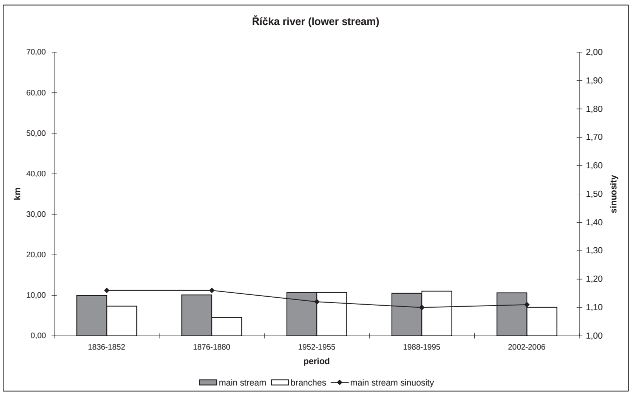


**Fig. 8 Říčka R. (lower stream) – changes in the length of the mainstream and side channels, changes in the mainstream sinuosity**

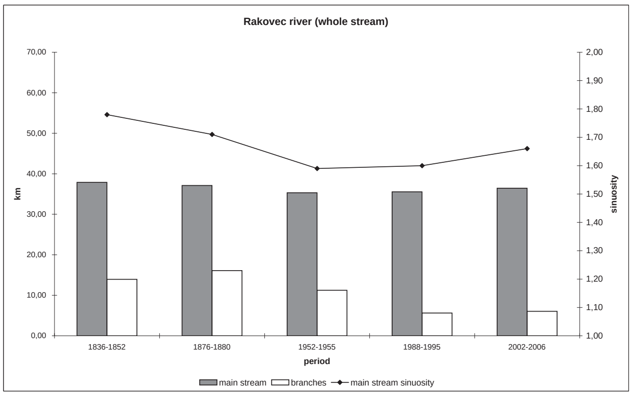


**Fig. 9 Rakovec R. (whole stream) – changes in the length of the mainstream and side channels, changes in the mainstream sinuosity**

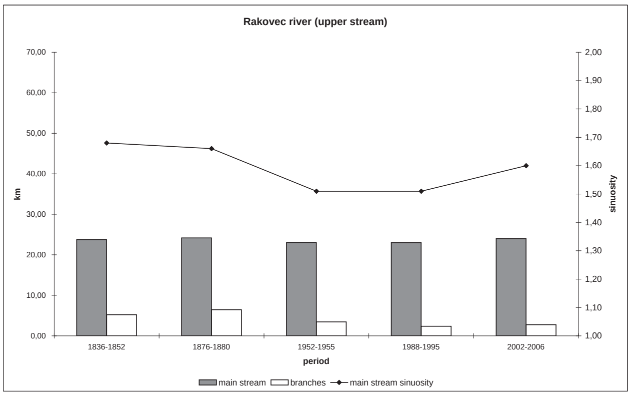


**Fig. 10 Rakovec R. (upper stream) – changes in the length of the mainstream and side channels, changes in the mainstream sinuosity**

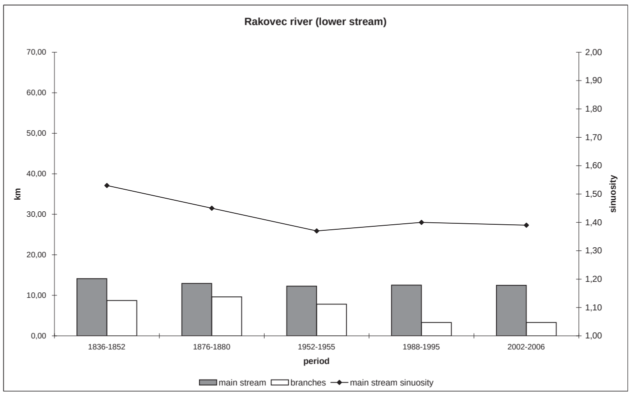


**Fig. 11 Rakovec R. (lower stream) – changes in the length of the mainstream and side channels, changes in the mainstream sinuosity**

**Tab. 1 Total change of mainstream length, length of side channels and main stream sinuosity in three longest streams in the Litava River basin in the period from the end of the first half of the 19th century until the present time (1836–2006)**

| River | Reach | Main stream length change | | Branches length change | | Sinuosity change |
|---|---|---|---|---|---|---|
| | | km | % | km | % | |
| **Litava** | Stream total | -5.6 | -8.7 | -46.9 | -86.8 | -0.12 |
| | Upper stream | -0.7 | -5.5 | -2.3 | -68.4 | -0.07 |
| | Middle stream | -3.0 | -10.3 | -21.0 | -80.7 | -0.10 |
| | Lower stream | -1.9 | -8.5 | -23.6 | -95.8 | -0.13 |
| **Říčka** | Stream total | 1.7 | 4.5 | -4.7 | -31.7 | -0.02 |
| | Upper stream | 1.0 | 3.7 | -4.4 | -59.2 | -0.01 |
| | Lower stream | 0.7 | 6.7 | -0.3 | -4.0 | -0.05 |
| **Rakovec** | Stream total | -1.4 | -3.8 | -7.9 | -56.7 | -0.12 |
| | Upper stream | 0.2 | 1.0 | -2.5 | -47.6 | -0.08 |
| | Lower stream | 1.7 | -11.8 | -5.4 | -62.1 | -0.14 |

historic map materials (e. g. Downward et Gurnell, 1994; Gurnell, 1996; Hooke et Redmont, 1989a; Hooke et Redmont, 1989b; Priestnall et Downs, 1999; Kilianová, 2000; Trimble, 2003; Hauser et al., 2004; Skokanová, 2005; Chrudina, 2007; Žikulinas, 2008 and others). River network (especially middle and lower reaches with their floodplains) represent landscape elements that have been used by man in the Central-European space for many hundreds of years and during this time, many of rivers and floodplains were considerably affected by this use (Klvač, 2004; Just et al., 2005). Limiting factor of analyses focused on long-term hydrographic changes in the river pattern of larger territorial units due to anthropogenic activities is a relatively short time for which suitable whole-area documentation (old maps) is available. Although the time horizon of approximately 250 years that can be analyzed in the case of Litava River does not provide possibility of relying upon the original or by man only little affected condition of river network in the analysis (a larger part of the sections of analyzed streams was somewhat changed already at the beginning of the surveyed period), it captures key periods from the preindustrial baroque landscape through the beginning of industrial revolution and the post-war intensification of landscape use until these days. The most important processes during which significant changes or even degradation of natural environment were induced by anthropogenic activities and the essential change or even damage to the multipurpose potential of floodplains was observed doubtlessly occurred especially in the period after the beginning of industrial revolution (Kukla, 2007; Just et al., 2005).

The anthropogenically conditioned hydrographic changes in the Litava River basin were caused by several types of processes. The most important of them was the *foundation and subsequent abandonment of water reservoirs*. The establishment of a water reservoir on the stream or next to the stream can be in many cases interpreted rather as an enhancement of the multipurpose potential of riparian landscape (provided that a unique or particularly ecologically important part of the floodplain is not inundated). On the other hand, a (permanent) abandonment of the reservoir and subsequent changes and hydrotechnical regulations within the space of the former reservoir had eventually often rather negative influence on the stream and its floodplain. Although the stream branching was temporarily increased by the construction of drainage channels, the main stream was rather straightened and plots within the space of the reservoir were then intensively used for agriculture or for other purposes. One of streams whose hydrography was most affected by this process is the Litava R. (most apparently in the second half of the middle reach and in a larger part of the lower reach where a number of original branches and meanders likely became extinct in the broad waterlogged floodplain) and the Dunávka R. (nearly the entire stream, although the character of both stream and floodplain was different than in the Litava R. – the stream is shorter and somewhat less water bearing, flowing through a relatively broad, but not so flat, floodplain – and so somewhat less pronounced hydrographic changes of natural course and branching can be expected). Most of other streams were apparently affected by this process, too.

Another significant type of processes was the *straightening of the originally sinuous to meandering streams*. Processes of this type are practically always a symbol for adverse intervention into the stream and its floodplain particularly because they lead to stream shortening and hence to the accelerated water diversion from the concerned territory (which supports decrease of water supply in the landscape and extreme course of flood levels). Sinuous stream sections were straightened on the studied streams mainly in floodplain parts intensively used for agriculture and in the space of settlements. In meandering streams, the meanders were cut-off and river lakes developed, which often became gradually extinct. This process is typical rather for the lower reaches of large rivers such as the Svratka or the Dyje (Skokanová, 2005; Demek et al., 2008). On the studied streams in the Litava R. basin, it was recorded only exceptionally (e. g. on the Litava R. near Hrušky village).

Another frequently observed process is the *extinction of side channels*. The process is usually connected with the main stream straightening or displacement into a new channel and it often follows the destruction of water reservoirs (provided that a system of side channels developed along the stream). The impact of such interventions is similar as in the straightening (if the extinction of natural stream sections is concerned) and can be therefore considered similarly negative. The extinction of side channels was observed to happen at a great extent in all streams that branched in a natural way even after the intervention of man (supply ditches of reservoirs, mill races etc.). The process was often rather extensive and a majority of mainstream side channels gradually disappeared (see results from the numerical analysis of selected streams).

The last type of observed processes is represented by *changes of headwaters* (spring area change). These changes may have different reasons, in some cases, they can be considered as a consequence of man's intervention (direct or indirect), and sometimes the stream transformations are natural. Considerable headwater area changes were recorded for three analyzed streams. In two cases, they can be attributed to man (the Dunávka and the Žlebový potok Brook), and in one case we can rather speak of stream variability in the karst area (the Roketnice).

Streams of the Litava River backbone network can be generally valuated as relatively considerably affected by human interventions, which particularly applies to their middle and lower reaches. In the floodplains of these streams, a number of settlements occur and the remaining alluvial land has been (with some single exceptions) intensively used for agricultural production, practically since the times of post-war intensification in the 20th century (Havlíček, Borovec, Svoboda, 2009, written communication). A larger part of water bodies in the Litava R. basin is categorized at the present as severely affected and their return to natural condition would be apparently difficult because their present use can be hardly changed (Povodí Moravy, 2008). More favourable situation exists practically only in the basins of the upper reaches of the Říčka and the Rakovec (relatively sparsely populated and considerably forested areas at higher altitudes, partly karst area).

Despite various differences and drawbacks, the applicability of the map documentation appeared sufficient for the used procedures and the level of details in the herein presented analysis of hydrographic changes of streams. The dissimilarity of the maps from the 1st Austrian military survey was mentioned above (see Chapter 3 and e. g. Zimová, 2005; Miškovský et Zimová, 2006). Here, we should only add that in the orientation vectorization of river network over map sheets, georeferenced with using map index (according to the position of map corners), a variable spatial error was found out, which was at some places reaching up to 5 km. A considerable distortion of relief forms (as compared with the more recent map collections) is obvious at many places already at a quick glance at map sheets. A more significant distortion of relief forms (and inferential topographic error) was however sporadically observed also in the more recent maps from the 2nd and 3rd Austrian military mapping in headwater areas of some streams (at places with articulated and thus not easy to survey landscapes at higher altitudes). In those cases, the stream had to be carefully vectorized not only with respect to the reference data set from the Digital Water Database (see Chapter 3) but also with respect to findings from the study of such areas in the preceding and following map collection (or collections) in order to minimize the impact of distortions. Regarding the most conspicuous processes that occurred on the streams in the Litava River basin in the past (development and abandonment of reservoirs), the oldest collection of maps from 1763–1783, capturing the still considerably preserved system of water reservoirs in the catchment (comp. Fig. 12–14) is of the greatest importance for comparison.

## 6 CONCLUSIONS

Results and findings from the study of hydrographic changes on selected streams of the backbone network of streams in the Litava River basin (and numerical analyses of three most important streams) for the period from 1764 until the present time (i. e. for about the last 250 years) can be summarized as follows.

(1) The course of all analyzed streams was relatively notably affected by human activities (i. e. use of stream and floodplain) with the impacts of these activities being most apparent in the middle and lower reaches. Considerable changes in the course and branching of streams were in some sections made already before the period of survey, i. e. before 1763.

(2) The hydrographic changes of streams were caused by four types of processes conditioned by anthropogenic activities: (a) foundation and subsequent abandonment of water reservoirs, usually of through-flow or by-pass types (in some cases, old reservoirs were later restored), (b) straightening of the originally sinuous to meandering streams, (c) extinction of side channels (this process usually accompanied the first two mentioned processes), and (d) changes of headwater areas or spring area location (here it was rather an indirect influence of land use by man or a rather natural process). The most significant process on most analyzed streams in the analyzed basin was the development and destruction of relatively large water reservoirs (in relation to the length and water bearing of streams).

(3) The collection of old map sets (including the oldest, in many respects problematic maps from the 1st Austrian Military Survey) in combination with the reference dataset of streams from the Digital Water Data Base (DIBAVOD) appeared useful for the presented type of the analysis of hydrographic changes on selected backbone streams in the Litava River basin. However, during the preparation of data and materials for the analysis (e. g. if the relief was largely distorted in the old map), it was necessary in some cases to make a comparison with older and newer map collection or collections provided that at least a bit comparable older map collection had been available (this is why the oldest analyzed map set from 1763–1783 was in the studied collection of old map sets important primarily for reference).

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# RESEARCH OF DISTURBANCE AND RECLAMATION PROCESSES IN THE CULTURAL LANDSCAPE MINES AFFECTED BY SURFACE MINING OF MINERALS

# SLEDOVÁNÍ DISTURBANČNÍCH A REKULTIVAČNÍCH PROCESŮ V KULTURNÍ KRAJINĚ NARUŠENÉ POVRCHOVOU TĚŽBOU NEROSTNÝCH SUROVIN

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**Abstract**

The presented study represents a partial output of a pilot project dealing with the strategy of development of reclaimed landscape of the Nástup Tušimice Mines. The purpose of the project was to use available materials and field analyses for a formulation of the basic idea of the achievable target condition of the territory, or for a definition of the further development of the studied landscape in all its territorial complexes with different purposes, uses and methods of management. An important part of the project is a survey of the historic development of the usage of present areas documenting the size and impact of land use changes in the landscape of the Nástup Tušimice Mines and their effects on the wider surroundings of the studied region.

**Abstrakt**

Předkládaná studie představuje dílčí výstup pilotního projektu zabývajícího se strategií rozvoje rekultivované krajiny Dolů Nástup Tušimice. Cílem projektu bylo za využití disponibilních podkladů a terénních analýz formulovat základní představu dosažitelného cílového stavu území, resp. definovat rozvoj studované krajiny ve všech jejích územních komplexech s odlišným posláním, využitím, a tím i odlišným způsobem péče. Důležitou součást projektu představuje přehled historického vývoje využití přítomných ploch, který dokumentuje, k jak velkým a razantním změnám ve využívání krajiny Dolů Nástup Tušimice došlo a jaký nezanedbatelný dopad to mělo i na širší okolí studovaného území.

**Keywords:** disturbances, land-use changes, reclamations, territory development

## 1 INTRODUCTION

Surface mining of minerals causes permanent destruction of the original landscape and continuous changes of its appearance by impact of anthropogenic activity. The mining causes changes of the mineral substrate, transformation of the soil and hydrologic conditions and modification of the relief.

The anthropogenic relief of the landscape affected by surface mining of coal creates a space for developmental seral processes. Reclamations, controlled or natural succession (Prach, 1995; Sádlo, Tichý, 2000 and others) give rise to new populations continuously forming the landscape character (Simon et al., 2006). The purpose of ecosystem restoration is therefore the return of degraded and destructed ecosystems to conditions similar to those of the original ecosystems (Schreckenberg et al., 1990).

Specifically in the case of mining landscape rehabilitation (Štrupl, 1960; Vráblíková, Vráblík, 2002) a new natural environment is created, often much different from the original one. An environment formed in this manner may be expected to fulfil, at least partly, its production and non-production functions like a natural landscape system in the medium- to long-term horizon.

Mining activity in the region of interest is currently performed by the joint-stock company Severočeské doly a.s., active in the area since 1994. The quarry Nástup Tušimice is a brown coal surface mine annually producing 13.5 million tons of mainly energy coal and up to 26.5 million m$^3$ of overlying earths. Excavated rocks are deposited on the internal spoil banks of the Nástup Tušimice Mines (SDAS, 2008).

By Government Resolution no 444/91 Coll. the coal mining within the current borders defined by environmental limits will be discontinued around 2030 and the whole area of the mine should be reclaimed by 2050. The main share of works will fall to forest reclamations, followed by the restoration of agricultural lands and streams. Annually, some 6 thousand hectares of exploited areas are rehabilitated and reclaimed.

The project consists of several logically interconnected parts. The starting point is represented by characteristics of wider spatial relations and natural conditions of the model territory, and by the specification of frameworks within which the mining-affected landscape may develop.

The author has assessed all known and currently existing approaches to the concept of ecosystem and landscape re-creation, judged the contributions of the implemented agricultural, forestry and other reclamation activities and compared these findings with analogical landscape segments on the basis of reconstruction of the natural vegetation (Simon et al., 2007; Simon et al., 2008).

## 2 STUDY AREA

The starting point in the formulation of proposal for a differentiated strategy of renewal and development of the devastated landscape in the surroundings of the Nástup Tušimice mines was a definition of the model region from the viewpoint of wider spatial relations and natural conditions. The author also reconstructed potential condition of the geobiocenoses, on the basis of which specific rehabilitation and reclamation measures have been suggested. The territory was defined in terms of relatively homogeneous areas for the application of a defined set of specific measures selected with regard to the similar to-date development of the areas and to a certain extent also with regard to their prospective functional potential. For that purpose the author applied principles and procedures of the geobiocenological concept of biogeographical differentiation of the landscape (Buček, Lacina, 2007).

The region of interest is situated in the biogeographic region of the city of Most forming part of the Hercyne subprovince (Culek, 1992). The relief can be characterised as flat to dissected hilly lands whose altitudes range from 220–350 m above sea level. According to Quitt (1971), the territory lies within the warm climatic zone (T2), with a strong effect of the rain shadow of the Krušné hory Mts.

The original, prevailingly agricultural use of the landscape clearly follows out from predominant soil types – Chernozem with islands of Vertisols. Present are also Cambisol and Pararendzinas on heavy clay substrates.

The natural vegetation cover of the region is mainly formed by the geobiocenoses of Altitudinal Vegetation Zone 2 (Beech-Oak) (56 % of the territory) and AVZ 3 (Oak-Beech) with the increasing elevation gradient (about 44 % of the bioregion area). In the area of the Podkrušnohorská pánev Basin, we find remainders of the originally prevailing association of thermophilic oakwoods. However, natural and near-natural communities were devastated by the mining and the substitute vegetation (if any) today mostly consists of secondary ruderal communities of spoil banks and industrial sites or of the vegetation cover of implemented reclamations.

Wider surroundings of the Nástup Tušimice Mines borders the Doupovský bioregion in the west and in a narrow transitional zone the Krušné Hory Mts. biogeographical region in the north, from which some submontane to montane plant species descend into the region of study (Culek, 1992).

The mining activity induced massive changes in the landscape formation. That is why a specific biochore 2AN Anthropogenic relief of mines and spoil banks was demarcated in the dry region of Altitudinal Vegetation Zone 2 (AVZ 2) (Culek, 2005), whose characteristics apply to the whole area of the Nástup Tušimice Mines.

## 3 MATERIAL AND METHODS

To describe the land use, its components or elements in the historic context it is necessary to compare several map sets from different periods of time. These analyses must be based on maps of relatively identical scales, quality and levels of generalisation to achieve maximum objectiveness of the outputs.

The methodological procedure of assessment of the region of the Nástup Tušimice Mines was based on the comparison of topographic materials originating from the 2$^{nd}$ military mapping, and map works from the years 1950, 1970, 1990 and 2005. Resulting analyses for the given periods provide information about the number of large-scale land use changes in the model region of the Nástup Tušimice Mines in two planes. The first plane captures wider territorial relations and is therefore referred to as a "***Broader hinterland of Nástup Tušimice Mines***", while the second plane is focused in a greater detail onto the actual territory of the Nástup Tušimice Mines and is referred to as a "***Nástup Tušimice Mines Territory***". The total **area of the broader hinterland** of the Nástup Tušimice Mines is **32,936.58 ha**, **while the area of the** "**region**" itself is **6,412.68 ha**.

The assessment of land use and the subsequent analysis of land use changes in the historic context were based on the methodological procedure developed within the research project MSM 6293359101 "*Research of Sources and Indicators of Biodiversity in Cultural Landscape in Context of Dynamic of its Fragmentation*", implemented by the Silva Tarouca Research Institute for Landscape and Ornamental Gardening, v.v.i. (VÚKOZ, v.v.i., Brno Office, Department of Landscape Ecology). The methodological procedure is based on a digital analysis of five sets of available cartographic materials (Mackovčin, 2009; Skokanová, 2008).

Its partial output is represented by maps of land use on a scale of 1 : 50 000 (Broader Hinterland of Nástup Tušimice Mines) and 1 : 40 000 (Nástup Tušimice Mines Territory) for the respective periods on the basis of which two resulting analytical maps of identical scale were constructed, evaluating the number of changes occurring in the period 1846–2006. The construction of maps illustrating landuse changes in the respective periods was made with the differentiation of 9 categories of land surface units (landuse elements):

1. Arable land
2. Permanent grassland – meadows, pastures
3. Garden, orchard – outside the intravillan
4. Vineyard, hop-field – outside the intravillan
5. Forest
6. Water surface – both natural and artificial surfaces
7. Built-up area – urban and rural developments, industrial and agricultural sites, etc.
8. Recreation surface – campings, sports grounds, garden colonies, etc.
0. Other – mining sites, spoil banks, waste banks, etc. – only outside the intravilan

In the last methodological step, the outputs were converted into graphs illustrating the developmental dynamics of individual spatial categories within the region of interest.

The study deals with anthropogenic disturbations and their action of landscape in time. For this purpose was analysed development of other (mining areas) and build-up area (concomitant industrial and production estates) to with comes under localities affected by surface mining of minerals. Compared to reclamation processes can be pursue within the scope of permanent grassland and forest progression. They were bringing into disturbed landscape repeatedly by means of various redevelopment remedials.

## 4 RESULTS

### 4.1 Land use in the period of the 2nd military mapping (1846)

#### 4.1.1 Broader hinterland of the Nástup Tušimice Mines

In 1846, the local landscape can be classified as agricultural with the absolute prevalence of arable land (covering 72.21 %) and forests (10.67 %); significant share in this area had also meadows and pastures (8.22 %).

The only larger forest complex was situated in the north-west to north of the surveyed area and belonged in the geomorphological unit of the Krušné hory Mts. The rest of the region belonged to the Mostecká pánev Basin, where small-scale field farming prevailed in the concerned period. The land use map shows arable land as a continuous matrix, which was in fact divided into a large number of small plots segmented by numerous linear elements (tree lines or rivers) in the historic maps.

The largest settlement in the broader hinterland was Chomutov, which already held the town status by that time. Another larger settlement Kadaň was situated in the southwestern part of the territory. The village of Prunéřov is situated immediately above it with its characteristic elongated shape.

Water surfaces were concentrated in the northern part of the region of interest and take up only 83.74 ha (0.25 %). An interesting attribute of the concerned region are hop fields representing one of characteristic features of the České Středohoří Mts. landscape. The share of hop fields in the total area of the region of interest is about 0.58 %, which represents ca. 190 ha.

Local quarries were used to extract mainly building materials such as stone, sand and loam. Brown coal mining was not recorded yet in this region.

#### 4.1.2 Premises of the Nástup Tušimice Mines

This material shows at a greater detail a similar condition as in the broader hinterland. The dominant land use area category is represented by arable land (whose share in the total area amounted to 87.29 %), locally broken by an enclave of meadows and pastures.

In this period, the region included 16 municipalities, most of which had to give way to the increasing spatial demand of the mining area operated by the joint-stock company Severočeské doly a.s.: Ahníkov, Brany, Brančíky, Bystřice, Čachovice, Kralupy u Chomutova, Krbice, Libouš, Milžany, Naší, Prunéřov, Přezetice, Račice, Vrchnice and Zásada municipalities.

In the southeastern part of the region towards the centre of the area at the boundary of the affected territory, there was the municipality of Tušimice, around which the mines developed and expanded in the following periods.

The area further included only 3 smaller forest complexes situated in the northeastern and the south-eastern part. Water surfaces in the region were represented by ponds in the northwestern part of the area.

### 4.2 Land use in 1950

#### 4.2.1 Broader hinterland of the Nástup Tušimice Mines

The spatial structure of the landscape in the 1950s appears a little more varied than in the previous period. The main reason was increased areas of permanent cultures (gardens, orchards, hop fields), and also an increased share of permanent grassland (hereinafter just "grassland"), especially in the northeastern corner of the region. These categories expanded at the cost of arable land whose total area decreased to 22,202.69 ha (decrease by 4.8 % in comparison to the year 1846).

Forests and built-up areas showed a negligible increase in size. Surface mining of brown coal was launched below the Prunéřov municipality, which was manifested by a moderate area increase of the given land use area category to 114.08 ha, which, however, was still far from exceeding 1 % of the total area of the surveyed region. Water surfaces remained virtually at the same level. The maps from this period did not show any recreational areas.

#### 4.2.2 Premises of the Nástup Tušimice Mines

The detailed depiction of the region shows an identical trend – increased area of permanent crops, permanent grasslands and forest stands.

In respect of settlements, the largest expansion was shown by the Prunéřov municipality, probably due to the commenced surface mining of brown coal in its close vicinity.

Other areas were represented by isolated surface quarries and sludge beds in the surroundings of Prunéřov, whose area, even if negligible in relation to the total area of the region, increased more than 12times (from 3.04 ha to 38.89 ha).

### 4.3 Land use in 1976

#### 4.3.1 Broader hinterland of the Nástup Tušimice Mines

This period saw the most progressive change of the landscape structure in the territory on both levels of detail. The largest area increase is doubtlessly seen, and is quite obvious even by visual comparison, in the category of other areas, which was mainly caused by the introduction of new surface mining technologies, replacing the time and energy consuming deep mining methods.

Increased mining area was probably the reason for the increased built-up area. This development was not so much projection of the sprawling of settlements but rather due to the construction of related industrial premises processing in various ways the extracted brown coal.

Another progressive category was water surface, whose area increased from 79.58 to 1,378.03 ha, thus "enriching" the landscape with another visual dominant – the artificial lake of Nechranice, with its 1,338 ha representing one of the six largest water reservoirs in the Czech Republic. The dam and the reservoir were built on the Ohře River in the years 1961–1968 as a water source for the Tušimice and Prunéřov power plants in the surroundings. Today the dam lake is mainly used for recreation. Its coming to existence was among other things conditioned by the inundation of villages Běšice, Chotěnice, Čermníky, Dolany, Drahonice and Lomazice. The increased water surface area was also contributed to by the increasing number of sludge beds and sludge fields, some of which are shown in the maps in blue colour and therefore included in category 6 (water surface) and not in category 0 (other areas).

In the seventies, on the other hand, the share of both permanent grassland and permanent crops marked a considerable decrease. Disappearing were particularly meadows, pastures and orchards in the northwestern part of the territory. Larger complexes of permanent grassland in the vicinity of mining areas, however, do not indicate grassland resources as such, but rather fallow land, which was determined for later devastation with the progressing mining wall.

For the first time within the studied period of time, the maps showed an increased area of forest stands (especially in the northwestern part of the region), with the total area amounting to 4,824.29 ha (14.65 %).

This was also the first period when the maps showed recreational areas, represented mainly by summer cottage colonies and camps situated at the Nechranice water reservoir and along the Ohře River. A smaller proportion of the recreation areas was also represented by private garden colonies on the peripheries of local larger settlements.

#### 4.3.2 Premises of the Nástup Tušimice Mines

The detailed map of the region of interest dating from the seventies shows an expanding mining area (category 0), whose area already ranks second after the largest area of arable land. The detail shows two mines – the Nástup mine on the northwestern side of the region and the Merkur mine situated southeast of the former Prunéřov municipality, replaced by the power plant of the same name. The mining wall progressed as far as the Libouš village, which became extinct, too. The quarry, which came to existence in this place, was to become the largest quarry in the Most brown coal basin later. For the purpose of the "mining area" expansion the village Tušimice itself had to be removed, giving the name to the area. The destructed settlements were replaced by huge industrial and manufacturing premises mutually connected by kilometres of railway sidings and conveyor belts.

As mentioned above, the grassland around the mines often represented fallow land intended for later coal mining.

This period and level of detail also show a moderate increase of the forest area. However, the concerned newly established forest stands were plotted in the map as an open (growing) forest.

### 4.4 Land use in 1988

#### 4.4.1 Broader hinterland of the Nástup Tušimice Mines

The largest land use area category remained to be arable land, which covered 53.36 % of the total area of the region (17,576.00 ha). The local forests continued to expand, still reaching only about one third of the area of fields (5,527.00 ha).

Mining sites situated within the broader hinterland of the Nástup Tušimice Mines showed the largest area of the whole analysed period exactly in the 1990s – 3,684.96 ha (11.19 %), the limit of which should not be exceeded pursuant to the stipulated ecological limits until the planned termination of mining activity in 2030.

A continuous spatial expansion was also shown by built-up areas, partilarly sprawling were the towns of Chomutov and Kadaň. Further increase of the area in this period was caused also by the ongoing construction of the Tušimice and Prunéřov power plants and their premises at margins of the mining area.

This development trend was apparent not only in the built-up area but also, somewhat paradoxically, it reflected with respect to the presence of the mining area also into the increasing recreational function of the surveyed territory, thus demonstrating that even this landscape severely affected by anthropogenic activities can become a place sought by people for rest and recreation.

The water surface area exhibited a very mild increase but this again as a result of the abovementioned increased number of sludge beds and sludge fields due to increased mining volumes.

The share of permanent crops in the territory was also observed to show a moderately improvement in this period due to the establishment of new hop fields and orchards. The most frequently planted fruit tree is apple (*Malus* sp.).

The only land use category showing a decreasing trend in the concerned period was permanent grassland, whose area dropped by about 1 % to 8,001.71 ha.

#### 4.4.2 Premises of the Nástup Tušimice Mines

The detailed image of the territory shows a remarkable prevalence of the "other areas". The mining edge continued to move in the eastward direction towards the municipality of Březno and in the northward direction towards Černovice.

The south-western area showed the first implemented reclaiming activities – especially agricultural – represented by grassing over and apple tree orchard planting. Forestry reclaiming was still represented to a lower extent – the main tree species planted being *Fraxinus excelsior, Acer pseudoplatanus* and *Larix decidua*.

The large grassland area in the south-eastern part of the region of interest only represents fallow land not yet reclaimed.

### 4.5 Land use in 2006

#### 4.5.1 Broader hinterland of the Nástup Tušimice Mines

The condition of the analysed territory in 2006 represents a very colourful landscape mosaic, but the map interpretation does not guarantee agreement with the realistic image, which is also documented in the submitted study. Data on the acreage of the respective land use units show at first sight a considerable decrease of arable land area (from 53.36 % to the mere 32.37 %), almost exclusively in favour of permanent grassland, in this period covering 6,256.88 ha (19.00 %). This fact is further supported by the nationwide trend of the 1990s – a mass transfer of arable land to grassland resources – but this category primarily includes nearly all accomplished agricultural reclamations on exhausted localities (with the exception of orchard areas). This is very clearly documented by the completed reclamation areas occurring to the northwest of the Tušimice power plant.

Thanks to this trend, the forest area increased considerably in that period, too, even though the newly planted forests were still at the beginning of their growth represented by open forest.

For the first time in the whole analysed period the areas directly affected by mining were reduced by nearly 750 ha, which represented about 3 %.

The built-up area was very linear in its growth in this period, which was contributed to both by the expanding urban and rural housing and by the development of associated industrial production (railways, waste management, fleet of cars etc.).

Together with the housing development, the recreational areas expanded too, and covered 194.86 ha in the concerned period. The recreational function was mainly assumed by settlements around the Nechranice dam lake.

#### 4.5.2 Premises of the Nástup Tušimice Mines

A view of the territory of the Nástup Tušimice Mines documents the situation described above in the chapter on the broader hinterland. The detailed view allows for an analysis of the progress and volume of reclamations commenced in the southwestern and southeastern parts of the region in the 1990s.

The mining further progressed towards the municipalities of Březno (eastern edge of the mining area) and Černovice (northern edge of the mining area). Before these villages, mighty earth embankments were built and planted with forest belts intended for dust and noise control. Not even one of 17 villages existing in 1846 were preserved inside the area.

## 5 DISCUSSION

The above results show that the historic map materials provide irreplaceable primary information for systematic study of cultural landscape development. They provide information about endurance and nature of settlement, dynamics of binding affecting the potential and specific character of landscapes, landscape structure changes, localisation of old ecological burdens, intensity of anthropogenic disturbances as well as the localisation of the stable intact areas, which represent the ecologically most valuable segments.

This is the reason for the currently exponentially growing number of research projects dealing with the study of landscape historic development. Some of the projects only deal with a few cadastral areas (Drobilová, 2007; Stránská, 2007; Moravčíková, 2006 and others), while the other ones apply the same methodological procedures to larger territorial units, or to the whole country (e.g. Kolejka, 1985; Mackovčin, Demek, Havlíček, 2006; Skokanová, 2008).

The main point of the methodological procedure for the interpretation of historic maps is the selection of data source itself. The territory of our country was covered in the past with a number of different cartographic materials of different age, varied quality and informative value. Many works use the maps of stable cadastre (Lipský, Nováková, 1994; Bičík et al., 1996; Skaloš, 2006 and others), which are most utilizable in the territorial detail at a level of cadastres thanks to their detailed map and tabular form. On the other hand, the interpretation of changes in larger territorial units is impeded by their considerable atomisation.

Another type of grid materials may be aerial photographs (Blažek, Vávra, 1998; Lipský, 2000), which are however applicable only for the last 40–60 years; their interpretation being however not clear enough, they usually have to be verified through field survey.

The choice of maps for the above described methodological procedure was made with an aim to achieve the greatest possible level of detail in the projection, scale and generalisation with a special emphasis on the country-wide coverage of the selected map collection so that a similar methodological procedure could be used for an analogical analysis of a larger area or the whole country.

## 6 CONCLUSION

The overall assessment of land use development in the broader hinterland of the Nástup Tušimice Mines clearly shows that the greatest changes occurred within the Most basin itself, while the stretch of the forest-covered part of the Krušné hory Mts reaching into the region of interest remained virtually without any changes throughout the period. The only variation was the mutual proportion of permanent grassland, gardens and orchards.

The greatest transformation recorded the landscape structure in the surroundings of the extinct municipalities of Tušimice and Prunéřov around which the mining areas were gradually expading and the former settlements were replaced by built-up areas of newly rising transport services.

However, the most progressive land use changes have been recorded directly in the area of the Nástup Tušimice Mines, where the original diversity of land use was gradually wiped-off in favour of expanding mining premises, but where the already abandoned excavated land was a subject to reclamation since the 1990s and hence to the commencement of the long-term process of return to the original agricultural and forest land resources from which they were exempted at the beginning of mining.

Concluding we emphasize that the landscape condition from the period of about 1846 cannot currently be restored completely, be it in respect of its spatial arrangement or land use. The required target state of the landscape severely affected by anthropogenic activities should be seen in a harmonic cultural landscape, which is as compared with the common cultivated landscape (namely urbanized landscape) reinforced with appropriately distributed stabilisation elements conditioning the universal functionality and usability of the concerned landscape in the future.

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# APPLICATION OF HISTORICAL STATISTICAL DATA OF THE LAND USE AS THE BASES FOR THE ANALYSIS OF CHANGES OF DISTURBED LANDS (THE SOKOLOVSKO MODEL AREA)

# APLIKACE HISTORICKÝCH STATISTICKÝCH DAT LAND USE JAKO PODKLAD PRO ANALÝZU ZMĚN DEVASTOVANÝCH KRAJIN (MODELOVÉ ÚZEMÍ SOKOLOVSKO)

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**Abstract**

Based on the performed analysis of the statistical data from the cadastral records of the years 1842–1843, the Sokolovsko model area being in the land area of 284.1736 km$^2$, may be described as a balanced agricultural landscape, where the natural elements are in a relative balance in economic ones, and these conditions exist despite of the developing coal mining and industry. The area stability is maintained mainly by the natural character of brook and river flood plains together with bogs and spring areas. Applying the analysis of historic statistical data on the landscape structure of every cadastre the historical landscape of the Sokolovsko area was divided according to the dominating landscape structures into 3 cadastre groups: the forest, field and the cadastres characterized by a balanced proportion of crops, dominating in the given area.

**Abstrakt**

Modelové území Sokolovska o rozloze 284,1736 km$^2$, je možné na základě provedené analýzy statistických dat z operátu stabilního katastru z let 1842–1843 popsat jako vyrovnanou zemědělskou krajinu, v níž jsou přírodní prvky v poměrné rovnováze s prvky hospodářskými, a to přes rozvíjející se těžbu uhlí a průmysl. Stabilitu území udržuje hlavně přírodní charakter potočních a říčních niv spolu s bažinami a prameništi. Aplikací analýzy historických statistických údajů o krajinné struktuře každého katastru byla historická krajina Sokolovska rozdělena podle dominujících krajinných struktur na 3 skupiny katastrů: lesní, polní a katastry s vyváženým poměrem kultur, které na území dominují.

**Keywords:** analysis, statistical data, stable cadastre, the Sokolovsko area, stability, landscape structures

## 1 INTRODUCTION

In order to assess the present state of the landscape in terms of understanding of its long-term development it is necessary to know its history, to recognize the still existing traces of its memory. This particularly applies for the landscapes devastated by human activities, where the majority of the landscape memory was erased, such as the model area of the Sokolovská brown coal basin. Apart from the existing preserved continual ecosystems (structures) in the present landscape, as the sources recorded or described landscape memory there can be considered the old maps and written materials. Therefore they are the material evidence of the landscape management within the specified space and time, and this under the condition of the specified socio-cultural metabolism.

In our long-time experience, the most suitable source for monitoring the landscape utilization history and its description, ca. 160 years ago, is the stable cadastre. It refers to the optimum source being processed for the entire territory of Bohemia and Moravia, on the basis of a trigonometrical measurement of all the lands in the respective cadastral localities of that time (Trpák and Trpáková, 2001, 2002, 2006, 2007). From it we can obtain the comparable detailed data on the landscape, including the rocks, bogs, water areas, small outputs and lands not utilized in another way, as well as on the other land economically utilized. The stable cadastre maps represent a uniform information source (Přikryl et al., 2001). Map data can be combined with the data of the written cadastral record. Then this data can be compared in time series further in the past and to the present. The existing state of application of processing the historical bases is represented especially by utilization of old maps. Still less frequently there are utilized the written cadastral records supplementing the map bases, although just these ones are significant, rich sources of detailed information on the method of land use and management in the landscape. The reason is mainly the handwritten form, the documents are mostly written in a cursive script in that time official language, i.e. in Old German one. While in the case of unfamiliarity of that time official language the maps are understandable to almost everybody. Therefore it is necessary to emphasize that a complex available picture of the old landscape must be put together from both of these sources.

A part of the written sources is the statistical data on the land use method, that time landscape structure and a method of management. The assessment of this data was the bases for a complex description and evaluation of the historical landcover and land use of the Sokolovsko model area (Trpák et al., 2006; Trpák and Trpáková, 2006).

## 2 STUDY AREA

The elaborated Sokolovsko model area consists of 65 historical cadastres (total area of 284.1736 km[2)]. The northern border of this area is formed by the cadastres of the municipalities of Kopanina, Květná, Krajková, Dolina u Krajkové, Boučí, Nové Domy, Háj u Jinřichovic, Dolní a Horní Nivy, Stará, Horní Rozmyšl, Mezihorská, Křemenitá, Tatrovice, Rájec, Stará Chodovská, Božíčany. In the east the boundary is formed by Mírová, Loučky, Dolní and Horní Chodov, Chranišov, Nové Sedlo. The southern border is formed by the cadastres of Královské Poříčí, Sokolov, Dolní Rychnov, Tisová, Hlavno, Bukovany, Citice, Dasnice, Kynšperk, Dolní Pochlovice, Kacéřov, Chlum Sv. Maří, while the western one is made by Hluboká, Dolní Častkov and Horka.

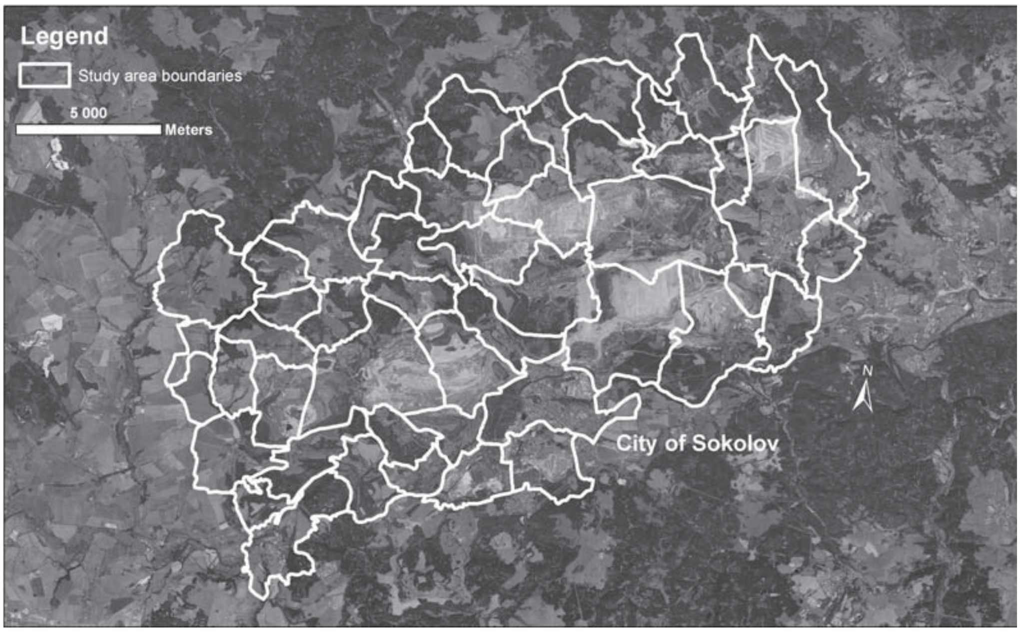



**Fig. 1 Interest area of Sokolovsko**

## 3 MATERIALS AND METHODS

The data collection proceeds from the own archive research of the stable cadastre fund of the National Archives Prague. The principal information sources of the stable cadastre for us are the indication drawings and their written cadastral records. In contrast with frequently utilized imperial imprints the indication drawings have a bigger information extent in the form of continually completed changes of the landscape elements (including the proposed cuts-off of brook and river meanders, changes of crops, new roads and buildings), ownership relations, and sometimes also other notes made by the land surveyor. Every of the coloured drawings is in fact the original copy elaborated by the respective processor and is as the other stable cadastre maps in scale of 1 : 2 880. For every locality it was also made a 10 times reduced drawing of the cadastre "Parzzelirungs Croquis" with a listing of the respective named locations and the number of economic, building, road and water plots.

The written cadastral record consists of the own stable cadastre containing the land plots protocol (Grunparzellen Protocoll), building plots protocol (Bauparzellen Protocoll) for the pro respective municipalities and their settlements and the Statement on the land use in the municipality (Ausweis über die Benützung des Bodens für die Gemeinde…) and of the Duplicate of the stable cadastre containing the duplicates of these basic protocols and the Statement with a significant cadastral assessment report (Catastral Schätzung Elaborat) and other documents, which were elaborated during the years. The document can be divided into two groups. The A group contains the preparatory, original and additional material of the years 1826–1878, the B group – the final report of 1858–1865 (Lišková, 1964). Another information source is the complaints and their settlement against incorrect record as to the area or quality deposited in the so called Fund, blue sheets named according to the blue colour of paper. At the end of the 60s of the 19th century there rose the need of elaborating the so called general assessment and classification of lands. Therefore there was issued the act on the cadastre revision of 24th May 1869 (Czech imperial law-book 88) and thus made a basis of the origin of the so called re-corrected cadastre.

For the assessment of the Sokolovsko area it was applied the statistical data from the cited Statement, which was verified with plotting on the map. The Statement on the land use in the stable cadastre contains 9 categories of the main crops and 7 of them have further the data on subordinated crops, according to their quality and nature. For example, for the main field category there can be reported up to 7 subordinated crops, i.e. arable one alternating in combination with another crop. In total this Statement can contain up to 56 data. As the areas are shown in that time applicable measures, i.e. in acres and Vienna square fathoms, they were converted into hectares and there was calculated a percentage representation of the respective landscape elements in the cadastres so as they could be compared with the existing state. Concurrently for the whole area there was created the aggregate table. The processed structural data consists of 33 data on the occurring crops, including the area and method of utilization. At the same time they contain also a data on the size of the respective cadastres. It refers to fields, meadows, pastures, gardens, hop-fields, forests, waters, bogs, moors, roads, development, small output, unused land. This data was supplemented with 7 new items (Agricultural land resources – ALR, clear deforested land, non-forest high greenery, clean water area, water area with bogs, index of ploughing, Coefficient of ecological stability – CES) so as to be possible to assess the functionality (ecological potential) of the historical landscape in the view of the present criteria. For calculation historical coefficient of ecological stability (HCES) was used ratio forest areas, water area, bogs, permanent grass cover, orchards and decorative gardens to fields, hop-fields, structures, rouds, small output. The same calculation was used for recent CES. In the simplest form, it is the simple ratio of relatively stable areas (S) to relatively unstable areas (L), (Gillarova et al., 2008). By this procedure for every cadastre there was obtained 40 or 41 data on cover and the land use of the period of 1842–1843. Thus for the model area if was acquired 5,200 basic data. These data provide quick but only approximate information the ecological stability or lability of territory. Further obtained data, e.g. on the landscape fragmentation exceeds the extent of this document.

At present the model area includes both the landscape disappeared due to the brown coal mining and a part of the adjacent landscape not disturbed by mining. It is necessary to mention that the model area in the 1st half of the 19th century was characterized by the agricultural landscape with the start of coal mining. The first mention of the coal mining near Královské Poříčí is of the year 1760, from 1793 there was a mine in Dolní Rychnov, later in Staré Sedlo, Svatava, Mírová and in Chranišov, while in the Habartov area it was only after 1830 (Jiskra, 1993).

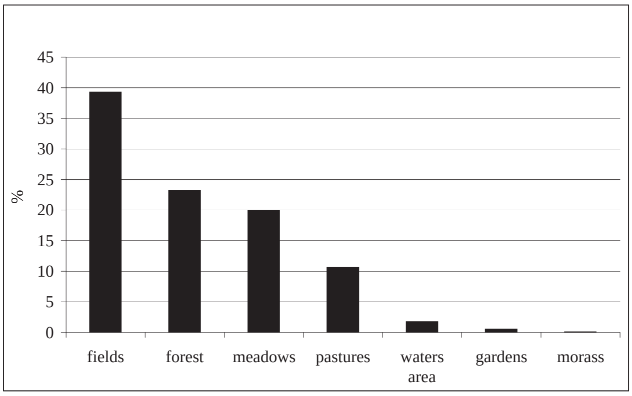
A role in the landscape change was played also by foundation of industrial plants, decrease of the forest area and the timber prices increase from 1850. This entire industrial development is carried out in the area, where for thousands years there was an intensive agricultural production and where in the course of time settlements were founded and perished, as documented by numerous archaeological discoveries. Most of the settlements in the Sokolovsko area were established in the river flood plains of the River Ohře and Svatava. The exceptions are only the settlements in a headland around the castle or the fortress, or the pilgrimage place such as Kynšperk nad Ohří, Hřebeny, Chlum Sv. Maří. In that time the flood plains are ploughed very little in their majority and the common lands were preserved. According to the landscape description in the Indication drawings and the detailed descriptions in the cadastral records there prevail forests, meadows and pastures over the arable land (Sixta et al., 2002). Brooks and rivers abundantly meandered, here are large bogs, wet meadows and still preserved pond systems. The landscape is interwoven with network of paths and roads (Trpáková and Trpák, 2006; Trpák and Trpáková, 2007).

## 4 RESULTS

In the 1st half of the 19th century the Sokolovsko area appears to be as a balanced area, where the natural elements are in a relative equilibrium with the economic ones. In that time there still continued the economic structures from the Renaissance period, such as ponds and farmyards, furthermore the residues of the Baroque serfdom economy, covered by starting industrial land use. The main role in the land use is played by agriculture, which is documented by the data on size of the agricultural land fund, where there pertain the data on fields, meadows, pastures, orchards, gardens and hop-fields. The characteristic of this area is shown in the following Tab. 1–3 and in Fig. 2–8.

A balance character of the area is also proved by a similar share of two main components of ALR, i.e. of fields (39.28%), permanent grass cover (30.61 %) and forests (23.24 %) of the total area of the territory. This is in accordance with the field representation (interval 30.2–39.61%) in the medium cadastre group – with a balanced proportion of crops, formed by 33 cadastres, thus a half of the total number. Other landscape elements, forming the deforested land, although with a certain percentage of the scattered greenery, are meadows with 19.98 % and pastures with 10.63 % of the total area of the interest region. They also include the existing natural river and brooks flood plains, non-damaged spring areas. Together with forest and water areas (1.77%) they create the most important stabilizing structures of the Sokolovsko agricultural landscape. Natural character of these elements is illustrated also by the data on the bogs and fenlands representation, which regularly occur in 25 cadastres. The total area of bogs is 27.32 ha, which represents only 0.096 % of the total area of the territory. An irreplaceable role is played also by "the older agricultural crops", such as fields, meadows, pastures and trees, and fruit trees and other woody plants. Their share in the total area is only 3 % and reaches 835.74 ha.

**Fig. 2 Basic landscape characterization of the Sokolov region in the years 1842–1843 (Trpáková and Trpák, 2008)**




From non-forest area forming 2.94 % is almost 1 % of fruit trees, including orchards kept in statistics as gardens. Separately growing fruit trees in the land out of orchards are in as big as area as hop-fields and the brushwood has the same area included in forest category. Although it refers to small size areas their importance consists in their frequency of occurrence. For example pastures with useful woody plants are not represented only in 2 cadastres in the whole interest area. The same crop with meadows occurs with 2/3 of cadastres. Similar situation is with grass crops with fruit trees, occurring in more than 2/3 of cadastres.

**Tab. 1 Characteristic of landscape structures of area Sokolovsko in 1842–1843**

| Interest area of 65 cad. Sokolovsko (1842–1843) | | |
|---|---|---|
| **Measure** | **ha** | % |
| Total area of the territory | 28417,36 | 100 |
| Clean fields | 11069,97 | 38,95 |
| Fields with fruit trees | 11,8827 | 0,04 |
| Fields altering with pasture | 81,0691 | 0,28 |
| Fields in total | 11162,93 | 39,28 |
| Meadows excl. woody plants | 5419,943 | 19,07 |
| Meadows with fruit trees | 75,8757 | 0,26 |
| Meadows with other woody p. | 182,6602 | 0,64 |
| Meadows in total | 5678,4788 | 19,98 |
| Pastures excl. woody plants | 2606,717 | 9,17 |
| Pastures with fruit trees | 32,8588 | 0,11 |
| Pastures with other woody p. | 381,955 | 1,34 |
| Pastures in total | 3021,531 | 10,63 |
| Permanet grass cover excl. woody plants | 8026,66 | 28,24 |
| Permanet grass cover in total | 8700,01 | 30,61 |
| High coniferous forests | 6257,657 | 22,02 |
| High deciduous forests | 20,5327 | 0,07 |
| High mixed forests | 149,0728 | 0,52 |
| Brushwood | 129,8962 | 0,45 |
| Forests in total | 6605,227 | 23,24 |
| Orchards in total | 146,5379 | 0,51 |
| Decorative gardens | 3,9713 | 0,01 |
| Vegetable gardens | 9,0019 | 0,03 |
| Hop-fields | 122,3046 | 0,43 |
| Gardens in total | 281,8158 | 0,99 |
| Gardens excl. hop-fields | 159,5111 | 0,56 |
| Total area with fruit trees | 267,1552 | 0,94 |
| Waste land | 158,3994 | 0,55 |
| Non-forest greenery | 835,7417 | 2,94 |
| Bogs excl. reed | 27,32834 | 0,09 |
| Ponds | 299,1836 | 1,05 |
| Water flows | 214,3572 | 0,75 |
| Water area in total | 503,8689 | 1,77 |
| Roads | 794,0213 | 2,79 |
| Quarries | 1,6824 | 0,01 |
| Sand quarries, mainly gravel | 7,2286 | 0,02 |
| Small output in total | 8,9110 | 0,03 |
| Structures | 150,8558 | 0,53 |
| Non-forest in total | 20963,61 | 73,77 |
| Agricultural land resources (ALR) | 19994,24 | 70,35 |
| Historical coefficient of ecological stability (HCES) | 0,85 | |
| Ploughing index | 1,29 | |

As well as we must mention field crops representing the fields category altering with pastures, which occur in this area in 0.72 % of the field land. These structures are still supplemented with fields containing fruit trees and fallow lands, caused by the method of management and the land category.

Forests of the Sokolovsko area share with 23.24 %, and prevailingly with high coniferous forests (22.02 %). Minimum percentage is made by deciduous forests (0.07%). These forests are located both in the field cadastres of Dolní Chodov, Boučí, Dolní Částkov, and in balanced cadastres of Smolnice, Stará Chodovská and in forest cadastres of Nové Domy, Královské Poříčí. It refers to remnants of the original forests on corresponding lands. Mixed forests occupy 0.52 % of the interest area and are spread in 16 cadastres, which correspond to fragments of the original forests and concurrently to the demand for fuel wood and timber.

Gardens in historic statistical data are usually mentioned together with hop-fields. For assessment due to present situation we do not take them into account. Garden use can be seen from the table. The largest area is occupied logically by fruit gardens (orchards). Further they are used as useful vegetable gardens. Decorative gardens occur only at bigger manor houses (Horní Chodov, Libavské Údolí, Luh, Loket and Zlatá). Of the whole cadastre spectrum there go beyond Loket and Sokolov, which are historical continual settlement centres. This also corresponds to composition of crops, e.g. a big percentage of the already mentioned gardens.

Water areas occupy the share 1.77 % (503.86 ha). From that the 1 % is the pond area. We must mention that small flows, being numerous in this area, do not have plot numbers and thus they are excluded from the statistics. As to water bearing of the area we must conclude further in combination with map bases within the assessment of flood plains and spring areas. Such water bearing is illustrated by the fact that in the biggest cadastre group the waters' share is between 1–2% of their territory.

Start of industrialization in the area corresponds to the size of

**Fig. 3 Proportion forest, no-forest vegetation and unwooded of interest area Sokolovsko 1842–1843 (Trpáková and Trpák, 2008)**

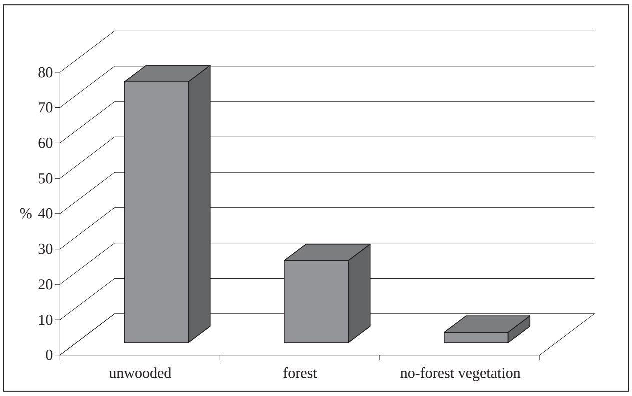



**Fig. 4 Character of forest in interest area of Sokolovsko 1842–1843 (Trpáková and Trpák, 2008)**

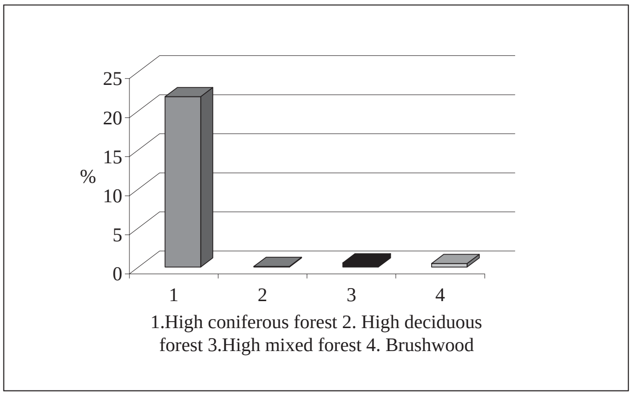



**Fig. 5 Garden pattern in Sokolovsko 1842–1843 (Trpáková and Trpák, 2008)**

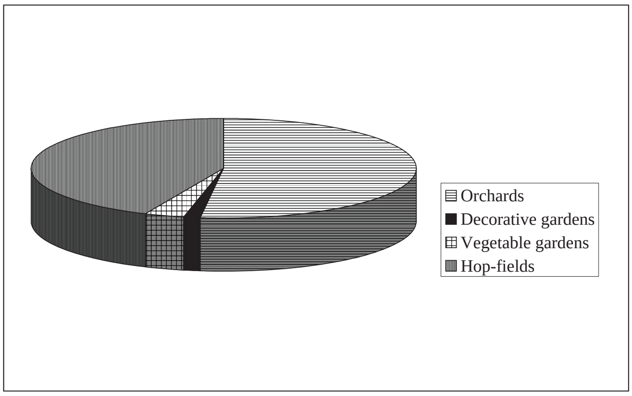
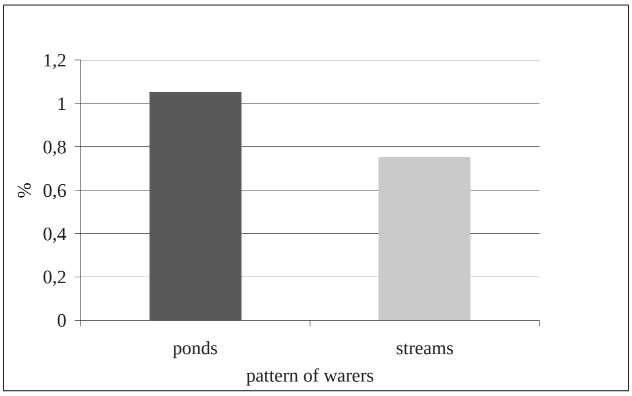



**Fig. 6 Water area – Sokolovsko 1842–1843 (Trpáková and Trpák, 2008)**




**Tab. 2 The comparison % representation cadastres in subrange HCES – CES (Trpáková and Trpák, 2008)**

| Interval | 0–0,39 | 0,4–0,89 | 0,9–2,9 | 3,0–6,9 | 7,0–38,6 |
|---|---|---|---|---|---|
| HCES 1842–1843 % | 6,2 | 18,5 | 70,7 | 4,6 | 0 |
| CES 2005 % | 20 | 13,8 | 29,2 | 6,2 | 18,4 |

barren area or agriculturally unused one (0.55 % – 158 ha), where the production plants are situated. In fine we mention performed us basic comparison of ecological stability this area at years 1842–1843 and 2005 on the basis calculation CES (HCES) owing to statistical data. The conparison illustrate more than 150 years evolution of landscape structures. Owing to coal mining was destroyed in interested area 8 cadasters, which means 12 % missing cadastres in second column of Tab. 2.

## 5 DISCUSSION

Applying the analysis of this historic statistical data on the landscape structure of every cadastre the historic landscape of the Sokolovsko was divided according to dominating landscape structures into the forest, field cadastres and cadastres with a balanced proportion of crops.

*Forest cadastres* are represented by the numerically smallest group of 6 cadastres, Háj u Jindřichovic, Královské Poříčí, Nové Domy, Rájec, Tatrovice, Týn, where the total forest cover share does not go down under 42.64 % (Královské Poříčí) and amounts the maximum value of 78.73 % in the Nové Domy´s cadastre. If we evaluate the average values of these forest cadastres, thus the average forest cadastre has 55.48 % of the forest representation, which is not amounted by the cadastres of municipalities of Královské Poříčí, Tatrovice, Týn and Háj, while the cadastral areas of the municipalities of Rájec and Nové Domy highly exceed this average representation.

The total size of the forest lands in the Sokolovsko area is 6605.227 ha. In terms of the quality and sort of forest covers the high coniferous forests represent the dominating group. Almost exceptionally we can find the largest area of low forests in the Tisová' s cadastral area, where the total area of 16.09 ha forms 4.4 % of the cadastre's area. This economic forest category represents a very small group of cadastres, where the most of values do not amount 1 % of the area of the respective cadastres. Such conditions of the forest representation are in accordance with the total area of the deforested land, which ranges from 20.17 % in the Nové Domy's cadastre to 53.46 % in the already mentioned cadastre of Královské Poříčí. Logically the lowest share of the high non-forest greenery of 1.08 % is in Nové Domy, while the highest share of such greenery was in the Tatrovice's cadastre. Relatively very low share in this forest cadastres group is represented by the reported water areas and courses including bogs, and this from the values of 0.02 % in Rájec to Královské Poříčí with 1.97 %. Here the statistics does not fully affect the function of the structure. The CES size ranges in the margin from the values of 1.91 in the cadastre of the Háj municipality and amounts the maximum value of 5.71 in the Nové Domy's cadastre, which is caused by the forest representation. While in the case of Týn, the CES value is influenced by a higher share of meadows and pastures and by a higher share of non-forest greenery. According to the present criteria of the landscape type assessment it refers to the landscape, where there are still dominating the values closer to the landscape relatively natural one, i.e. the C type.

*The field cadastres* are represented by a group of 26 cadastral areas, where the total field area does not go down under 42 %. The fields area of the field cadastres always ranges above the value of the field share in the entire interest area. To this group there belong the municipalities of Horní Chodov, Dolní Chodov, Hlavno, Chranišov, Dasnice, Chlum Sv. Maří, Cítice, Horní Částkov, Kacéřov, Lvov, Dolní Rychnov, Tisová, Markavarec, Horní Nivy, Boučí, Chotíkov, Lítov, Dolní Částkov, Horka, Hluboká u Milhostova, Květná, Krajková, Kopanina, Mírová, Zlatá and Dobrože. Percentage representation of the field area ranges from 42.46 % in Boučí to 75.92 % in Hluboká u Milhostova. The deforested land size ranges from 69.93 % in Horní Nivy to 99.64% in Chotíkov, where there is not any forest. The average size of the deforested land is 86.94 %.

This data also correlates with the ploughing index value, whose values range from 1.14 in Citice to 3.65 in Hluboká u Milhostova. The average ploughing index value is 1.89.

For field cadastres the share of the non-forest greenery ranges from 0.35 % in Hlavno to 6.34 % in Horní Nivy.

Within these cadastres there is a relatively lower difference in values of the historical CES having the lowest value 0.38 in Dolní Částkov and the highest one 1.89 in Horní Nivy with the highest non-forest greenery and the second largest forest area for the field cadastres (26.71 %). This range of values documents that the historical CES completely and clearly indicates the intensively utilized landscape, transforming into the B landscape type – i.e. the cultural intermediate landscape.

And the average value of the historical CES of field cadastres of 0.85 is documenting still relatively more natural character of the agricultural management, although on the limit of the B landscape type.

*Cadastres having a balanced proportion of crops* are represented by the biggest group of 33 cadastres, whose medium and balanced proportion of the respective crops dominates to the landscape character of the Sokolovsko area, and this including two cadastres of Sokolovo and Loket, where there are situated the largest and old settlement centres of this region. Their significant share in the view of the stabilization function for the whole region is absolutely and clearly documented by the CES values of these historical landscapes, ranging, with the exception of the Sokolovo city (CES 0.96) in the margin from 1.24 in Staré Sedlo to the value of 2.06 in Nové Sedlo. Certainly it is not an uninteresting comparison that the average CES for the whole Czech Republic at 1. 1. 1981 was 1.144, which corresponded to the B landscape type – the intermediate landscape. And this margin of 0.9–2.9 in the years 1970–1978 represents a common cultural landscape, where the technical elements are in a relative accordance with the natural element character (Löw, Michal, 2003).

This is to certify comparasion coefficient of ecological stability historical area and coefficient of ecological stability coexist interest area. Whereas especially contemporary CES can be take only informative indication and quality of him particular elements must be verify in field. While us use historical statistical data is their verification determined character again to make use tax data, next verified economy data from among documentary stable cadaster.

Another specifying indicator is the ploughing index, ranging in the margin from 0.73 in Luh to 2.0 in Pochlovice.

Therefore it is relatively interesting to see a narrower range of the field size areas from 30.2 % in Nové Sedlo to 39.61 % in Velké Pochlovice. As the interesting opposite poles are the forest area values. With the exception of the urban cadastre of the Sokolov municipality, where the forest area reaches the minimum value of 1.4 %, the forest area size range from 14.28 % in Horní Rychnov to 37.12 % in Křemenitá.

In this medium character of this cadastre group there also shares a relatively similar representation of meadows, whose total areas range from 14.28 % in Mezihorská to 35.72 % of meadows in Sokolov. For the purpose of this assessment it is necessary to mention that the urban cadastre of Sokolov is completely specific, for it had 17.1 % of gardens, which is the largest garden area in the entire model area. It is fully understandable that these cadastres are characterized also by the shares of pastures within the margin from 4.4 % in Vřesová to 25.15 % in Čistá. This situation is also in accordance with the value range of the non-forest land size from 54.48 % in Stará to 80.78 % in Vřesová. This also corresponds to the non-forest greenery values, ranging from 0.25 % in Velké Pochlovice to 9.79 % in Stará.

*Water bearing of the area.* In connection to statistical data we evaluate according to representation of the so called clean water, i.e. without bogs and wetlands or moors. The total area of the water plots is 503.86 ha of the area. In terms of the water representation we can divide 65 cadastres into the following groups as too the percentage representation:

The lowest water bearing cadastres**,** where the water quantity does not amount the value 0.1 %. (Interval 0.02–0.1 %). To this group there belong 7 cadastres, namely Mezihorská, Horní Nivy, Chotíkov, Rájec, Háj u Jindřichovic, Stará, which are represented evenly in all the three preceding groups being divided according to the crops. They contain both the forest cadastres and the field ones and as well as the cadastres with a balanced proportion of crops.

Cadastres with waters below 1% of the area, where there belongs a half of the area, i.e. 31 cadastres. (Interval 0.1–0.99). Again there are represented all the three groups divided according to the prevailing crop. However, at the most there are represented with the cadastre group with a balanced proportion of crops.

Cadastres with waters above 1 % of the area, but not amounting 2 % of waters. (Interval 1–1.9). They contain 8 cadastres in total, and namely Hlavno, Čistá, Chranišov, Staré Sedlo, Libavské údolí, Lítov, Dolina, Dobrože. They are present in the group of both field ones and the cadastres with a balanced proportion of crops.

Cadastres with waters above 2 %, but not amounting 3 %. The highest value in this group is in Svatava (2.98 %). Here there are represented 10 cadastres, and namely Nové Sedlo, Vintířov, Pochlovice, Svatava, Loučky, Stará Chodovská, Kynšperk, Citice, Dolní Rychnov, Mírová. Mostly they are in the group with a balanced proportion of crops and three last cadastres belong to the field cadastre group.

Considerably water bearing cadastres. Into this group there belong the cadastres from 3 % to 12.73 % of waters of the cadastre area. Into this group there pertain 9 cadastres, and namely the pond cadastres (Božíčany, Vřesová, Tisová, Smolnice, Horní Chodov, Lipnice) and the river cadastres (Loket, Sokolov and Dasnice). The most water bearing cadastre is Horní Chodov with 12.73 %, belonging to the field cadastres as well as Dasnice and Tisová. The remaining cadastres belong to the group with a balanced proportion of crops. However, the location is important, too. It applies just for the field cadastres situated in the river flood plain (Dasnice and Tisová), while Horní Chodov is located in the brook flood plain and near to the pond basin. It refers to the agricultural management in the most fertile parts of the area, in flood plains. In this connection it is necessary to mention that in the area there occurs the only moor, and actually in Kacéřov being in the area of 6.22 ha.

Comparison of the size of an average historical land use in the Czech Lands in 1845 (Bičík, Jeleček, 2001) and in the Sokolovsko area in 1842–1843 (Trpáková and Trpák, 2008) is showed by the following table.

The core of the landscape structures of the Sokolovsko area in 1842–1843 is represented by farmland, whose total share is by 3.45 % higher than the national-wide average of 1845. Stability of this agricultural landscape as compared to an average Czech landscape is made by almost twice as big extent of the area of meadows and pastures and by 9 % smaller share of arable land. And this existed despite the fact that in the Sokolovsko area there was by 5 % lower the forest representation. This fact emphasizes the importance of a natural character of brook and river flood plains, and especially in the time, when tiny and small water courses were not registered as plots. As documented by almost twice as big size of water areas in the Sokolovsko area there did not come to a further liquidation of ponds. Natural character of these elements is illustrated also by the data on representation of bogs and wetlands, which are regularly situated.

These original data about historical lanscape 65 cadastres of Sokolovsko constitute principle information because is on the present change character of their landscape of 65 % these cadastres, 12 % cadastres quite disappeared by brown coal mining and only 23 % of them have relative natural evolution. Generally by coal mining passed to increase share destable territory and simultaneously to formation small cluster

**Tab. 3 Comparison of the histiorical land use in the Czech Lands in 1845 and Sokolovsko 1842–1843**

| Year | Arable % | Meadows % | Pastures % | TTP % | Farm land in total % | Forest % | Water area % | Gardens, orchard, vineyard, hop-field % | Buildings % |
|---|---|---|---|---|---|---|---|---|---|
| 1845 | 48.2 | 9.3 | 8.3 | 17.6 | 66.9 | 28.8 | 0.9 | 1.1 | 0.6 |
| 1842–1843 | 39.28 | 19.98 | 10.63 | 30.61 | 70.35 | 23.24 | 1.77 | 0.99 | 0.53 |

cadasters with improvement lanscape of increase to forest area, permanent grass cover, reducing part of fields and succession.

## 6 CONCLUSIONS

Both the entire map of the stable cadastre landscape documented a picture of relatively balanced landscape, and the analysis of the statistical data on the landscape structure of the respective cadastres made by us confirmed the fact that the core of the Sokolovsko area was formed by a relatively balanced agriculturally managed landscape, characterized by a dominating balanced intermediate cadastres, where then applied technological procedures of the agricultural management (e.g. fallow lands, pastures,…) maintained the ecological stability of the area obtained by the historical development, despite of the beginning industrialization. A relatively detailed description of the structural arrangement of the landscape emerging from the source analysis in the sense of description of its fragmentation degree is above the framework of this contribution. A further detailed analysis particularly of the written part of the stable cadastre together with a detailed description of the management and with this data can help to clarify the ecologic potential of this in many cases disappeared historical landscape. Comparing enviromental stability coefficients of historic cadastres of Sokolov region dating back to 1842 and enviromental stability coefficients of the current cadastres affected by brown coal mining, we may conclude that the memory structures of the landscape unambiguously determine the level of the current enviromental stability of the territory. Identification of memory structures and their verification with this data will enable to anchor the newly originating restored landscape in time. In many cases the unique character of the historic statistical data thus makes possible to overcome also the absence of the historical description.

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# A MANAGEMENT PROPOSAL FOR THE PŘEDNÍ KOUT SUPRA-REGIONAL BIOCENTRE BASED ON ANALYSES OF LANDSCAPE DEVELOPMENT

## NÁVRH MANAGEMENTU NADREGIONÁLNÍHO BIOCENTRA PŘEDNÍ KOUT NA ZÁKLADĚ ANALÝZ VÝVOJE KRAJINY

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**Abstract**

This paper deals with using analyses of historical development of the landscape for a proposal of optimum management of the Přední Kout supra-regional biocentre, which is located in the South Moravian Region to the northeast of Hustopeče. Based on the analyses of old maps and mapping of current landscape conditions, zones for establishing optimum land management were created for the supra-regional biocentre. Trajectories of change (stable, quasi-stable, gradual, cyclic, dynamic, without any clear trend) were determined by analyzing the historical development of the territory. After comparing maps of the trajectories of change with current landscape conditions, 4 management zones were defined (maintenance management zone, moderate management zone, zone requiring radical management and priority management zone). The acquired information and analyses can be used in the planning of landscape spatial and production potential planning, in landscaping and land use planning by state administration bodies and other subjects.

**Abstrakt**

Příspěvek se zabývá využitím analýz historického vývoje krajiny při návrhu optimálního managementu nadregionálního biocentra Přední Kout, které se nachází v Jihomoravském kraji, severovýchodně od Hustopečí. Na základě analýz starých map a mapování aktuálního stavu krajiny byla provedena zonace nadregionálního biocentra pro stanovení optimálního managementu území. V rámci analýz historického vývoje území byly stanoveny trajektorie změn (stabilní, kvazistabilní, stupňovitá, cyklická, dynamická, bez jasného trendu). Po porovnání map trajektorií změn s aktuálním stavem krajiny byly vymezeny 4 zóny managementu (zóna udržovacího managementu, zóna upraveného managementu, zóna radikálně upraveného managementu a zóna prioritního managementu). Získané poznatky a analýzy se mohou uplatnit při plánování prostorového a produkčního potenciálu krajiny, dále např. na úrovni krajinného a územního plánování, orgánů státní správy a dalších subjektů.

**Keywords:** supra-regional biocenter, land use changes, old maps, landscape mapping, management zones, trajectories of change

## 1 INTRODUCTION

The concept of territorial systems of ecological stability was created in the Czech Republic in the 1990s within the framework of nature conservation and land use planning. The main idea is to create a mutually connected network of ecosystems, known as biocentres, to maintain landscape equilibrium at the local, regional and supra-regional levels. Supra-regional biocentres (SRBC) in the Czech Republic represent important territories for the expansion of biodiversity into the surrounding landscape and are one instrument for preserving the ecological stability of the landscape (Buček, Lacina, Míchal, 1996). The current condition of the structure of almost every landscape has been markedly influenced by long-term land use changes. Factors influencing land use can be sorted into two basic groups: socioeconomic and natural factors (Cousins, 2001; Petit and Lambin, 2002; Kolejka and Marek, 2006). Individual factors always affect and regulate the formation of consequent landscape appearance together, and mutually influence and supplement each other. The methodological principles of monitoring land use development and the ecological evaluation of land use development in the form of historical analysis are based on several works (particularly Lipský, 1992, 1995, 2000; Lipský and Nováková, 1994). Questions about the historical development of the landscape and about the critical influencing factors offer up a crucial base for dealing with environmental questions in land use planning and nature conservation today (Haase et al., 2007).

## 2 STUDY AREA

The Přední Kout biocentre is located in the South Moravian Region (Fig. 1) approximately in the central part of the Hustopečský bioregion (Culek, 1996), to the northwest of Hustopeče. It is an important complex of forests and non-forest communities in the agricultural cultural landscape. The territory belongs to the Divácká vrchovina Upland with markedly hilly relief and the range of elevations is between 250–410 m a.s.l. with wide rounded, divide ridges and deep valleys (Demek et al., 2006). Most of the SRBC is a part of a NATURA 2000 site and several small-scale specially protected areas are located here.

The territory is built on the Outer Carpathian Flysch of the Ždánice unit. Along the watercourses, fluvial sandy loamy, or deluvio-fluvial sandy loamy sediments of low thickness developed. In the southern part, there are rather thick layers of loess and loess-loams. On the forested area, luvisols predominate, and on agricultural land, typical chernozem and brown earth predominate (Collective of authors, 1998). According to the map of climatic regions of the Czech Socialist Republic 1 : 500 000 (Quitt, 1975), the entire territory of the Přední Kout SRBC belongs to the warmest T4 region.

On a majority of the areas with preserved forest vegetation, Carpathian oak-hornbeam forests (union of *Carpinion betuli,* association of *Carici pilosae-Carpinetum*) have developed, whereas Pannonian oak-hornbeam forests (*Primulo-Carpinetum*) are less represented. There are also transitional types of Carpathian oak-hornbeam forests with beech (the Roviny Nature Reserve, where beech trees are in places interspersed in the surrounding stands). The presence of Pannonian thermophilous oak forests (*Quercetum pubescenti-roboris*) is only indicated. At the bottom of the valley, there is vegetation that can be considered to be fragments of a stream alluvial forest (*Pruno-Fraxinetum*). On the northwestern and southern edge of the biocentre, there are several localities where substitute grassland vegetation has developed, in particular broad-leaved dry grassland mostly belonging to the association of *Cirsio-Brachypodion pinnati*. Impoverished and untypical communities of Sub-Pannonian steppe grasslands of the association *Festucion valesiacae* occur in smaller areas. Similarly, fringe communities of thermophilous oak forests (*Geranion sanguinei* and *Prunion fruticosae*) are limited to small areas (Collective of authors, 1998).

## 3 MATERIALS AND METHODS

The first step in defining optimum management zones was made by analyzing the historical development of the landscape (Stránská, Havlíček, 2008). On the territory of Přední Kout a total of five sets of maps were used ranging from the period of the second military mapping (1836) until today (2006). Basic land use categories were monitored – arable land, permanent grasslands, gardens and orchards, vineyards and hop fields, forest, water areas, built-up areas, recreational areas and other areas. In the next step, analyses were made in order to ascertain trajectories of change (Swetnam, 2007). This method helps define areas that are most prone to land use changes. It involves the calculation of three indices. The turnover index captures how many changes have occurred in the monitored period. The diversity index captures the number of different classes over the monitored period. The similarity index gives information about the dominant class in the given locality during the monitored period. Through a combination of these three indices, 6 groups that indicate definite trajectories of change (Tab. 1) can be acquired.

The stable class includes areas with the same land use category over all the analyzed time periods. The quasi-stable class includes areas that have undergone 1 or 2 changes. The gradual class contains areas on which one change between two dominant categories occurred. Frequent change between two categories indicates the cyclic class, whereas frequent change between more than 3 categories is classified as the dynamic class. The last class is without any clear trend, and indicates various changes without any clear trend.

Finally it was important to ascertain the current landscape conditions and the dispersion of vegetation communities on the territory of the biocentre for defining management zones. The landscape mapping method (Pellantová et al., 1994) was used for mapping the current landscape conditions, and the defined mapping units were assigned degrees of ecological stability (Míchal, 1994). The highest degree (4) was assigned to forest vegetation with natural tree species composition, and natural grassland and steppe communities, which form the base for restoring ecological relationships in the surrounding ecologically unstable spaces. The lowest degrees on the other hand are assigned to localities that are heavily influenced by human activity (dumps, arable land, built-up areas, etc.)

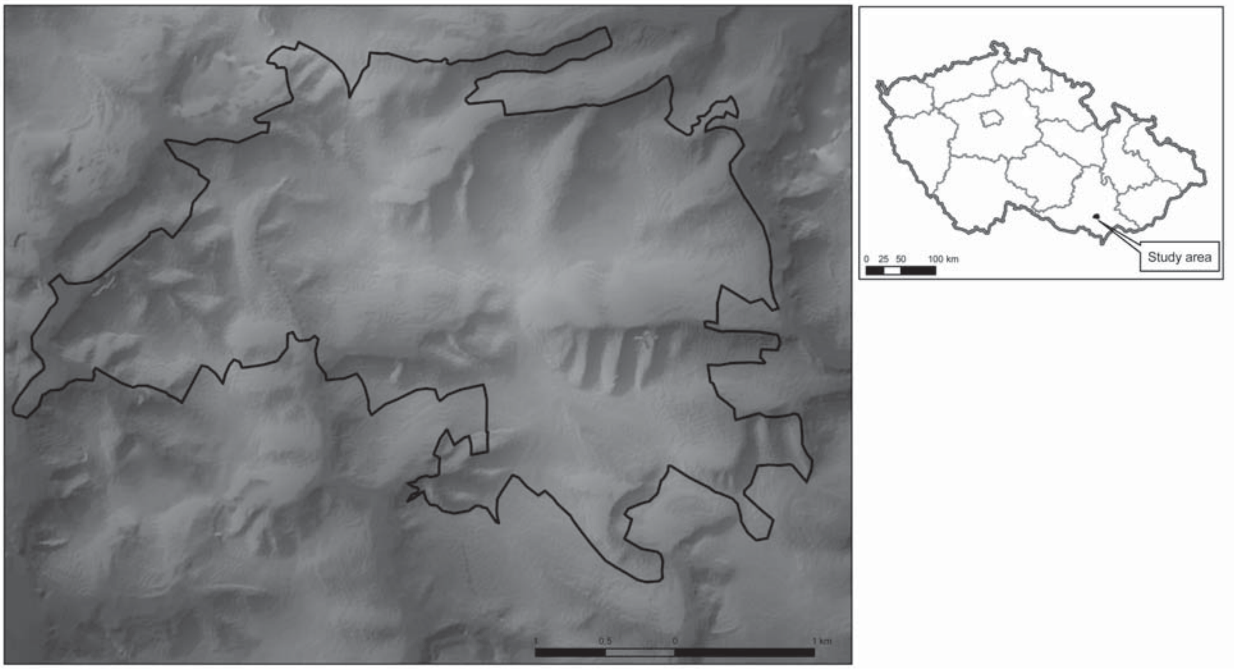


**Fig. 1 Localisation of the study area within the territory of the Czech Republic**

**Tab. 1 Characteristics of the change trajectory types**

| Turnover | Diversity | Similarity | Class | Shorcut | Example |
|---|---|---|---|---|---|
| 0 | 1 | 5 | Stable | ST | AAAAA |
| 1 | 2 | 3 | Stepped | SP | AABBB |
| 2,3,4 | 2 | 2,3 | Cyclical | C | ABBAA |
| 3,4 | 3,4,5 | 1,2 | Dynamic | D | CABBA |
| 2,3 | 2,3 | 3 | No constant trend | NCT | ABBBA |
| 1,2 | 2 | 4 | Quasi-stable | QS | ABAAA |

These analyses resulted in the creation of zones of the supra-regional biocentre for the needs of establishing proper management with respect to the historical development of the given territory, as well as with respect to the current conditions of the territory in interest (Tab. 2).

# 4 RESULTS

## 4.1 Analysis of the historical development of the landscape

**Forests** were the most pronounced category represented; here there are stable forest complexes covering more than a half of the area of the biocentre (Tab. 3). During the studied period, the forest area grew with time, particularly at the expense of permanent grasslands, arable land and vineyards. Over the monitored period, the largest part of the forest area and location can be called stable, as the factors, which cause land-use change have been resisted. **Arable land** was relatively balanced until the 1950s; since the 1990s, its area has been decreasing and currently it has dropped to nearly half. It takes up about 12 % of the biocentre's area.

**Tab. 2 Defining management zones on the basis of trajectories of change and mapping of current landscape conditions**

| Class of change | Degree of ecological stability | Management zone | Description |
|---|---|---|---|
| stable,<br>quasi-stable, gradual | 4 | A<br>(maintenance management zone] | Stable areas from the perspective of long-term land use as well as from the perspective of ecological stability. This zone does not require changes in management. |
| cyclic,<br>dynamic,<br>without any clear trend | 3,4 | B<br>(moderate management zone) | Territory that is as a rule ecologically stable, but from the perspective of long-term land use, dynamic changes occurred here. Small management measures are necessary here to improve ecological stability. |
| stable,<br>quasi-stable, gradual | 0,1,2 | C<br>(zone requiring radical management) | Areas that are stable from the perspective of long-term land use (e.g. arable land), but have a low degree of ecological stability. It is necessary to change management practices in order to improve ecological stability. |
| cyclic,<br>dynamic,<br>without any clear trend | 0,1,2 | D<br>(priority management zone) | Territory that is overall unstable both from the perspective of long-term land use, as well as from the perspective of ecological stability. It is necessary to implement management measures that will ensure the gradual restoration of near natural ecosystems. |

**Permanent grassland** recorded a significant drop particularly in the 1950s; however, its area has been gradually increasing and today it has reached its maximum – 13 % of the biocentre's area. Another category typical for the territory of interest is **vineyards**. They made up about 6–7% of the biocentre's area at the period of the second and third military mapping. They were typically narrow, of a small area, and localized above all in the central and southeastern parts of the territory. Together with meadow vegetation and interspersed fruit trees, they created a characteristic landscape mosaic. In the 1950s, two **water areas** were built in the southeastern part of the biocentre. Other forms of land use are not present, or are not significantly represented and are not included in the total analyses.

In order to capture quantitative landscape changes over the course of the entire period studied a separate change analysis was conducted, which involved overlapping vectorized sets of maps of which each captures the landscape conditions at the given time period. Through analysis, the total number of changes in the studied land use categories for the entire period from 1836 to 2006 was ascertained. Tab. 4 portrays the area and percentage of the number of changes in relation to total area.

From the mentioned results it follows that 64 % of the territory's area witnessed no land use change; these areas are relatively stable and have resisted the effects of the set of factors which cause land use change. Following this, 18 % of

**Tab. 3 Area of land use categories on five sets of maps**

| Land use category | 2nd Military Mapping | % | 3rd Military Mapping | % | 1950 | % | 1990 | % | 2006 | % |
|---|---|---|---|---|---|---|---|---|---|---|
| Arable land | 240,28 | 21,1 | 271,73 | 23,9 | 250,25 | 22,0 | 202,11 | 17,8 | 134,35 | 11,8 |
| Permanent grassland | 119,09 | 10,5 | 68,29 | 6,0 | 54,65 | 4,8 | 98,21 | 8,6 | 152,43 | 13,4 |
| Orchard | 0,00 | 0,0 | 0,00 | 0,0 | 25,18 | 2,2 | 19,20 | 1,7 | 17,32 | 1,5 |
| Vineyard | 73,23 | 6,4 | 89,94 | 7,9 | 26,93 | 2,4 | 2,65 | 0,2 | 5,06 | 0,4 |
| Forest | 704,03 | 61,9 | 706,67 | 62,2 | 772,12 | 67,9 | 807,23 | 71,0 | 818,27 | 72,0 |
| Water area | 0,00 | 0,0 | 0,00 | 0,0 | 7,50 | 0,7 | 7,23 | 0,6 | 7,93 | 0,7 |
| Other area | 0,00 | 0,0 | 0,00 | 0,0 | 0,00 | 0,0 | 0,00 | 0,0 | 1,27 | 0,1 |
| Sum (hectares) | 1136,63 | 100,0 | 1136,63 | 100,0 | 1136,63 | 100,00 | 1136,63 | 100,0 | 1136,63 | 100,0 |

**Tab. 4 Area of number of land use changes**

| Numer of land use changes | Area in hectares | % |
|---|---|---|
| 0 | 727,65 | 64 |
| 1 | 202,20 | 18 |
| 2 | 147,18 | 13 |
| 3 | 52,09 | 5 |
| 4 | 7,52 | 1 |

**Tab. 5 Trajectories of change and their proportion (%) in the SRBC Přední Kout**

| Class | Proportion (hecters) | Proportion (%) |
|---|---|---|
| Stable | 738,1 | 65 |
| Quasi-stable | 80,4 | 7 |
| Stepped | 118,7 | 10,5 |
| Cyclical | 56,3 | 4,9 |
| Dynamic | 20,1 | 1,8 |
| No constant trend | 122,7 | 10,8 |

the territory's area recorded only one change. Forest is most frequently found on the stable areas, but arable land and permanent grasslands can partially be found, in particular at the Kamenný vrch Hill near the Kurdějov Nature Reserve where land use is particularly stable.

Besides the analysis of total change (turnover index), two other indices were determined to better analyze the spatial and temporal characteristics of land use. The aim of this method is to define locations with GIS that are most prone to change (Fig. 2). Based on this method 6 classes were defined in the biocentre ranging from most stable ones to those undergoing very dynamic change (Tab. 5). Logically the stable class of long-term land use is most represented, and is made of forest vegetation and arable land. On the other hand, it follows from the analyses that only 1.8 % of the total area of the biocentre underwent dynamic change, which indicates relative stable land use of the territory.

### 4.2 Analysis of current landscape conditions

After the complete evaluation of the territory's current conditions (Tab. 6) it was ascertained that forest communities taking up about 70 % of the territory are significant by the presence of stands with the natural species and age compositions, which were assigned an Ecological stability degree 4 (ESD 4). These communities form about 48 % of forest areas. However a part of the forest communities is endangered by the planting of monocultures of non-native tree species, particularly Scots pine, and in places a relatively high proportion of black locust – about 11 % of the forest area.

Non-forest vegetation makes up about 30 % of the biocentre's territory. Valuable areas of substitute vegetation rich in species with a number of specially protected species present make up only 6 % of the non-forest vegetation area. Of lesser quality, but still significant, species-rich vegetation with ESD 3 makes up about 33 % of the non-forest vegetation area. However, a relatively large percentage is made up of fields and ruderal vegetation at about 48 % of non-forest vegetation area.

In the total evaluation of the biocentre, areas evaluated with ESD 4, which are most valuable and best preserved, make up more than 35 % of the area of the whole biocentre. On the other hand, areas where there was an increased concentration of management activities (disturbed areas with non-native vegetation or ruderalized areas) make up about 15 % of the biocentre's area.

### 4. 3 Zoning of the supra-regional biocentre based on susceptibility to change and current ecological stability

The biocentre was zoned based on the analysis of the historical development of the landscape conducted and the mapping of the current conditions of the Přední Kout SRBC (Fig. 3). Ecological stability of the landscape based on field mapping of its current conditions was the first criterion for zoning and the second criterion was the susceptibility of the areas to land use change. In this way, 4 management zones were defined (see chapter Materials and methods). Zone A (the maintenance management zone) is characterized by high ecological stability as well as by a balanced long-term land use trend. This zone is made up of steppe communities (particularly the Kamenný vrch Nature Reserve – Fig. 4) and near natural forests (Fig. 5), which create the core area of

**Tab. 6 The area of mapped units of the current landscape conditions**

| Mapping unit (according to Pellantová, 1994) | Degree of ecological stability | Area (ha) |
|---|---|---|
| forests with natural species composition | 4 | 389.8 |
| semi-cultivated forests containing native tree species | 3 | 158.9 |
| forests with unsuitable species composition | 2 | 254.3 |
| near natural pastures, fallow land, steppe slopes | 4 | 19.6 |
| semi-cultivated meadows, pastures and fallow land | 3 | 37.9 |
| cultivated meadows and pastures | 2 | 17.7 |
| agricultural fallow land | 2 | 10.2 |
| extensive and abandoned old orchards | 3 | 61.6 |
| small-scale gardens, orchards and vineyards | 3 | 0.8 |
| large-scale gardens, orchards and vineyards | 2 | 17.8 |
| artificial bodies of water with vegetation | 3 | 8.6 |
| arable land | 1 | 153.9 |
| ruderal areas (dumps) | 0 | 5.5 |

the biocentre (the Roviny Nature Reserve). The maintenance management zone takes up 65 % of the biocentre's area in total. Zone B (the moderate management zone) includes territories that have a degree of ecological stability of 3 (and exceptionally 4), but are highly prone to changes (classes of change – cyclic, dynamic, without any trend). Zone B takes up about 10 % of the total area of the biocentre and old abandoned orchards, semi-cultivated forests, semi-cultivated meadows, etc. fall into this zone (Fig. 6). With respect to historical development, it is important to note that these used to be often steppe communities, but currently occurring here today we can see intense natural self-seeding of forest tree species or even young forest stands. The third zone is the zone requiring radical management (zone C) and represents about 17 % of the biocentre's total area. From the historical perspective, these are areas with stable land use that are not prone to changes, but from the perspective of current conditions there is mostly arable land represented here (Fig. 7). The last zone is zone D (the priority management zone), which has received the lowest scores on both criteria – there are ecologically unstable communities, as well as areas strongly prone to land use change (about 8 % of the biocentre). Currently there are fields here, but from the perspective of the historical development of the landscape, there used to be vineyards, small orchards and permanent grasslands here that were completely removed and replaced by agrocenoses and/or large-scale orchards in the 1950s. These areas should be the object of increased interest and care in order to increase ecological stability.

## 5 DISCUSSION

Old maps are valuable sources of information not only for the geographical sciences, but also for landscape ecology, land use planning and practical nature conservation. In combination with field mapping of landscape conditions valuable information can be gained, which forms an important background for the care of supra-regional biocentres among other areas.

From historical point of view the most interesting categories are permanent grasslands and vineyards. The grasslands have decreased radically in the 50th in the 20th century. The significant drop in area in the 1950s was caused mostly by the intensification of agriculture, when grassland was converted to arable land. Today its growth is caused particularly by a decrease in agriculture and letting a part of the arable land lie fallow. This is mostly on steep slopes, where today we can find many protected species of fauna and flora (Kamenný vrch u Kurdějova Nature Reserve). The most significant changes of vineyards appeared at the end of the 20th century.

We can consider the period at the turn of the 20th century to be critical for vineyards; the reason for this was the calamity caused by phylloxera, which attacked most of the vineyards in South Moravia. A steep decline was recorded in the 1950s. On the territory of the Přední Kout SRBC, vineyards were often replaced by large-scale fruit orchards, which started to grow in the 1950s. Thus, the appearance of the landscape began to change in the 1950s and the original mosaic of small-land holdings, where vineyards, meadows and small parcels of arable land intermixed, was replaced by more wide-scale, consolidated blocks of arable land, as well as permanent grasslands and fruit orchards. It is possible to speak about "the simplification of landscape structure".

The analysis of historical development in combination with landscape mapping supported the limitation of the most permanent areas within land use and ecological stability. Thanks to the analyses the management zones of supra-regional biocenter have been proposed in order to create the optimum management.

The proposed management measures should concentrate above all on areas that are located in zones C and D, where it is necessary to apply radical procedures in order to improve the ecological stability and restoration of near natural ecosystems.

It would be appropriate to apply the following basics for care:

- promote a greater portion of geographically native tree species in the forests;

- many areas that were classified on old maps as permanent grasslands have transformed into forest communities. For these segments which have a tendency to degradation and overgrowing with woody species, it is necessary to ensure management – mowing, grazing, tree removal;
- gradually remove geographically non-native tree species (especially the invasive black locust) and respect the natural tree species composition in accordance with the types of geobiocenoses;
- try to restore landscape structures based on old maps (the mosaic of permanent grasslands and orchards);
- eliminate arable land in the biocentre;
- ensure at least minimum management for areas that are abandoned and currently not maintained and thus restrict gradual ruderalization;
- use national and European resources for care;
- promoting limits and limiting land use in binding parts of land use plans;
- ensure incorporating limits and restrictions in regional plans of forest development and forest management plans.

## 6 CONCLUSIONS

At the Přední Kout SRBC, we can document stable, long-term, intensive agricultural land use with a low level of industrialization. The territory is characterized by having a long-term high proportion of forest and a stable proportion of forest to open land. Land-use change development was analyzed on five sets of maps dating from 1836 to the present.

Using modern geographical information methods it was possible to determine the most stable areas of the biocentre and at the same time define the most fragile areas. The analyses resulted in the zoning of the supra-regional biocentre, where individual zones are graded based on the ecological stability of the landscape and the susceptibility of the landscape to land use changes, and thus it is possible to propose the optimum management of each zones. The aim of these measures should be to ensure the functionality of the biocentre, the preservation of existing natural and near natural ecosystems, and if possible the gradual restoration of parts with low degrees of ecological stability.

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# EVALUATING ECOLOGICAL NETWORKS IN THE LANDSCAPE

## HODNOCENÍ EKOLOGICKÝCH SÍTÍ V KRAJINĚ

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**Abstract**

This paper deals specifically with territory in the administrative district of the municipality with extended competence (hereinafter referred to as MEC) of Kuřim in the South Moravian Region. An analysis of historical cartographic maps from the period between 1836 and 2006 was conducted in order to determine the most stable parts of the landscape. Consequently, a methodological procedure for evaluating ecological networks in the landscape was applied on the studied model areas that evaluates to what extent current conditions conform to optimal conditions.

**Abstrakt**

Příspěvek se konkrétně zabývá územím ve správním obvodu obce s rozšířenou působností (dále jen ORP) Kuřim v Jihomoravském kraji. Pro toto území byla provedena analýza historických kartografických podkladů z období let 1836–2006 za účelem vymezení nejstabilnějších části krajiny. Na sledovaných modelových plochách byl následně aplikován metodický postup pro hodnocení ekologické sítě v krajině, která vyhodnocuje míru shody aktuálního stavu se stavem optimálním.

**Keywords:** territorial system of ecological stability, historical development of the landscape, ecological stability, evaluation of conditions, functionality

## 1 INTRODUCTION

In the current state of land use planning and urban planning the concept of territorial systems of ecological stability (TSES) is perhaps the only instrument substantiated by legislation, which helps to bring the current cultural landscape closer to sustainable use. After November 1989 in the Czech Republic TSES was laid down not only in conservation regulations, but also in land use planning and agricultural regulations. This concept is fully convergent with others that have been created and applied on landscapes not only throughout Europe, but throughout the world (Jeditzke, 1994; Lammers, Zadelhof, 1996; Smith, Helmund, 1993; Růžičková, Šíbl, 2000, etc.)

The real possibility of increasing the ecological stability of the landscape stems from the assumption that the degree of ecological stability of the cultural landscape cannot be understood as the weighted average of the degrees of each individual part, but instead these degrees are dependent on their arrangement – on their suitable spatial arrangement. In order to preserve the landscape's high and permanent productiveness and its ecological stability it is necessary to isolate individual ecologically unstable parts of the landscape with a system of stable and stabilizing ecosystems (Löw et al., 1992).

Therefore, the aim of planning TSES is to "defend" critical areas of the natural infrastructure in order to ensure the ecological stability of the landscape, and/or sustainable land use. As far as planning preparations are concerned practically the entire Czech Republic is covered by TSES proposals of all categories including decisive local TSES. However, most of these are only at the "master plan" level, and must be further specified in land use planning documents, complex land consolidation documents and forestry planning documents (Míchal, 2000).

All planning documents, including those for TSES, should lead to one main goal – actually carrying out the plans. For ecologically significant landscape segments, or "framework of ecological stability", this means above all that they should be preserved in their current form, as they were created by years of balanced interaction between humankind and nature. In practice, this entails ensuring continuous care while continuing to follow current land use patterns.

Of course, however, as it often happens, information about the current conditions of the landscape's component elements is not based on adequate field research. Potential geobiocenses conditions are usually only reconstructed by transferring information from forest type data (Plíva, 1971), and perfect localization (through GPS systems) is often lacking no less, which would precisely define landscape segments as well as help monitor landscape development dynamics (e.g. Bičík et al., 1996; Lipský, 2000; Mackovčin, Demek, Havlíček, 2006; Žigrai, 1978).

Currently the methodology for evaluating small-scale specially protected areas is used for the evaluation of TSES component element conditions (Svátek, Buček, 2005). This methodology however is more oriented towards territories falling under special protection in accordance with Act No. 114/1992 Coll., on nature and landscape conservation.

The current conditions of the territory as well as care for it are evaluated. However, management documents (care plans) are lacking for TSES component elements, and therefore it is not possible to objectively assess the extent to which current conditions are in accordance with optimal conditions. Criteria for evaluating functionality, which are critical for conservation, restoration and establishing entire ecological network complexes are also missing.

## 2 STUDY AREA

The municipality of Kuřim is located about 4 km northwest of Brno. It belongs to a category of municipalities with extended competence (hereinafter referred to as MEC); its administrative district takes up a total of 7,711.30 ha and consists of 10 constituent cadastral territories (c.t.) (Česká, Čebín, Hvozdec, Chudčice, Jinačovice, Kuřim, Lelekovice, Moravské Knínice, Rozdrojovice and Veverská Bítýška).

The landscape of the monitored territory is a mix of forests and agricultural land; 46 % of its total area is made up of non-forest area. The matrix is made up of extensive areas of arable land, and linear vegetation (windbreaks, riparian stands, and alleys), permanent grasslands and extensive gardens are isolated. More varied landscape structure has remained preserved only marginally in the area around the municipality of Lelekovice, where arable land has been pushed back by a "mosaic" of oak coppices, grassy fallow land, shrubby balks and wetlands.

Forest vegetation takes up about 37 % of the model territory's area; of course, secondary conifer (spruce and pine) plantations predominate, whereas there are less hardwood and mixed forests. Larger area fragments of near natural and natural stands outside of specially protected areas are found only in the Bílý potok stream valley (beech forests, ravine forests) and in the Baba and Podkomorské lesy Woods Nature Parks (thermophilous oak forests, oak-hornbeam forests).

Currently there are 5 proclaimed specially protected areas with a total area of 64.25 ha in the administrative district of MEC Kuřim. Furthermore there are 3 nature parks present on the territory (Baba, the Podkomorské lesy Woods, and the Údolí Bílého potoka Stream Valley), as well as 125 registered significant landscape elements (Martiško, 1997).

## 3 MATERIAL AND METHODS

### 3.1 Used data

In order to determine the most stable parts of the Kuřim landscape the methodological procedure developed within the framework of research project MSM 6293359101 "Research of biodiversity sources and indicators in the cultural landscape in the context of the dynamics of its fragmentation", managed by The Silva Tarouca Research Institute for Landscape and Ornamental Gardening (Brno, Department of Landscape Ecology) was applied. The given methodological procedure is based on the digital analysis of five sets of available cartographic maps from the period 1836–2006, which are stored in digital form in the Institute's database and are used for background materials (Mackovčin, 2009; Skokanová, 2008). Maps from 1836 (from the period of the 1st military mapping), 1878 (from the period of the 3rd military mapping) and further maps from 1950 (the 1st Czechoslovak military mapping in the S-1952 coordinate system), 1990 (4th updated Czechoslovak and Czech military mapping) and 2006 (ZABAGED) were used for this study.

### 3.2 The selection of representative areas

Based on the conducted analyses several representative areas within the study territory where defined, which show relatively high stability in land use development, regardless of under what kind of protection they are under today. Currently they meet the criteria arising from the conceptual base of TSES – they indicate at least medium or high degrees of ecological stability, and at the same time certain representativeness or uniqueness of habitats for the natural gene pool of the Brněnský bioregion (Culek et al., 1992).

Consequently, the proposed methodological procedure for evaluating ecological networks in the landscape was applied to the defined areas, and/or its parts dealing with evaluating the framework of ecological stability, that is to say currently existing ecologically significant landscape segments (hereinafter referred to as ESLS).

### 3.3 Evaluating ecological networks in the landscape

The methodological instructions are divided into two separate parts – the first part deals with **evaluating the framework of ecological stability**, that is to say currently existing ecologically significant landscape segments (hereinafter referred to as ESLS), and the second part deals with **evaluating the conditions and functionality of newly established component elements** of the TSES, as these issues are the main aim when assigning and creating most involved planning documents.

The selected methodological procedure is based on the basic principles of simplicity, universality, speed and comprehensiveness. The conditions and functionality of the monitored ESLS are evaluated with the aid of a total of 15 criteria, which are thematically and rationally broken up into 4 groups as presented in tables 3.1.1 to 3.1.4.

Within the methodological procedure it is crucial that all criteria are evaluated. Exceptionally, some criteria need not be evaluated due to serious or exceptional causes, which of course must by rationally substantiated. Spatial structure criteria and criteria evaluating the current conditions of the studied territory must be evaluated at all times.

In order to ascertain the importance of each individual criterion, each criterion is assigned a "multiplicator", in other words a multiplication coefficient that raises the significance of the given criterion above the others. The given evaluation

**Tab. 3.1.1**

| The evaluation of spatial structure criteria | Brief characterization of the criterion |
|---|---|
| Spatial parameters | An assessment of actual spatial parameters in regard to their defined minimums |
| Connectivity | An assessment of the mutual connectivity of individual elements of the TSES |

Tab. 3.1.2

| The evaluation of current conditions | Brief characterization of the criterion |
|---|---|
| Significance for ecological stability | An evaluation of the portion of natural and near natural communities |
| Habitat diversity | An assessment of landscape diversity (geodiversity) |
| The level of anthropic influence | An assessment of anthropic influence on the territory |
| Polyfunctional potential | An assessment of the possibilities for polyfunctional utilization |

Tab. 3.1.3

| The evaluation of biodiversity | Brief characterization of the criterion |
|---|---|
| Diversity of communities present | An assessment of the accordance of potential conditions with current conditions |
| The presence of protected and endangered species of flora | An evaluation of species diversity in the natural gene pool |
| The presence of protected and endangered species of fauna | An evaluation of species diversity in the natural gene pool |
| Biogeographic significance | An evaluation of the level the segments are represented in the bioregional division of the Czech Republic |

Tab. 3.1.4

| Supplementary criteria | Brief characterization of the criterion |
|---|---|
| Functionality of the ESLS | An assessment of the incorporation of the segment to the landscape system |
| Ensuring protection | An assessment of the level of worked up documentation |
| Invasive and expansive species | An evaluation of the extent to which invasive and expansive species have spread |
| Negative influences | An evaluation of internal and external negative influences |
| Assumptions about future development | An evaluation of the territory's conditions with an accent on its future development |

degree is multiplied by this coefficient, which gives the actual point value to be calculated in the resulting calculation (see tables 3.2.1 to 3.2.4).

Fast field surveys of the selected territory, focused on gaining current information about the actual territorial conditions and its incorporation into the landscape, form the base for evaluation.

It is essential that after completing field research that a numbered evaluation degree by given to each criterion along with a brief and accurate written description. Photographs that support the observed conditions should also be taken during field research.

During field research, it is possible to evaluate all of the listed criteria with two exceptions – "*biogeographic significance*" and "*ensuring protection*". For the former academic literature (Culek, 1992 and 2005) must be worked with in order to define the representativeness of biochor types. For the latter the level of existing scientific documentation of the selected landscape segment must be evaluated. The fine tuning of field research through inventory research is critical for the criteria "the presence of protected and endangered species of flora" and "the presence of protected and endangered species of fauna".

Before actually evaluating the territory it is fully appropriate and favorable to obtain all available information, which in the case of TSES can be done best from planning documents (the master plan, plan and TSES plan) – these are of course created on different levels and are of differing quality. Due to this it is

**Tab. 3.2.1 Weight of individual criteria**

| The evaluation of spatial structure criteria | Degree | Multiplication coefficient |
|---|---|---|
| Spatial parameters | 1–5 | 3 |
| Connectivity | 1–5 | 2 |

**Tab. 3.2.2 The weight of individual criteria for evaluating ESLS conditions**

| The evaluation of current conditions | Degree | Multiplication coefficient |
|---|---|---|
| Significance for ecological stability | 1–5 | 2 |
| Habitat diversity | 1–5 | 1 |
| The level of anthropic influence | 1–5 | 1 |
| Polyfunctional potential | 1–5 | 1 |

**Tab. 3.2.3 The weight of individual criteria for evaluating ESLS conditions**

| The evaluation of biodiversity | Degree | Multiplication coefficient |
|---|---|---|
| Diversity of communities present | 1–5 | 2 |
| The presence of protected and endangered species of flora | 1–5 | 1 |
| The presence of protected and endangered species of fauna | 1–5 | 1 |
| Biogeographic significance | 1–5 | 1 |

**Tab. 3.2.4 The weight of individual criteria for evaluating ecologically significant landscape segment conditions**

| Supplementary criteria | Degree | Multiplication coefficient |
|---|---|---|
| Functionality of the ecologically significant landscape segment | 1–5 | 1 |
| Ensuring protection | 1–5 | 1 |
| Invasive and expansive species | 1–5 | 1 |
| Negative influences | 1–5 | 1 |
| Assumptions about future development | 1–5 | 1 |

therefore necessary to take into account and supplement this obtained information with area-wide field research.

Points gained by assigning a degree to each of the 14 criteria shall be totaled, with which resulting information about the actual conditions and functionality of the monitored ESLS can be calculated. The resulting evaluation shall be expressed as a percentage of the maximum amount of possible points, which is equal to 100 points.

## 4 RESULTS

From the analyses it is clear that rise in the area of arable land lasted only until the 1870s and was followed by slight decrease. Distinctive change in the shape and size of cultivated fields is apparent even here – formal mosaic structure of field cultures was transformed into unitary form of large-scale arable fields during and after the collectivization of agriculture. This trend continues to appear in the present landscape structure (Drobilová, 2007).

The forest area showed slight exponential rise during the whole research period; pronounced decline in the forest area has been identified only in the local scale around the Čebínka peak where the forest was replaced by expanding limestone quarry.

Recreational area, represented mainly by garden colonies outside the residential area, occurs since the 1990s but its proportion is insignificant with the comparison to other land use categories (0,59 % in 2006).

From the perspective of spatial changes, built-up area can be without doubt assessed as the most dynamic category. This spatial unit encompasses the dynamism of the development of both rural and urban built-up areas as well as industrial areas (in this case mainly limekiln near Čebín village) (Drobilová, 2008).

The selected territories form a representative sample of near natural and natural communities present in the territorial district of MEC Kuřim. The functional and biogeographic significance of the TSES elements were taken into account during the selection of localities. Therefore segments at the local and regional levels are represented, and biocenters, habitat corridors and interactive elements were evaluated in order to prove the universality of the selected methodological procedure used.

In total 15 criteria where evaluated from more than 30 ESLSs, and for the purpose of detail the following are evaluated:

- Local biocenter "***Dálky***" (c.t. Čebín)
- Interactive element „***Malý kopec***" (c.t. Čebín)
- Local biocenter „***Čebínka – Hrbatá***" (c.t. Čebín)
- Local biocenter "***Kuřimský vrch***" (c.t. Kuřim)
- Local habitat corridor "***Mozy***" (c.t. Kuřim)
- Local biocenter "***Opálenka***" (c.t. Kuřim)

**Tab. 2.3.1 Scale of the resulting evaluation of ESLS conditions**

| Resulting evaluation of ESLS in % | Expressed in words |
|---|---|
| 71–100 | ESLS conditions are completely satisfactory. |
| 51–70 | ESLS conditions are satisfactory. |
| 31–50 | ESLS conditions are somewhat satisfactory. |
| 0–30 | ESLS conditions are unsatisfactory. |

- Local biocenter "***Podlesí***" (c.t. Kuřim)
- Regional biocenter "***Zlobice***" (c.t.. Kuřim, c.t.. Malhostovice)
- Local habitat corridor "***Pod Babím lomem***" (c.t. Lelekovice)
- Local biocenter "***Čihadlo***" (c.t. Moravské Knínice)
- Interactive element "***Rybníček v oboře***" (c.t. Moravské Knínice)
- Local habitat corridor "***Strachovské strže***" (c.t. Rozdrojovice)
- Local biocenter "***Chudčický háj***" (c.t. Chudčice)
- Interactive element „***Hvozdecká vápenice***" (c.t. Hvozdec)
- Regional habitat corridor „***Svratka***" (c.t. Veverská Bítýška, Holasice, Sentice, Tišnov, Březina, Heroltice, Štěpánovice, Předklášteří)
- Local biocenter „***Hájek***" (c.t. Veverská Bítýška)

The resulting values of the above named ESLSs are projected in map and graph (Fig. 3, 4). During the selection of model areas the largest emphasis was placed on their relatively high stability over time, while taking into consideration functional and biogeographic significance for attaining the widest possible range of representative ecological network elements.

## 5 DISCUSSION

The main impulse for the development of a separate methodological procedure for ecological network evaluation was the need to focus on and at the same time differentiate between particulars of individual landscape segments arising out of their different land use, protection status, and particularly assumptions about their future development.

Territories incorporated into the framework of ecological stability are as a rule suitably categorized as specially protected areas in accordance with Act No. 114/1992 Coll., where current monitoring of protected areas is conducted on the basis of the methodological procedure (Svátek, Buček, 2005) evaluating current conditions and the level of existing care. Furthermore these territories can be registered as significant landscape elements (hereinafter referred to as SLE), or directly as individual TSES elements (biocenters, habitat corridors, or interactive elements). In this case the applicability of the above mentioned methodology is somewhat lower, as the efficiency of care cannot be objectively evaluated – for SLEs care plans are lacking, nor does any similar document exist on the basis of which it would be possible to carry out the second part (care evaluation) mentioned in the methodology.

Another basic conflict between evaluating specially protected areas and component elements of TSES using the methodology of Svátek and Buček (2005) is the differing societal requirements expected of the territory's current conditions and its future development. Specially protected areas are specifically defined as objects of protection, which must have management leading towards ensuring conditions for their permanent existence. Opposed to this, the conservation goals of TSES are specified "only" on the general level such as the ecostabilizing effect on the landscape, support and development of the landscape's natural gene pool, and the support of polyfunctional land use. Therefore, for these territories it is more than appropriate to define a different methodological procedure with specifically focused criteria that would more adequately reflect required conditions.

## 6 CONCLUSIONS

Much information about the landscape structure development of a monitored territory can be gained by interpreting old maps. From the quantification of land use changes from individual time periods alone it is obvious that this territory is under permanently growing pressure from the expanding urban agglomeration and if suburbanization is not restrained, it is likely to occur that in the most proximate cadastres the border dividing the rural landscape and the urban shall be blurred.

Therefore, output values gained were purposefully applied during the selection of representative ESLSs for evaluating the conditions of the ecological network, because as far as landscape structure changes over time are concerned they represent the most stable part of the studied landscape area.

From the resulting evaluation of the selected ESLSs it is obvious that the conditions of these territories are at the optimal level on average; it is however necessary to take into account the fact that representative segments with high ecological stability and community diversity were selected. Area-wide research of the monitored landscape would certainly turn up more gaps in the fulfillment and ensuring of the TSES concept.

The presented proposal for a methodological procedure evaluating ecological networks in the landscape will be further applied and refined during field research on a variety of ESLSs. The aim is to achieve its incorporation into valid TSES legislation as one of the possible instruments for ensuring permanent and effective care of ecological network elements in the landscape.

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# METHODOLOGY FOR IDENTIFICATION OF HISTORICALLY AND ECOLOGICALLY STABLE ELEMENTS AS THE BASIS FOR THE LANDSCAPE ECOLOGICAL STABILITY RESTORATION

## METODA IDENTIFIKACE HISTORICKÝCH PRVKŮ EKOLOGICKÉ STABILITY JAKO VÝCHODISKO PRO OBNOVU EKOLOGICKÉ STABILITY KRAJINY

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**Abstract**

The objective of the work is to test the methods of identification and analysis of historical elements of the ecological stability. The elements involved have both, their ecological and culturo-historical importance as a part of the so-called landscape memory structure. The method was applied within the Cadastral area of Hrochův Týnec (576 ha), which represents a segment of an old cultural landscape with an intensive agricultural utilization. The Emperor's prints of the Stable Cadastre Maps (1839) and the present aerial photographs of 2006 have been used as the research basis. A satisfactory amount of quantitative data obtained on a sufficiently large scale is the main contributions of this method. In 1839, the ecologically relatively stable segments of landscape (permanent grass and woody vegetation, and water surfaces) covered 15 % of the study site area. Within the study site area a proportional representation of the stable segments decreased from 15 % to 11.2 % in 2006. Only a small part of the relatively ecologically stable areas has sustained to present time (33.6 % of the ecologically stable segments area, 5 % of the study site area). The study has indicated that in 2006 woody vegetation dominated in the frame of the ecologically stable segments structure (56 %), the permanent grasslands covered only 43 % of the area. On the contrary, the permanent grass vegetation created the dominant part of the ecologically stable land cover in 1839 (70 %). The woody plants areas are also the segments with the highest time stability as they represent the major part of the historically stable segments of ecological stability (almost 67 %). Total sum of ecologically stable elements has decreased. However, the representation of woody vegetation, which is generally of a higher ecological value than the one of permanent grassland, has grown.

**Abstrakt**

Cílem práce bylo testování metody identifikace a analýzy tzv. historických prvků ekologické stability krajiny. Uvedené prvky mají jak ekologický, tak rovněž kulturně-historický význam jako součást tzv. paměťové struktury krajiny. Metoda byla aplikována v katastrálním území Hrochův Týnec (576 ha), které představuje segment intenzivně zemědělsky využívané staré kulturní krajiny. Jako podklad byly použity císařské otisky map stabilního katastru (1839) a současné ortofoto letecké snímky z roku 2006. Hlavním přínosem metody je získání dostatečného množství kvantitativních údajů ve velkém měřítku zobrazení. Relativně ekologicky stabilní segmenty krajiny (trvalé travní porosty, porosty dřevin a vodní plochy) zaujímaly v roce 1839 15 % plochy studovaného území. Zastoupení stabilních segmentů pokleslo z 15 na 11,2 % plochy zájmového území v roce 2006. Pouze malý podíl relativně ekologicky stabilních ploch se dochoval do současnosti (33,6 % z plochy ekologicky stabilních segmentů, 5 % z plochy studovaného území). Studie ukázala, že v roce 2006 porosty dřevin ve struktuře ekologicky stabilních segmentů krajiny dominovaly (56 %), trvalé travní porosty zaujímaly 43 %. Naopak, v roce 1839 byly převažujícím ekologicky stabilním krajinným pokryvem trvalé travní porosty (cca 70 %). Porosty dřevin jsou zároveň i segmentem s nejvyšší stabilitou časovou, protože tvoří hlavní podíl historicky stabilních prvků ekologické stability (téměř 67 %). Celková plocha ekologicky stabilních prvků poklesla, ale uvnitř této kategorie vzrostlo zastoupení dřevinných porostů, které mají obecně vyšší ekologickou hodnotu než trvalé travní porosty.

**Keywords:** land cover change, historical segment of ecological stability, old maps, aerial photographs, GIS

## 1 INTRODUCTION

Landscape is characterised by dynamic and continuous change, which may be expressed by quantitative changes of landscape structural characteristics. The rate of change varies in accordance with fluctuations of natural and anthropogenic processes (Skånes, 1996). Natural conditions represent the most important factors that set the limits to the utilisation of land. However, it is rather a framework for the way in which land is finally used, as it is the farmer and his actions that "have the last word" about the way in which agricultural landscape will appear (Helström, 2002). The Czech cultural landscape has experienced a dynamic history, full of dramatic reversions and changes (Lipský, 1995; Sklenička, 2003; Löw and Míchal, 2003). The Industrial Revolution, which began to gather force in the first half of the 19$^{th}$ century, led to the first significant impact on the Czech landscape, and for this reason we will focus here only on the landscape history from the mid- 19$^{th}$ century onwards. Before the industrial revolution, human activities are considered to have been in balance with natural processes. Since only the power of human beings and livestock could be used for cultivating the landscape, the extent to which natural ecosystems were cultivated was low, and natural processes were not disturbed (Sklenička, 2003; Löw and Míchal, 2003). Despite rapid industrialisation at the turn of the 20th century, the cultural landscape was still regarded as diverse and harmonic during the 1930s and 1940s (Sklenička, 2003). The end of World War II is taken as a turning point for the Czech society as well as for the Czech landscape, and indeed for the whole of Europe (Hietel et al., 2004; Jordan et al., 2005). Changes in landscape had never been so pronounced before 1945. Modern technologies in agriculture began to develop, along with intensification and specialisation. When the Communist Party took power in former Czechoslovakia after the Putsch in 1948, these changes were characterised by large-scale Soviet-type farming, with agricultural co-operatives as major agricultural landowners. Collectivisation of agriculture is one of several significant actions in the history of former Czechoslovakia after 1945 that left great marks not least on the face of the Czech cultural landscape. Collectivisation officially made its start in 1951 (Jech, 2001). The so-called Velvet Revolution in 1989 brought about new economic and social conditions leading to a new institutional framework. Landscape users were greatly affected.

The landscape of Hrochův Týnec is an old agricultural landscape (Lipský, 1998) settled since the Neolithic Age, because of its favourable natural conditions (Roček, 1926). Within the cadastral area arable land (almost 70 % in 2006, determined on base of this work) represents its dominant land cover type. Local fertile soils, the so-called brown chernozem (Novák et al., 1992), are exposed to a maximum pressure from the side of agriculture, what is the main reason why we almost do not find woody or scattered vegetation in this landscape as they represent a potential obstacle for the land utilisation. That is one of the reasons why the collectivisation in the 50s attacked this area the same way as other fertile areas, i.e. with its full intensity and brutality because in such areas the force for fast collectivisation process was stronger (Jech, 2001). Most of all, the landscape of Hrochův Týnec has been influenced by its agriculture and construction (residential and industrial built-up areas). Although the original sugar factory was built up already in the 19th century, it did not have a remarkable impact on the landscape, due to its localisation within a developed part of the village. At the end of the 20th century, in an open landscape, approximately 1 km NE of the village, the new sugar factory, one of the biggest ones within Czechoslovakia, was built up. It is the paradox of the time that after finishing its production it had been demolished and the structure was removed so the present landscape character is almost the same as it was in thesese places before 1969. The landscape has been influenced by woodland management in minimum, namely within the territory of the so called Dvakačovice Forest but it is already situated within the area of neighbouring cadastral territory of Dvakačovice (Štěpán, 2001; Roček, 1926; Chronicle of the Hrochův Týnec municipality, 1958–1973).

Ecological stability is the term discussed frequently at the present landscape and nature protection (Kolejka, 1992; Míchal, 1994; Larsen, 1995; Upadhyay et al., 2000; Belovsky, 2002). The term is defined as the ability of ecological systems either to resist disturbing outside factors or to reproduce their substantial characteristics (Míchal, 1994). We mean the elements of historico-ecological stability these relatively ecologically stable segments of landscape (e.g. forests, permanent grass vegetation, water surfaces), which occurred within the study site in 1839, as well as in 2006. Then these surfaces can be characterized by their ecological stability as well as by their time stability. The elements of historico-ecological stability are also in accordance with the so-called landscape memory concept, in this case being applied only to relatively ecologically stable landscape segments. This definition suggests the importance of the elements of historical and ecological stability from the point of view of landscape ecology and regenerationl as well as in consideration of its cultural landscape heritage (Trpák and Trpáková, 2002). At present, the information on the historical stability elements structure can contribute to recovery of relatively ecologically stable ecosystems, which creates a significant part of present territorial systems of landscape ecological stability (Buček and Lacina, 2001; Buček, 2009), but also to a renewal of other aesthetically and historically significant elements of landscape, i.e. historical routes or alleys (Sklenička, 2003). These characteristics could become an important basis in the framework of individual forms of agricultural planning and also at revitalization of non-productive functions of agriculture or at the agrotourism support (Brůna et al., 2002). The proposed principle of determining the memory landscape structure can be a suitable procedure for identification and quantification of values of the so-called "ordinary" cultural landscape by course of the European Landscape Convention (Weber et al., 2004), which was signed by the Czech Republic in 2002, ratified by the Parliament and came to force on 1 October 2004. In Article 2 – "Extent" it is written that "subject to the provision of Article 15 of this Convention shall be applied to the whole territory of the Parties and shall cover natural, rural, urban and suburban areas. It includes continental face surfaces, inland water surfaces and sea areas. It concerns, on the one hand, landscapes that may be considered to be remarkable, and on the other hand those ordinary and eroded ones. The joining countries also pursuant to the Convention bind themselves to further collection and analysis of the data on landscape (typology, changes including causes, characteristics) including raising the consciousness of the landscape values."

The objective of the work is to test the method for identification and spatial determination of historical elements of the ecological stability applied on a concrete model territory in the Cadastral area of Hrochův Týnec. This may serve as the grounds for the determination and quantification of values of a so-called "ordinary" cultural landscape. There should belong among follow-up activities – which are a call into the future – on the one hand the assessment of the actual state of elements of the landscape memory, definition of their target state and possible methods of management and education within the scope of protection and care for historic cultural landscape, which is a part of our cultural heritage. In addition, protection of these elements within the scope of the nature and landscape protection process is important, since a part of the landscape memory elements forms ecologically relatively more stabile ecosystems in the landscape that perform numerous functions (ecological, aesthetic, ameliorative and others).

## 2 STUDY AREA

The Hrochův Týnec study site is located in the Pardubice Region (Fig. 1, 2). The study area coincides with the Hrochův Týnec cadastral administrative unit. It has therefore been delimited by the cadastral boundaries, which have shown long-term historical consistency since the 19th century. The historical cadastral boundaries, based on the Stable Cadastre Map of 1843, were chosen as the historically continuous basis for our analysis. The altitude ranges from 257.7 metres to 300.9 metres above sea level.

The Hrochův Týnec study site is located in an old cultural landscape (Lipský, 1998) situated in the so-called Bohemian Cretaceous basin (Vítek, 2002; Novák et al., 1992). The site provides a typical example of an intensively utilised type of collective open-field landscape (Meeus, 1995). This study shows that land cultivation has had a long tradition on this site, with arable land as the most abundant type of land cover between 1839 and 2006 (89.1%–89.4%). The dominant land cover type is arable land, which uses 89.4% of the land. In the Pardubice Region as a whole, arable land accounts for 44.5%, and in the whole country, the figure is 38.7% (Statistics Czech Republic 2006). The bedrock dates back to the Mesozoic period, especially to the Cretaceous period. It is composed of sedimentary rocks, such as arenaceous marlstone, marlstone and in places sandstone. The upper layers from the Quaternary – Pleistocene Period contain eolian sediments, loess and loess loam. This type of bedrock leads to the formation of highly fertile soils, including black earth. The Hrochův Týnec study site lies on the border between black earth and brown earth, which lies further to the south (Novák et al., 1992). The climatic conditions in the Pardubice Region are strongly influenced by its location in central Europe, where a continental type of climate prevails (Faltysová, 2002). The study site is situated in the Slightly Warm zone (Nováková, 1991). The annual mean temperature is 8.2 °C, and the annual rainfall amounts to 622 mm (Faltysová, 2002). The territory is in the watershed of the Elbe River. Hrochův Týnec lies in the Czech Thermophyticum District; the landscape belongs to the "Gradus collinus" zone (Slavík, 1988; Skalický, 1988). The vegetation types are oak-hornbeam (*Melampyro nemorosi-Carpinetum*) and alluvial woodlands (Neuhäuslová et al., 1998).

## 3 MATERIALS AND METHODS

### 3.1 Basis data used

Direct measurements including observations of special processes represent the determining phase of work at all research areas and at all applications. Also the data collection has been proved as one of the most complicated and one of the most expensive steps of GIS based projects. The quality and the quantity of gained data are significantly influenced by the quality of direct measurements. It directly influences the outputs reliability (Tuček, 1998; Streit, 1997). Five main sources of data have been used in this study:

1) Official statistical data on land cover in the Czech Republic (Database on Historical Land Cover, 2009; Statistics Czech Republic 2006). These official statistics were used only to provide overall information on changes in the area of land use in the landscape (Lipský, 1995; Fjellstad and Dramstad, 1999). Although the official statistics on land cover provide mainly background information, with no references to the interrelations of the landscape compounds, they can nevertheless provide some valuable information. A unique database of historic statistical data on land cover is available for almost


**Fig. 1 Location of the Hrochův Týnec study area in Europe (CENIA, 2009)**


**Fig. 2 Hrochův Týnec study area on an aerial photograph**

the entire territory of the Czech Republic. The data in the database relates to four time horizons, which may be taken as turning points in the history of the country and its landscape (1845, 1948, 1990 and 2000).

2) Stable Cadastre Maps from 1839 and 1843 (original scale of 1 : 2 880). Stable Cadastre Maps were the first geodetically objective maps in the Czech Republic. A series of Stable Cadastre Maps were produced between 1825 and 1843 for taxation purposes (Semotánová, 2002). They are unique, since they show the state of the landscape at the rural/industrial transition point. As they are geodetically objective, characteristics interpreted from the Stable Cadastre Map may be quantified in GIS. However, a field survey and precise identification of identical points are necessary in order to reduce and circumvent problems in transforming the old Stable Cadastre Maps to a modern coordinate system (Hamre et al., 2007). The issue of transformation of old maps to a modern coordinate system was discussed in detail by several authors (Pärtel et al., 1999; Hamre et al., 2007; Domaas, 2005, 2007). The raster photographs of these maps were of jpg format, and of a horizontal and vertical resolution of 300dpi.

3) Aerial photographs (2006). The use of aerial photographs in landscape research is comparable in importance to the invention of the microscope in biology (Míchal, 1994). Application of aerial photographs is stated to have given the initial impulse in the process of constituting landscape ecology (Troll, 1939; Finley, 1960; Howard, 1970; Ihse, 1995; Cousins and Ihse, 1998). Aerial photographs have become a relevant source of data in landscape change research over the last 40 to 60 years (Skånes, 1996; Lipský, 2000). In the Czech Republic, a large collection (approximately 800,000 items) of aerial photographs is available in the Military Geographical and Hydrometheorogical Archive in Dobruška. It is based on systematic black and white aerial photographs monitoring the territory of the country from 1936 onwards, at 5–7 year intervals (Sklenička, 2003; Lipský, 2000). In this study, aerial photographs from 2006 have been utilised.

4) The basic map of the Czech Republic (1 : 10 000) for the purposes of transformation of the Stable Cadastre historical maps (VÚKOZ, 2003).

### 3.2 Data processing

The six raster images of the Emperor's prints of the Stable Cadastre maps have been connected together to generate a size of the area desired. The Hrochův Týnec cadastral map in horizontal and vertical resolution of 300dpi.has been the result. It was necessary due to the high requirements for interpretation purposes and due to the quality of the old maps. For the raster images, the software of Photoshop by Adobe was used and consequently they were georeferenced in the TopoL XT 8.0 GIS , using the affine transformation (Hamre et al., 2007; Domaas, 2005) to the S-JTSK Krovak East North coordinate system. The transformation was undertaken on the basis of using identical points for the old map, the aerial photograph and the present map on a scale of 1 : 10 000. Since both study sites are characterised by a relatively dense man-made infrastructure, the number of identical points was high enough to achieve a satisfactory level of transformation accuracy. Ortophoto aerial photographs were taken from the server of geoportal.cenia.cz (CENIA, 2009) and they were vectorised without any further processing.

Vectorisation of captured raster data was conducted in the environment of the ArcGIS 9.2 program by ESRI. For each of the two time horizons (1839, and 2006), the landscape elements were distinguished visually according to the land cover type. These delimited elements were then vectorised. To avoid statistical discrepancies, the minimum polygon size was corrected. After the landscape elements had been digitised in accordance with the classification system, the area in square metres and the perimeter in metres were calculated in the database table for each polygon. Then, polygons smaller than 10 $m^2$ were excluded in order to avoid numeric distortion of the results. Finally, the basic quantitative characteristics of the landscape macrostructure and microstructure were calculated. The tabular data was processed in Microsoft Excel 2003. At final incorporation of graphic data into designs protuberances were overlaid by light exposure for better terrain modelling, which had been calculated based on the azimuth and altitude.

### 3.3 Land covers classification system

With respect to comparability of the Stable Cadastre Maps of 1893 to ortopho aerial pictures of 2006 the Stable Cadastre Maps legend has been used for the purposes of the land cover determination and the subsequent land cover changes analysis. The land cover categories identified in the aerial photographs have been simplified to be compatible with the Stable Cadastre maps legend. The legend of the land covers categories is applicable for both of the basic documents (Tab. 2).

### 3.4 Monitored characteristics

The main monitored characteristics were the absolute abundance of land cover categories in hectares or the abundance ratio in percentage.

### 3.5 The principle of determination of historical elements of land covers ecological stability

The historical elements of ecological stability represent that part of the relatively ecological segments of stability of 1839, which, regardless of the land cover transformations and changes, sustained to 2006 within the individual relatively ecologically stable categories. Technically was determination undertaken by the "intersection" function in ArcGIS software, which identified overlaid areas. By the intersection of the layers of the ecologically stable segments of landscape in the monitored years were determined those ecologically stable elements, which were able to sustain within the monitored period – the historico-ecologically stable segments of landscape. Subsequently, the ratio abundance of these historical segments in the land area of ecologically stable areas for individual monitored years has been calculated. In both time horizons the following types of land covers have been evaluated as the areas relatively ecologically stable: Permanent grasslands, woody vegetation and spring surfaces (at present only to the nature close spring surfaces with considerable abundance of natural vegetation and without their banks or bottoms reinforcements).

## 4 RESULTS

### 4.1 Land cover transformations

Figure no. 3 visually presents the extend of the land cover transformations within the study site area. On the base of the land utilization comparative analysis within the whole territory of the Czech Republic the study site area may be characterized as above the average cultivated (tilled) land (Fig. 4). While in 1839 almost 77 % of the area was utilized as arable land, in 2006 it was only less than 70 %. The main decrease has been identified in permanent grasslands (10.4–4.8 %), in the roads network surface (2.9–2.1 %), and minimally in the area of

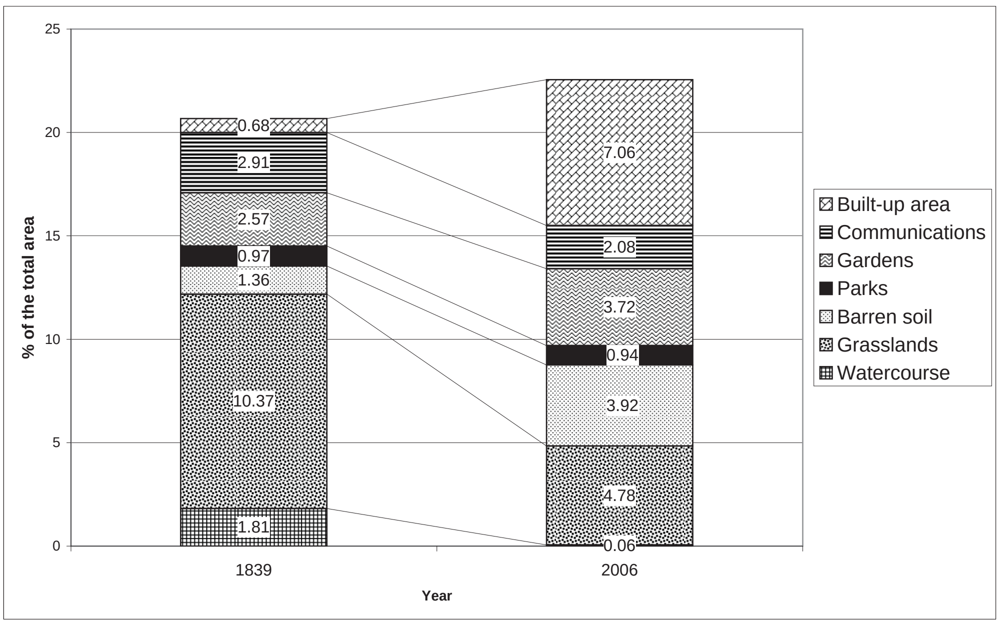


**Fig. 3 Land use changes of the Hrochův Týnec cadastral area between 1839 and 2006 (excluding arable land)**

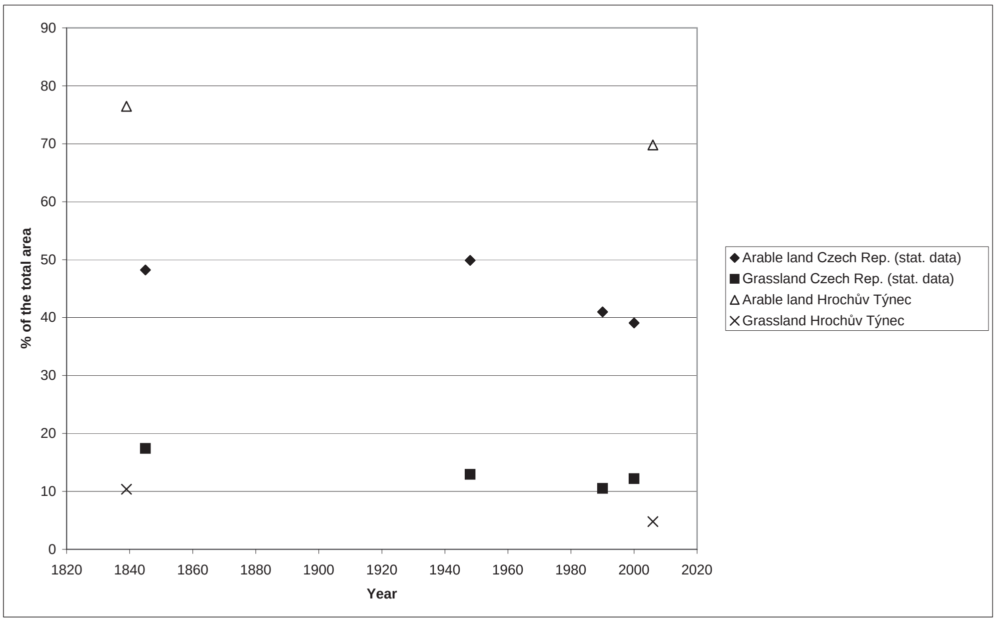


**Fig. 4 Changes in arable land and grasslands – comparison of the official statistics for the whole country to the interpreted data for the Cadastral Area of Hrochův Týnec**

parks (1.0–0.9 %). On the contrary the acreage of the built-up areas within the study site has grown (0.7–7.1 %) and in connection with it also the areas of gardens (2.6–3.7 %) and barren land (1.4–3.9 %) have grown. The percentage abundance of woody vegetation has grown from 2.7 to 6.3 %.

The comparison of the arable land and the permanent grasslands abundance development within the cadastral area of Hrochův Týnec to the development within the Czech Republic has proved the extreme measure of agricultural utilization of the study site. In comparison with the whole territory of the state, the area of study is extremely cultivated. A decreasing trend in abundance of arable land within the cadastral area of Hrochův Týnec is in agreement with the territory of the Czech Republic. The grasslands abundance is of similar trend. The measure of grasslands abundance within the area of the study site is lower than within the total territory of the Czech Republic (Fig. 4).

### 4.2 Historical elements of ecological stability

In 1839, the relatively ecologically stable segments of the landscape covered 15 % (i.e. 86 hectares) of the cadastral area of Hrochův Týnec. In addition, it has been found out that at that time a dominant land cover was represented by vegetation of permanent grasslands (69.1 %). The smallest share in the composition of the ecologically stable landscape ecosystems of Hrochův Týnec was that of water elements (12.7 %). The method has discovered a fall from 15 to 11.2 % in abundance of these elements within the study site (i.e. by more than 20 hectares). The most significant decrease was that of permanent grassland areas (almost by 30 %) and of spring surfaces (by almost 10 %). These changes have resulted into the structural transformation of the relatively stable landscape ecosystems. In 2006, on the contrary, to 1839, the woody vegetation dominated (56 %), the permanent grasslands represented 43 %, and the spring surfaces repeatedly represented the smallest part (almost 1 %) (Tab. 1, 2).

**Tab. 1 Abundance and utilization of the study site ecologically relatively stable areas**

| Ecological stabile areas in 2006 | | | |
|---|---|---|---|
| **Land cover category** | **Area in ha** | **% of the stabile areas** | **% of the cadastral area** |
| Grassland | 27.50 | 42.8 | 4.8 |
| Wood species cover | 36.16 | 56.3 | 6.3 |
| Water areas | 0.57 | 0.9 | 0.1 |
| Total | 64.24 | 100.0 | 11.2 |
| **Ecological stabile areas in 1839** | | | |
| **Land cover category** | **Area in ha** | **% of the stabile areas** | **% of the cadastral area** |
| Grassland | 59.70 | 69.1 | 10.4 |
| Wood species cover | 15.76 | 18.2 | 2.7 |
| Water areas | 10.95 | 12.7 | 1.9 |
| Total | 86.41 | 100.0 | 15.0 |

**Tab. 2 Abundance and utilization of segments of the historical stability**

| Segments of the historical stability in 2006 | | | | | |
|---|---|---|---|---|---|
| **Land cover category** | **Area** | **% of the category** | **% of the cadastral area** | **% of the stabile areas in 1839** | **% of the stabile areas in 2006** |
| Grassland | 9.16 | 31.6 | 1.6 | 10.6 | 14.3 |
| Wood species cover | 19.32 | 66.6 | 3.4 | 22.4 | 30.1 |
| Water areas | 0.53 | 1.8 | 0.1 | 0.6 | 0.8 |
| Total | 29.00 | 100.0 | 5.0 | 33,6 | 45.2 |
| **Segments of the historical stability in 1839** | | | | | |
| **Land cover category** | **Area** | **% of the category** | **% of the cadastral area** | **% of the stabile areas in 1839** | **% of the stabile areas in 2006** |
| Grassland | 17.78 | 61.3 | 3,1 | 20.6 | 27.7 |
| Wood species cover | 2.88 | 9.9 | 0.5 | 3.3 | 4.5 |
| Water areas | 8.35 | 28.8 | 1.5 | 9.7 | 13.0 |
| Total | 29.00 | 100.0 | 5.0 | 33.6 | 45.2 |

The application of presented method has detected that the area of historically relatively ecologically stable ecosystems has covered the surface of 29 hectares. This surface represents 5 % of the cadastral area and equals to approximately 34 % of the surface with relatively ecologically stable landscape segments in 1839 and to 45 % of this surfaces in 2006. In other words, 5 percent of the cadastral area is not only covered by relatively ecologically stable ecosystems, but also these elements have not changed for almost 170 years, sustaining their positive influence – seen from the ecological landscape stability point of view. Results of the work have proved that more than one third of the relatively ecologically stable ecosystems of 1839 has sustained up to 2006. The landscape ecosystems developmental trend is the same. In 1839 the permanent grasslands prevailed (61,3 %, woody vegetation only about 10 %), at present, the woody vegetation prevails (almost 67 % of all relatively ecologically stable areas, which have sustained to present time, permanent grasslands about 32 %) (Tab. 2, Fig. 5, 6).

## 5 DISCUSSION

The results of analysis of the land covers changes within the study site show that the trends of changes in the land covers main categories within the cadastral area of Hrochův Týnec and within the territory of the Czech Republic are of similar kind (arable land abundance decrease, a smaller share of permanent grasslands in 2006 in the contrary to 1839). A higher measure of cultivation and a smaller share of permanent grasslands within the study site in the contrary to the republic mean have been caused by relatively sufficient natural conditions (land types, geomorphology, climate etc.) creating proper conditions for the intensive agricultural utilization of the site, situated the area of the so-called Bohemian Cretaceous Basin (Faltysová, 2002; Vítek, 2002; Novák et al., 1992; Roček, 1926; Štěpán, 2001).

A relatively significant decrease is visible in the abundance of arable land. The arable land has been partly built up (increase in built-up areas from 0.7–7.1 %), or partly replaced by barren land, whose area has enlarged from 1.4 to 3.9 %. The site of the original sugar factory, built up on the plots of arable land in the second half of the 19th century is concerned (Roček, 1926). This sugar factory was closed in connection with the construction of a new, modern one in Hrochův Týnec in 1969 (Chronicle of the Hrochův Týnec municipality, 1958–1973). The arable land has been grown over by woody vegetation as the result of a general desertion of agricultural land. The bigger share of gardens (2.6–3.7 %) naturally accompanying the built-up areas has been connected with enlargement of the built-up areas. Within the period of 1839–2006 the surface of meadows and pasture-land has decreased (10.4–4.8 %), mostly as the consequence of the arable land areas enlargement at the expense of the permanent grasslands, particularly on the flood plains of the Novohradka and Ležák rivers (Fig. 5, 6). The share of the road network surface has decreased (2.9–2.1 %) due to the country roads elimination in relation to the land consolidation within the frame of village collectivisation. Figure no. 3 clearly displays a sharp decrease in the area of water elements (water reservoirs and lakes as well as in the area of watercourse). While the area of water reservoirs and lakes has sustained without any remarkable changes, the area of watercourses has decreased. However, this fact is more the result of the used documents different characters than of a real decrease of water area. While on the Stable Cadastre map, the area of watercourse is displayed and can be detected by GIS, on the present ortophoto aerial photographs the watercourse is hidden and overlaid by treetops of riparian stand and cannot be delimited by GIS accurately. With regard to classification of this type as one of the relatively ecologically stable landscape segments that are analysed as one group, the results have not been misinterpreted. The fact that the watercourse area with its riparian vegetation in the centre of village was not classified as one of the relatively ecologically stable landscape segments in 2006 (it is a part of a built-up area) is another matter in issue of the methodology. In 1839, this area is classified as one of the relatively ecologically stable landscape segments due to a loose character of the built-up area and due to significant vegetation abundance in this part of village. For that reasons the area has not been classified as historically ecologically

**Tab. 3 Classification system for land covers interpretation based on old maps and aerial photographs**

| Category | Description | Commentary | Relatively stable/ unstable |
|---|---|---|---|
| Built-up area | Continuous and non-continuous built-up area (scattered settlement outside the intravilan). | Depending on their character it includes residential built-up areas as well as various technical buildings, yards, storehouse areas, parking places etc. It includes buildings as well as other built-up areas excluding roads. | Unstable |
| Road network | All types of roads. | Paved roads of all classes as well as unpaved ones, so-called country roads, railroads and other road types for specific purposes are concerned. | Unstable |
| Barren land | Unused plots with various land covers and of various utilization. | Plots often have very diversified land covers and the types of land utilization are difficult to be determined. | Unstable |
| Clay pit | Area influenced by clay exploitation. | | Unstable |
| Arable land | Agricultural land utilized as arable land. | It includes large, intensively utilized agricultural lands as well as small sized lands, the so-called croft fields. | Unstable |
| Permanent grassland | All types of permanent grassland. | Permanent grassland utilized by mowing for haymaking as well as pastureland. Various herbaceous vegetation in side ditches or growing on degraded land have been included into the category of barren land. | Stable – it creates the elements of a landscape stability |
| Woody vegetation | Vegetation created by various wood species and woody plants. | Vegetation consists of various wood species and woody plants (trees and bushes) without reference to determination of their function as lands determined for the function of forest, accompanying or scattered green in an open landscape with the exception of large garden areas. | Stable – it creates the elements of a landscape stability |
| Gardens | Gardens areas situated at the outskirts of a continual built-up area, continuously joining the open landscape. | | Unstable |
| Parks | Larger areas of park green inside or on the outskirts of the settlement built-up areas. | | Unstable |
| Orchards | Extensively or intensively utilized areas with the growth of fruit wood species are concerned. | | Unstable |
| Graveyards | The areas of graveyards outside the village intravilan. | Graveyards are characterized by their specific combination of a landscape cover (small part of a built-up area, vegetation of ornamental plants of native as well as introduced woody species. The vegetation aesthetical value is emphasised. | Unstable |
| Playgrounds | Mostly larger areas with a permanent grass cover. | Management intensity and a final state of permanent grassland may vary a lot at these growths. The utilization purpose of the area for relaxation and sports is the determining element. | Unstable |
| Spring surfaces | Includes all the types of water surfaces. | Springs surfaces without regard to their origin, vegetation type or the extend of their banks or bottoms reinforcement. | Stable – it creates the elements of a landscape |
| Streams (watercourses) | The category includes stream surfaces within the study site. | | Unstable |

stable (it is represented by discontinuances of riparian vegetation on the map displaying the structure of ecological stability historical elements (Fig. 6).

Only one third of the relatively ecologically stable areas has sustained up to 2006. It can be explained by the above-mentioned sufficient natural conditions and by the intensive agricultural utilization of the landscape (proved by its above the land average measure of cultivation of the study site and by decreasing share of permanent grasslands). However, the area covered by these historically and ecologically stable elements is relatively large (29 ha) and represents a certain kind of natural potential as well as a reservoir of ecologically stable surfaces. These surfaces cover 45.2 % of the area of the permanent relatively ecologically stable landscape segments. Changes in the structure of land covers historical elements of ecological stability within the period of 1839–2006 are obviously of the same trend as those of relatively ecologically stable landscape segments. While in 1839 the permanent grasslands dominate in the landscape composition (61 %), in 2006 the woody vegetation prevails (66,6 %). Enlargement of the woody vegetation area and decrease in the water elements areas have been caused partly by the fact discussed in the paragraph above, i.e. by the fact that the Stable Cadastre maps do not record the riparian areas at all and on the other side it is impossible to delimit the boundaries of watercourse accurately. Then the results are partly distorted, overestimating the increase of woody vegetation on the one side and underestimating the decrease of watercourses area on the other side.

Determination of the ecological stability historical elements on the grounds of only two time horizons – historical and present ones, offers the information on the absolute dynamics of ecologically significant landscape segments changes, i.e. we obtain data only on the fact that given element was present at a certain site in 1839 and in 2006 but the monitored segment might have been changed even within the given period of time, e.g. the forest vegetation recorded in 1839 could have been cut down and later renewed again (so we identify it repeatedly in 2006). Therefore, this way ascertained information predicates of the absolute dynamics of monitored segments in marginal time horizons but not of their real developmental dynamics.

Other authors have already dealt with this matter in the past (e.g. Brůna et al., 2002; Trpák et al., 2006; Trpák and Trpáková, 2002). Their studies offer valuable information on the given topic, but none of them provides a satisfying amount of specific quantitative characteristics in a sufficiently large scale applied at the interpretation of the basic graphic material. The Stable Cadastre map of 1839, which was used to obtain information on land cover in the past, is a really suitable basis, mainly because of its large scale, geodetical accuracy and spatial extend of its coverage – almost the whole territory of the Czech Republic. The fact the map actually does not display a real state of the landscape (Semotánová, 2002) being just the result of the reality interpretation may become a disputed point. A certain inaccuracy, which occurs in many cases at transformation of raster digital documents into the vector basis, may become another point of difference. Such an inaccuracy when being compared to modern ortophoto aerial photographs at the analysis of the landscape structure changes in GIS may induce false results (due to differences in location of maps and aerial photographs in coordinate system we may detect changes which actually do not exist). The issues of transformation and old map processing in GIS has been discussed in detail by some authors (e.g. Hamre et al., 2007; Domaas, 2005, 2007). Different characters of old maps and aerial photographs may give trouble at identification of identical types of land cover on both of the documents, but such an identification is, for the concept of identical areas time changes analysis, essential. In this study, the problem has been minimalized by application of simplified version of the Stable Cadastre Map Legend for modern aerial photographs. To eliminate the mentioned problems in the future it will be necessary to complete the present-day aerial photographs with the same type of basis graphic documents, e.g. modern cadastral maps, which will be updated by present landscape state mapping. One of the biggest advantages of the aerial photographs is their availability, which makes the final effectiveness of work higher when being measured by the quality of outputs vs. time and financial investments. To elaborate this methodology, the further research on this topic is necessary in the future.

## 6 CONCLUSIONS

Provided the basic preconditions are fulfilled, the method is fully functional and enables to carry out a high quality analysis of ecological landscape stability historical elements. A considerable amount of quantitative data on structure and abundance of historico-ecological landscape stability elements on a sufficiently large scale is the main gain of this method. The basic preconditions necessary to be met for the methodology right utility are following:

- Properly selected basic documents, mainly old maps, and up-to-date cadastral maps checked and proved by mapping in the landscape. The ortophoto aerial photographs used in this study to gain information on the present state of a landscape turned up not to be a fully suitable material for quality data acquisition if they are used as an individual data basis.
- Properly selected method for the raster data transformation executed with adequate accuracy.
- Good compatibility of land cover classification system legend with both, the historical and the modern maps used as data basis.

With regard to a large scale and a detail the method is applied in, its highest effectiveness is achieved only when the method is applied with smaller areas, i.e. 1–2 (3) cadastral areas. Although nothing limits the use of this method for larger areas, due to a large scale the landscape segments (land cover types) are interpreted on, as well as due to financial and time demands on study which are growing excessively in accordance with the area enlargements the effectivity of work sharply falls down.

The study only deals with the changes of quantitative characteristics of areas (area in hectares and ratio in percentage) but it does not deal with the changes of the quality of monitored land cover types (species composition, vegetation health state, etc.). It means if a certain ecologically stable land cover type had been identified as the segment, which has sustained to present, what means it belongs to a group of ecologically stable segments representing a certain quality in a landscape (no quality changes of this segment in landscape have been studied). If the quality of the area is not being studied we do not detect that the original natural plant species composition of a good quality might have been changed significantly, by what means also the ecological value of the ecosystem fell down (spruce monoculture on new locations, etc.).

The study has proved that within such an intensively utilized landscape of the agricultural type the ratio of ecologically relatively stable areas is rather low (at present they cover about the tenth of the cadastral area size here), and analogically the ratio of historico-ecologically stable segments is equally low within the frame of ecologically stable areas (about one third) as well as within the frame of the whole cadastre (five percent). It means only a small ratio of relatively ecologically stable areas have sustained to present time and the measure of their transformation and change in unstable areas is high. Further, if we conduct a gross comparison of the ecologically stable land covers at present to those in the past (visually only; the quantitative analysis of the landscape microstructure was not the goal of this study), we will discover that in the past these areas were more compact (and covered larger area), they were less fragmented than today.

The results demonstrate quite complicated change dynamics of the ecologically stable land covers but it is not possible to make any conclusions only on the grounds of their total size change. On the one side the total sum of relatively ecologically stable land covers has decreased (from 15 to 11.2 %) of the cadastre area, (i.e. from 86 to 64 ha), on the other hand within the composition of these areas woody vegetation which is generally of a higher quality than permanent grasslands, has grown. Within the study site woody vegetation of all species dominates in the structure of relatively ecologically stable segments (56 %). In the past permanent grasslands, which formed about 70% of the area, represented a dominant stable land cover. The increase in the area of woody vegetation has been caused by riparian vegetation spreading along the springs of Novohradky and Ležák (Fig. 5, 6) and by overgrowing of unused surfaces within the area of a former the so-called old sugar factory in Hrochův Týnec.

The work has proved that woody vegetation not only prevails within the scale of the present ecologically stable landscape elements but it is also a segment of the highest stability in time as it represents the major share of the ecological stability of historically stable elements (almost 67 % ). On the contrary the permanent grasslands are the least ecologically stable elements with a high scale of changes and transformations (probably due to enlargement of the arable land areas by tilling and cultivation of meadows and pasture-land of the floody plains of watercourses, which represented one of the last reservoirs of quality arable land. Woody vegetation is historically stable, particularly due to riparian vegetation along the watercourses, which have not changed much.

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# THE KŘEMŽE BASIN LANDSCAPE CHANGE ANALYSIS AND REVITALIZATION – CASE STUDY BASED ON THE 1827 STABILE CADASTRE MAPS

# ZMĚNY KRAJINY V ANALÝZE MAP STABILNÍHO KATASTRU Z R. 1827 JAKO ZÁKLAD STUDIE REVITALIZACE KRAJINY KŘEMEŽSKÉ KOTLINY

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**Abstract**

The case study of the Landscape Change and Landscape Reformation is the essential part of the General Revitalisation of the Křemže Basin Project (by Daphne Ecological Institute, 2008). The study concentrated in the Křemže Basin watershed. Initial goal of the study has included proposal of measures for protection of aesthetic and historical values and to reform the spatial structure. Landscape character, economic use, eco-tourism and traditional state (documented by old maps and in many existing features) were highly respected. The work has been based on processing of the Stabile Cadastre maps (1827), as well as on the historic military maps of the area.

**Abstrakt**

Studie změn krajiny křemežské kotliny a návrhy revitalizačních opatření byly zpracovány jako součást komplexního generelu revitalizace krajiny křemežské kotliny. Rozsah řešeného území byl v rámci celého povodí Křemžského potoka. Cílem studie bylo mj. navrhnout opatření na ochranu a obnovu estetických, kulturně historických a prostorových prvků a struktur, s respektem a při zachování (či obnově) daného charakteru krajiny, ekonomických toků a ekoturismu a respektování tradičního obrazu krajiny, daného a dokumentovaného starými mapami. Práce byla založena na analýze území podle map stabilního katastru (1827) a na analýze historických vojenských map.

**Keywords:** landscape change, development and revitalization, stabile cadastre, historic, space forming and aesthetic landscape values

## 1 INTRODUCTION

The Case Study “Landscape Change and Reformation of the Spatial Structure of Křemže Basin”, has been completed as a part of the “General Revitalisation of Křemže Basin Project”, elaborated by the Institute of Applied Ecology Daphne. The extent of the study area concentrated in the central part of the Křemže basin, delineated by Křemžský brook watershed. The aim of the study was to propose the measures for the protection of aesthetic and historic values and for reformation of the landscape spatial structures. Respect was taken to the landscape character, economic use, eco-tourism and to the tradition, all documented by old maps (mainly in the maps of the stabile cadastre from 1827) as well as by many existing features.

A comprehensive output of the study reflects the analyses of the landscape change research that was done on the stabile cadastre basis, and used for standard landscape analyses and survey. The results have been summarized in the evaluation of territory, by mapping and in final processing of proposals for rehabilitation (improving or better the maintaining of existing state), as far as cultural-historical and aesthetic values are concerned. The final result is in form of a text and graphical part, drawn in using GIS technologies in basic maps and orthophoto maps (1 : 25 000 and 1 : 10 000 scales). Now available in the administration centre of the Protected Landscape Area Management Office, Blanský Forest, Agency for Nature Conservation and Landscape Protection of the Czech Republic. The study included evaluation of the landscape scene (in the final graphical process using GIS, by Hronovská, 2008). The results have included given evaluation as well as proposals of measures for increasing the aesthetic value, tourism attractiveness of the area, maintaining and strengthening of positive elements of the landscape and proposals to enhance the impression and perception of the landscape.

The stabile cadastre is an exceptional cartographic work; it is our oldest (and the first) map of a modern type, that can be easily and accurately converted to the present maps. For our purposes, however, it especially shows how landscape was utilized historically and before changes, evoked by the economic-technological revolution of the 19$^{th}$ century. It represents a breakthrough work from the present point of view, considering the conditions in which it was coming into existence. The amount and quality of the work is important basis for research work on the environmental grounds of landscape formations. The primary purpose of the stabile cadastre mapping included obtaining an objective basis for land and property taxation. In this aspect it followed the previous partial and less accurate (mostly text ones) papers of tax lists (acquired from 1573) and later the Theresian and Joseph rustic cadastres. Joseph the II. Tax reform of 1789 introduced the term cadastral units, whose delimitation is largely valid until present time.

In the early 19th century the development of surveying technologies and topographical display systems enabled creation of a map work, whose importance can be found in the fact it widely exceeds the frame of fiscal finality. Everything is measured there; both fertile and barren, rustic and demesne (then) land, in a perfect mosaic with naming specific types and usage: forests (divided into coniferous, deciduous and mixed ones, in 4 categories of height instead of age), ornamental and vegetable gardens, parks, vineyards, hop-gardens, dry and wet meadows, meadows with fruit trees, private and municipal pastures, marshes, reeds, arable land, arable land with fruit trees, various undergrowth, barns, quarries, sand pits, clay pits, moors, lakes, ponds, rivers, brooks, waste lands and barren rocks. However, during the work some press signs were omitted and cultures were often simplified. Each plot of land was measured in the map by hair planimeter and its yield (value) classified. The measurement further included public and private objects (divided into stone and wooden ones), ruins, mills, religious objects, post offices, pubs and gamekeeper's lodges. Finally there was a "convention" of marking of various types of boundaries, paths, bridges, line and point phenomena, many of which are still successfully used today, including distinction of lettering in descriptions. A remarkable thing is that the menu does not include allées and lonely trees – they are recorded just as something extra. Measurement of individual map lists was taken, based on a triangulation net and artillery boards. Various points were surveyed by a rule with a dioptre (aperture), either by forward intersection or measuring distance on ray, using a chain 10 fathoms (18.96 m.) long.

Works of stabile cadastre mapping were initiated on a basis of the imperial charter on land tax from 1817. It was clearly stated that measurement was not to serve for the land tax only, but for all sectors of the public administration. Unlike the previous ones, this cadastre was marked as a stabile one, i.e. the tax assessment according to land yield was to be constant for the future, whether yield decreased or increased ("individual hard work was not to be sanctioned"). The cadastral map and the list of land were to be unchanging, consolidation of plots and land layouts were probably not counted with. Apart from the originals, the indication sketches where owners were recorded were also drawn; fair copies were lithographically printed and manuals were colored and described in hand. In addition to the surveying operatum, a written operatum of plots of land, ground plots, summary of cultures and a list of holders were acquired. Cassini's transverse rolling projection of land, modified by Soldner, was chosen as the cartographic projection. The 1 : 2,880 scale was based on a square surface with a side of 40 fathoms (Klaftern) in terrain that corresponded to one Lower Austria acre (Joch) – 5,754.642 $m^2$ (area one man was able to plough in one day). That was represented in the map by a square with a side of one inch (Zoll) $(2.634\ cm \times 2.880)^2$; eq. 5,754.6 $m^2$. This scale one level higher – 1 : 28 800, the so-called Militärmaß was already used before at the 1st military mapping (1763–1787) and indicated a relation of 1 Vienna inch in the map to 400 Vienna fathoms in reality that represented 1,000 quicksteps (1 quickstep = 75.86 cm). Preparation of the triangulation net, training of surveyors, proper mapping, plan metering of areas, written operatum, redrawing, printing and coloring of appropriate number of copies of all 164,357 map lists of the entire Austrian monarchy took, with some breaks, 45 years (1824–1842 in Bohemia). Today, the stabile cadastre especially amazes experts with its breadth, detail perfection and accuracy, with respect to the difficulties and level of the then technology and handling. Well, these cadastral maps were used in updated form still in the second half of the 20th century. It is a work that is literally a basis of our modern mapping. Apart from its remarkable accuracy, it also features classical fineness and nobleness of lines and colors. Despite its long time of processing and hand work to the full extent (from start to completing) it is absolutely uniform. In our study area the measurements took place from 1826 to 1827.

## 2 STUDY AREA

The extent of the study area (of roughly forty three square kilometers) is concentrated in the central part of the Křemže basin, delineated by the Křemžský brook watershed (GPS orientation: 48°57´46.58″ S, 14°11´28.33″ V, 48°52´50.08″ S, 14°21´12.66″ V; 48°53´32.40″ S, 14°14´35.24″ V, 48°56´12.26″ S, 14°19´ 06.34″ V). Area is in the central part of Blanský Les (Protected Landscape Area), north-west of Český Krumlov, in the South Bohemian region. Geomorphological data; Province: Czech highlands, System: IB Šumavská hornatina in I Šumavská soustava (IB-2 Šumavské podhůří, IB-2D-e Křemžská kotlina). Climatic zone relatively warm (Veg. 4), with precipitation slightly under the average (MT5). Area is part of Českokrumlovský biogeographical region, in Hercynian biogeographical subprovince, located in the eastern part of Prachatice highlands and geologically composed of granulites with serpentinite infills. Cambisols, acid cambisols, gleysols, rendzinas and pararendzinas are the most common soils represented, with character rather acidic, stony. Tectonic basin (in the direction north-west to south-east) is sunken (roughly in the central part of the Blanský les) and delineated by characteristic mountainous to hilly ring of Kleť 1084 m, Bulový 953 m, Buglata 832 m, Kluk 741 m, Vysoká Běta 804 m, and other smaller hills. At the basin the terrain is denudated, modeled by erosion and broken into number of stream valleys, with the common southeast inclination towards Vltava valley under the Třísov prehistoric oppidum (La Téne period).

Mountainous type of the landscape in upper parts gradually changes into the agricultural and pastoral landscape. For this region rather high ratio of fruit tree plantations (cherries, apples, pears, walnuts) along the roads, local paths and in the village gardens form an excellent example of the traditional and often so called landscape garden (also adjacent Lhenice landscape). Current landuse is formed by large and medium sized fields, divided by communications and partial remnants of the former path system (documented on the maps of the 1. and 2. military mapping of 18th and 19th centuries), balks and hedges. Forests of cultural Pine with Spruce are newly formed on the slopes in small and medium scale. Yet smaller are the Spruce and Alnus growths along the streams. Oak growths are rare and in the form of dispersed vegetation within the agricultural landscape. Indigenous Beech forests are in relicts in the upper parts of the basin. Wet meadows are the most common grass areas. Arable land often consists of large (formerly collectivized and drained fields) on slopes, often corn monocultures with high erosion impact.

## 3 MATERIALS AND METHODS

Areas of cultures (soil types), both unchanged (solid) and their increase or decrease (by section lines), so that it could be evident from which culture and for which culture benefit the change had taken place, have been distinguished in our study. Similarly the progress of line phenomena (communications and water courses), have been captured too. To get the maximum of these comparisons and for their use in the subsequent landscape rehabilitation, the following manner of graphic presentation in map appendices has been chosen. Most importantly a comparison map scale of 1 : 10 000 had been selected. That corresponds to the highest accuracy of basic topographical maps of 1 : 1 000 and 1 : 2 000. The graphic form of the stabile cadastre enables this scale transformation by reduction. Results of the given evaluation (after converting to a graphic form) are an essential basis for further processing in landscape research and analyses that are predicted and modified based on them. Compilation of the obtained layers (and related terrain data and information) is followed by proposals of measures for recreating the spatial landscape structure.

### 3.1 Source data

The initial goal of our map analyses has been based on processing of the 1827 Imperial prints of the Stabile Cadastre, provided by the File Centre of the Czech Office for Surveying, Mapping and Cadastre in Prague. It has involved scanning of individual map lists, computer processing and trimming edges, composing and geo-referencing to a sheet of a seamless map, fully compatible with the present basic map. That has given rise to a raster map, into which selected line elements (forest boundaries, developments, road networks and water courses) of the (ZM 10) basic map from the traced Zabaged 1 (fundamental basis of geographical data) have been put for comparison. To identify the stabile cadastre phenomena, include them in the digitalized vector map of the current state (Zabaged 1) and evaluate on a quantitative basis, it has been necessary to digitalize (by contouring) the decisive elements, lines and delimitation of cultures of the stabile cadastre. Obtained information had been compared and verified with the maps of historic military mapping to get the whole picture in concern to the paths, roads and water feature systems, as well as the information on the individual trees and thickets within the cultural landscape. The final proposal measures maps (in scale 1 : 25 000 and 1 : 10 000), were processed in GIS, using the basic maps and orthophoto maps as the base (Fig. 4).

### 3.2 Landuse change classification and data processing

*3.2.1 Landscape transformation – projection of selected elements of the stabile cadastre and of the basic map (1 : 25 000, based on line phenomena of the derived state map).* It involves highlighting of only those phenomena that create the basic landscape picture: forest lines, developments, water areas, water courses, paths and roads. Surface phenomena are divided into original (unchanged) ones, their increase and decrease, abandoned paths and changed water courses. The landscape morphology is supported by vertical surveying. For the percentage representation (comparability) of territory it is important that its delimitation includes basin on ridges, in contrast to artificial boundaries of cadastres. It needs to be noted that the available Zabaged 1 version (2000) is not absolutely accurate, either any phenomenon is not recorded at all, or a phenomenon is out of date, especially data on the arable land and permanent grass areas cannot be guaranteed today (e.g. the Podnovoveský pond is filled again). The time has not allowed provide revisions (of the state map work!). Despite that and based on the available data, we can mention the following changes that took place in past 174 years: forest land has increased by 37.16% and reaches nearly a half of the area handled (47.55%). Developed area has increased by 456.11% and although the present total share in the territory area is minimum (3.42%), its share in the open landscape without forests is considerable (6.52%). Although the arable land has increased just by 8.5%, the ratio between it and permanent grass area that was according to the stabile cadastre 1:1.14 (0.77) has decreased by more than half to 1:0.45 (2.185). That means the environmental stability in the open landscape has significantly worsened; not only on a statistical basis. By the look at the results graphical part one sees to what extent land fragmentation has decreased and that balks and rural roads almost disappeared (Fig. 1).

*3.2.2 Stabile cadastre selected elements – projection to the basic map (1 : 10 000).* It concerns reduction of the stabile cadastre (with clear descriptions, delimitation and color of lands, communications, individual objects and their color distinction). Present lines of the forest, developed area, paths, roads and railways have been inserted from the basic map (Zabaged 1). The purpose includes general comparison of these two periods while keeping the legibility of the proper stabile cadastre, more details, more accurate distinction of various categories of permanent grass areas and numbers of plots of land, which is possible by zooming the picture on a computer (Fig. 2).

*3.2.3 Stabile cadastre landuse change – projection to the basic map (1 : 10 000).* It concerns graphical display of changes to the land use, where unchanged use is represented by the color of solid (meadows, pastures only in the stabile cadastre, just meadows elsewhere; dumps in current state only). Changes are represented by color of the original use as a basis of today's use by section lines. Present paths and roads, railways are inserted from the basic map just for orientation; removed paths, new road routes, eradicated water courses (original meanders) and present streams are especially highlighted (Fig. 3).

### 3.3 Analyzed characteristics

All the characteristics analyzed were measured in hectares and transformed into the percentage ratio. That well represents the change in the land use during the past two centuries, increases and/or decreases of the monitored land use categories. As shown in the table of results, the analyzed landuse categories were those (see also the methods above) covered by the 1827 stabile cadastre map of the study area; forests and shrubberies, arable land, meadows, pastures, parks, water areas, developed areas, others (not spec.).

## 4 RESULTS

Environmental stability in open landscape has significantly worsened; not only on a statistical basis, shown in percentage points (for each of the phenomenon) in the table. By the glance at the graphical part is clear to what extent land fragmentation has decreased. The developed area has increased by 556.11% (!), although the present total share in the territory area is at a minimum level (3.42%), its share in the open landscape without forests is more significant (6.52%). The total forest land has increased by 137.16% and reaches nearly a half of the area of the territory under review (47.55%). Although the arable land has increased just by 108.5%, the ratio between it and permanent grass areas that was 1: 1.14 according to the stabile cadastre has decreased by nearly a half to present 1: 0.45. The study proposals of measures to revitalize the area (as seen on the appendices map) reflect the above data with clear design solutions for individual landscape elements analyzed.

Graphical appendices of the results:

- Landscape Reformation Maps; Projection of selected elements of the stabile cadastre and basic map (Fig. 1–3).
- Map of the Landscape Structures Reformation (Fig. 4).

## 5 DISCUSSION

Settlements, habitations and developed premises: According to the area balance, the developed area has increased by 556.11% although the present total share in the territory area is at a minimum level (3.42%), its share in the open landscape without forests is more significant (6.52%), which still does not correspond to the actual visual load (pollution), of the landscape that especially involves the scattered and individual technological development. The recent increase in the family housing developments, experienced by escaping from cities to the country, is not yet included in this work in full (similarly as its aesthetic, urban and social evaluation). The new development does not avoid any of the original settlements; on the contrary, it often tries to find lonely, perspective-exposed locations within the open landscape. It is a wonder that the protected landscape area conditions do not allow more strict regulations that would correspond to its position. The highest development can especially be found in Křemže, then in Holubov, Chlum, Brloh and Nová Ves; rather smaller-scale development includes villages like Krasetín, Mříč and Chmelná. No doubt it is a failure (or rather an absence) of urban plan that should have regulated this extent by more suitable urban planning. In reality the development area is dictated only by the market oriented offer of lands (Chlum). The stabile cadastre records the villages in their primary and pure urban form.

According to the stabile cadastre the forest stands were considerably fragmentary, a persisting result of the previous management with significant wood consumption (building, heating) and especially as a result of forest grazing. That spread along streams upwards, but there were also extensive clearings in the middle of the forests. The following stands were uninterrupted, even though significantly semi-articulated: Kleť mountain complex, more uninterrupted towards the Basin, hilly complexes of Kluk, Švelhán, Skalka and a smaller one of Bory, between Mříčí and Vltava. Other fragmentation especially occupied spurs and individual hills and all forested hillocks in the middle of the Basin as we know today. By the beginning of the 20th century there was a large-scale consolidation of forests. The northwest part of forests (above the Basin) became integrated and closed up with Albertov, Bulový, Vlčí kopec, Buglata and Vysoká Běta. The Kleť complex edges shifted to the Basin but preserved their considerably broken nature. As from the 1930s, the forest increase has been at a minimum level, in some cases there have even been some forest clearance. The stabile cadastre also records the division of forest-tree species into coniferous, deciduous and mixed ones according to the prevailing nature, however, not the height as originally prescribed. The total forest land has increased by 137.16% and reaches nearly a half of the area of the territory under review (47.55%).

Water courses and water basins: The stabile cadastre only records water courses that are bigger and could thus be assigned their own plot numbers. Upper sections of courses and small streams are only recorded as a plot boundary (if formed by them), so a number of small brooks and races (we know from the 1st military mapping) are not recorded at

**Tab. 1 Land use change of the selected categories (from the 1827 stabile cadastre maps) within the past two centuries; results interpreted as % ratio increase or decrease for all the selected categories**

| Area balance of cultures | Stabile cadastre year 1826–1827 | | Zabaged 1 year 2000 | | Increase/ decrease |
|---|---|---|---|---|---|
| **Soil type** | **hectare** | **%** | **hectare** | **%** | **%** |
| Forests and shrubberies | 3,303.13 | 34.67 | 4,530.73 | 47.55 | 137.16 |
| Arable land | 2,832.03 | 29.72 | 3,072.87 | 32.25 | 108.5 |
| Meadows<br>Pastures | 1,945.46<br>1,285.70 | 20.41<br>13.49 | 1,406.72 | 14.76 | 43.53 |
| Gardens and orchards | 24.23 | 0.25 | 1,18.82 | 1.25 | 490.38 |
| Water areas | 78.90 | 0.84 | 55.70 | 0.58 | 70.59 |
| Developed areas | 58.59 | 0.61 | 325.83 | 3.42 | 556.11 |
| Others (not spec.) | 0.52 | 0.01 | 17.97 | 0.19 | |
| Total | 9,528.60 | 100.0 | 9,528.64 | 100.0 | |

all. On the historic maps and stabile cadastre landuse change analysis, though with slightly different aims, it is important to mention Neusiedler landscape study (Draganits, 2008), the analysis of nearby landscape of Záblatí (Brůna and Křováková, 2004) and works of the VUKOZ, v.v.i., GIS Applications department (Mackovčin, 2006). Nevertheless, the original progress of richly winding streams (before regulation) is recorded there. It concerns the Brložský – Křemžský brook (that was virtually regulated in its entire length) from the pass between Bulový and Šibeník (where it is in a natural state) and then the more-or-less natural part is under the Vackův mill up to Křemže, with some short sections up to Dívčí Kámen (where a water cascade was built around 1900 within torrent control measures). Original meanders of Olešnice brook under Brloh pond (the original stream for the upper part, also regulated, is not known) and of lower reaches of Lhotecký, Chlumský and Chmelenský brooks are recorded, too. Though the surface of water basins has decreased (the restored Podnovoveský pond has not been included) so the actual total surface balance is nearly equal. The surface of the Křemže and Bory ponds has slightly decreased and a number of original ponds had been abandoned; a pond at the western edge of Rojšín (1.8 ha) was the largest. Smaller one was at the western edge of Chlum. Other abandoned small ponds were rather of a landscape importance only; a small "lake" on the way from Pasíčka to Bohouškovice, two small ponds south and north of Chmelná (the small pond deeper in the forest is new one) and between forests southwest of Vinná. Both nice ponds at Lesák (above Bohouškovice) are of new date as well as Starostův pond in Křemže (where a small pond at the crossroad next to Agrio development was abandoned).

Agricultural land: The stabile cadastre's advantage (in contrast to present cadastral maps – and this puts it close to topographical maps) is that it uses color to distinguish arable lands, meadows and pastures. If the map is decreased to the scale of 1: 25 000, the alignment and layout of various cultures remind of an organic cellular tissue. There the islands of arable land are nourished by permanent grass areas (with a significant backbone) along the Křemže brook and its tributaries. On the northeast side the arable land reaches up to the forest edges. The southwest part of the Basin was more roughly grassed in places, where the forest spread later. Apart from meadows and pastures, municipal pastures (Gemeinde Weiden, which were the lands for free pasture of livestock, similarly as pasture in forests) are distinguished there. Grass areas usable with difficulties (such as balks and rural roads) were included. This traditional free territory was also a subject of tough disputes with the nobility. Deciduous and coniferous growths and thickets are often recorded to be present on meadows and pastures; however, we do not know their density and accurate locations. Although the arable land has increased just by 8.5%, the ratio between it and permanent grass areas was 1:1.14. According to the stabile cadastre it has decreased by nearly a half to present 1:0.45.

That means the environmental stability has significantly worsened in the open landscape; not just on a statistical basis, but simply by looking at the graphical part one can instantly see to which extent the landscape fragmentation has decreased or how most balks and rural roads (with usual side vegetation) totally disappeared. The most significant result proposal of a measure thus must involve direct and (with respect to the processing scale) unusually detailed measures of vegetation treatment with ecological as well as spatial composition functions in the landscape. Especially the proposal of planting local species along minor water courses, other traditional species along the rural roads, main roads and in the open landscape. Individual proposal aspects such as restoration or emphasizing of signposts, vistas, but also partial efforts like stressing architectural dominating features and small religious buildings. New tree solitaires, restoration and provision of areas of linear, group and scattered vegetation are conceived especially where such proposals are realistic, suitable and necessary in terms of reasonable current use of the landscape and management (including suitable species composition, also in regard to local biodiversity enhancement and water runoff prevention). That also concerns the surroundings of farms and other small industry objects at the edge of the newly developing areas.

To reform the traditional spatial landscape structure it has been necessary to respect such elements, techniques and procedures that have been always shaping the traditional agricultural landscapes. Landscape articulation, scale and soft modeling, given by the settlement types and farming procedures (including the contour ploughing practice, steep slopes breakup by balks and linear vegetation etc.) before land reforms does not exist anymore, or is found only in indications and traces (Hendrych, 2008). They are especially represented by terrain indications in landform (roads, balks, small field terraces, dry walls, stony outcrops etc.) and by vegetation remnants such as tree solitaires, linear tree plantings, or naturally dispersed due to the existence of unmanaged terrain features (balks, stone piles, abandoned roads and their edges, etc.). The proposal of reforming of the spatial landscape structure is based on the idea to supplement visually dominant and primarily perceivable features in the landscape scene (Vorel, 2008), that well work together with the other ecological functions of such vegetative structures. They include: linear vegetation elements (allées and tree avenues forming and traditionally enhancing the scale of the landscape), groups (vegetation being a dominant feature in the landscape, breaking down the spatial monotony, emptiness and flatness) or solitaires (dominant figures of trees reforming composition, scale, diversity, variety of colors, structure, mosaic and the esprit and picturesque aesthetics of managed and well farmed landscape). Much of the basin area had been historically owned, traditionally and systematically cultivated as an important part of the Rožmberk estates, later Schwarzenberk dominion. A number of proposals of the submitted study concern new plantings of solitaires, groups and lines along the water courses, paths and road network. The proposals for abandoned country roads restoration are based (where functional and practical) on historical military maps (the 2$^{nd}$ and 3$^{rd}$ military mappings of 18$^{th}$ century) and by verifying this information with the stabile cadastre (Fig. 4).

The study is supplemented by detailed proposals of care for small landscape elements, features and historical structures of the landscape, proposals of observation points, rests and other details in the landscape and measures in various places of interest. Part of the study also includes a proposal of new tourist routes, their interconnection, instructional and educative trails with respect to the cultural-historical nature and aesthetics of the landscape (proposed adjustments of the path network, tourist trails, cycle tracks and instructional trails focused on the cultural landscape observation and the active use of the landscape). Finally the proposal recommends the study for the territorial and land use planning documentation and to other documents, acquired by the municipalities and the region.

The proposal of group planting is based on both analyses of historical maps, identified and documented traces and surviving fragments of the current landscape. The proposed group planting should support the structure in the surroundings of municipalities and serve as high greens in the vicinity of economic premises (agricultural, production, storage areas, parking; as in Rojšín, Nová Ves, Brloh, Chmelná, Mříč, Chlum, Chlumeček, Třísov). The group planting is one of the basic building elements of the open landscape where it is suitable in terms of strengthening the dominant feature, accent, in connection with the restoration of extinct paths and balks. This is important in regard to the water movement within the steep slopes of exploited agricultural land. Total amount of water surface (including much of the wetland areas) lost in past seventeen decades (over 70%) illustrates not only the loss of ponds (some restored lately) but the loss of the landscape water retention capacity (that is in global national scale often documented by periodical floods with often fatal consequences down the streams; 1997, 2002, 2006, 2009). One of the authors of this study has been, to his own surprise at the environmental resort institutions meeting preparing the environmental agenda for the national government environmental strategies, challenged with the theory that wetland restoration causes such a high water evaporation upstream, that prevents the water to feed the downstream watercourses… Loss of pastures and meadows was 43% over the same period; parts were transformed into arable fields during the agricultural reform in second half of the 20th century. The damage (next to the littoral and wetland reductions), caused by the ill landuse planning during the 20th century, was aimed to eradicate the ecologically important narrow stripes of private meadows and pastures, including the balks with scrub or tree thickets. Often on steep slopes, where they served as water runoff barriers. They were designed and created over the centuries, based upon the experience and the traditional art of landscape and terrain prediction. This art should be in the center of interests of any Landscape design strategy as well as the water movement prediction (Hendrych, 2008). Their elimination severely damaged not only the landscape retention capacities, local biodiversity, but the aesthetics and landscape character as well.

The group tree planting is proposed solely with local species. Near settlements, historical premises and gardens there is a preference of traditional species such as cherry (*Prunus cerasus, P. avium*), lime (*Tilia cordata*), apple tree (*Malus domestica*), pear tree (*Pyrus communis*), in the shelter of villages also wallnut (*Juglans regia*). In open landscape sceneries there are forest oak (*Quercus robur*), sycamore (*Acer pseudoplatanus*), maple (*Acer platanoides*), elm-tree (*Ulmus glabra*), small-leaved lime (*Tilia cordata*). Near to forest edges, where the farmland changes to hilly forest straps, there are forest oak, sycamore, maple, birch (*Betula verucosa*) and rowanberry (*Sorbus aucuparia*). The study was not concerned with scrub and brush planting (*Ligustrum vulgare, Rosa canina, Prunus spinosa* etc.), in regard to the general scale of work; also rules out planting of fast-growing species (biomass plantations of poplars, willows, etc.); on the territory of protected landscape area such plantations are not traditional and welcome.

Linear plantings follow the idea of emphasizing and restoring the landscape articulation (mosaic, verticality, structure, spatial diversity), restitution of legible meaning, hierarchy of communications and restoration of traditional functions and amenities of tree company of paths and roads (shade, protection from wind and erosion, catching dust and microscopic particles from air, orientation within the landscape, refuge of birds and animals, etc.). The linear tree plantings are essential topics, reflecting the historical state, traditional scene of the Křemže Basin landscape and the current situation, when alées (fundamental features of the cultural landscape) are threatened as never before. Tree avenues in the landscape remain one of the few possibilities to preserve such significant element of the traditional agricultural landscape (Hendrych, 2008). Within the Křemže basin various tree avenues (often in disconnected lines and of different species and in regard to their original placement) of Oak, Lime, Maple, Birch, Cherry, Apple and Pear trees are prescribed to enhance the road and path system hierarchy, to provide the amenities mentioned. This task is possible also through restoration and maintenance [using traditional and high-quality planting material, suitable technologies and procedures (Tábor, 2003)].

Solitaire plantings serve for the visual break up of large meadows and fields, strengthening the variety, mosaic, richness, dominant and contrast of solitaire scene elements (Hendrych, 2008). The proposal assumes use of selected places (e.g. also near hideous shafts of subsoil drains) and its irregular distribution along the borders of existing and restored roads (also on the principle of the dispersed English alée). Except for planting of alder (*Alnus glutinosa*) stabilizing of banks and bringing visual buffer of straightened stream channels, the traditional landscape dominant features of full-grown tree species of forest oak (*Quercus robur*) and small-leaved lime (*Tilia cordata*) are especially considered along the more important roads. Solitaires are documented in historical maps (2nd and 3rd military mapping) and their locations are usually confirmed by the stabile cadastre (rarely were found yet in the current state, e.g. four forest oaks in the field by Lhotka as the relict of historic balk). It is not a purpose to reconstruct the historical state; rather a compromise and reflection of the possibilities and limits of landscape use and management. The distribution of solitaire (but also group) plantings proposes to plant spatially empty niches along existing and restored roads, ditches (at unsightly features such as the shafts of subsoil drains; here with the strategic potential to help the water runoff slow down on steep and by ill planning drained slopes), for their visual valuation, or screening respectively. In some places it also concerns a significant dominant enhancement of minor architecture and urban structures (planting trees at wayside crosses, village chapels, crossroads, small bridges, etc.), while elsewhere it is simply aesthetic supplementation of an empty and monotonous landscape of reclaimed, toilsome and monoculture fields. Other assets are the enhancements of the harmonious scale, stressing of the necessary dominating features that are visually related to adjacent hills and belts of forested horizons of Kleť, Buglaty, Švelhán and other important peaks. Near range of Šumava massif can be identified as well. Described system of tree avenues, groups and individual solitaires is presented in the graphic form in GIS map (Fig. 4).

The aim of the study included an emphasis on soft and sustainable ways of care and presentation of historic elements of the landscape by interpretation, conservation and by creating their more suitable environment (Hendrych, 2008). That involves emphasizing by vegetation, visually diverting or surrounding negative elements of new disturbing development, etc. In some cases it is necessary to propose a solution of the problem arisen, which might be transfer of an element from a risky location. Generally, all such elements deserve a regular care and maintenance of their environments, from terrain to greens, including historic buildings within; these dominating features have created a primary structures and linkages in the landscape and its settlements (Fladmark, 1991). Their visual appearance is essential (visual corridors). Many buildings (in current developments) use the landscape as picturesque background only, where any spatial connection or dialogue is missing. The landscape has thus become just a frame and its meaning is subordinated to being a coulisse. It creates rather parasitic relation. Landscape suits the interiors, from which panoramic views are framed by over scaled windows. Such a state had been introduced times ago by the Modern movement that in the name of functionality dissolved most of the traditions and principles, cultivated over the long time. Respect, insight and understanding of the aesthetic qualities of nature within the cultivated landscapes were abandoned for machinery of functionally planed developments. Now it peaked at difficult and decisive point of loyalty to basic principles (including the care of inherited values), or of the course of abandonment, with bitter consequences of overall social, cultural and environmental decay; no matter how this process is slowed down in the name of biodiversity and selective species protection. In the fact such protective interests evolved over the time from the holistic appraisal of the nature and its aesthetics (enlightement, romantism), where the complex qualities and values of nature are based on our ability to aesthetically perceive the overall quality of landscape and nature; bird watch, butterfly watch and other particular interests are just peripheral activities to the more important battle on the field of the whole environment issue, including human beings and their quality of life within their livable environment. If we are about to protect the traditional landscapes and its healthy environmental nature, we also need to protect the local and traditional nature of any urban development (Hendrych, 2008); to regulate new buildings and development in the landscape (terrain, form, scale, sizes, materials, etc.). Any builder should be familiar with these principles, limitations and obligations (given by the protection nature of the statutory protected areas of nature and landscape) before drawing plans and implementing the final solution (Fladmark, 1991).

Numbers of identified elements of minor architecture are in very close contact with adjacent communications and operations that threaten them and reduce their spatial qualities. It is necessary to consider their evaluation, conservation or transfer to a more suitable place (features in Třísov, Chmelná). Other elements are in remote places and threatened by unwanted damage or insufficient maintenance. It is necessary to consider their conservation and presentation in the landscape (wayside cross above Brloh near the road directing to Nová Hospoda, cross in Hradiště pod Rojšínem). Apart from the preserved landmarks and other monuments of the prehistoric, medieval and modern reclamation and settlement of the landscape, other landscape dimensions can be seen. We must proceed in care of the landscape story and genius loci that form the comprehensive picture of the landscape. This should be a subject of interest and care, as it can positively influence the relation of people to the landscape, their respect (and esteem) to the landscape, in which they "write" their own life. In the present world this aspect of care is of even greater importance (at the educational and spiritual level). It is important also in regard to the wave of suburbanization of settlements and extinction of their traditional landscape environments. It seems as if principles of new urbanism and of urban transect, based on traditional types of settlement structures, have failed to find their way (not to specifically mention the Křemže Basin) here.

The proposal to interconnect the existing tourist trails within exploring and educational tours aims to better the use of restored roads around Loučej, Chlum, Chmelná, České Chalupy and Rojšín. The topic of the exploring tour includes historical urbanism and settlements (Holašovice, Chmelná, Křemže, Třísov, Rojšín, Brloh, Kuklov, Chvalšiny), with number of intersects to other tourist trails and bicycle lanes; as the UNESCO trail or regional routes. It will also be connected to the exploring trail in the Brloh area and an exploring trail is planned along the Křemže brook. The restoration of old paths will bring aesthetic enhancement to the landscape and to movement within, by just using such trails we may bring their life back again at many places. The anti-erosion function of paths with balks is an important aspect that was taken into account; especially to stabilize slopes, cut down the runoff or break the wind flow in open areas. A number of paths extinct in the past cannot be restored, it would not be purposeful anyhow; the movement of landscape users has fundamentally changed and such paths would remain unused and without maintenance. However, in some places the original road location can be used for connecting the existing or proposed paths and trails. Paths with trees and scrub shall also become temporary refuges and enhance the system of ecological stability in agriculturally exploited land.

The changing land issue and its inevitable consequences, also in the global context (Geist, 2005, 2006; Lambin, 2006) are the hottest themes of our days. Sensitive landscape designing, based on the historic information from old maps, could help to solve many of the arising socio-ecological problems on the local scale, cadastre by cadastre. Common understanding, cooperation and participation within the communities, as well as with a broad spectrum of professionals would help to better perceive and sustain our landscapes. This case study enabled a process of international students of landscape architecture to design with the local community and to be part of the revitalization efforts in Kremže basin. Currently a group of Pennsylvania State University students worked closely with the local communities in Kremže and

Chlum on landscape and urban studies. This learning through the experience (Orland, 2006) extends the results of the case study into instant application in the upcoming land consolidation process. Some of their expertise is based on the very traditional farming practices learned in Iowa, Pennsylvania and Virginia, within local communities of bio-farmers (as are the Sioux City Sue Local Food Network in Woodbury County, Iowa, Polyface Farm in Swoope, Virginia, or small scale family farms in Pennsylvania), whose roots and agricultural techniques are based on, or experienced by the traditional farming practices (good farming practices) of the past centuries, that originated in Europe and were developed over the time without much disturbance. That includes not only organic farming principles, water retention issue, but also the traditional landscape scale protection and soft treatment of the farmed land; principles abandoned by our society after the collective reforms of the land in the past century. Principles that are traceable by the stabile cadastre maps analysis and that should be the essential inspiration for any current landscape and ecological design.

## 6 CONCLUSIONS

- Relevant case studies and detailed projects within the Křemže brook are inevitable next steps, based on the principle of local community support to the complex landscape revitalization (within the ongoing consolidations of plots and land layouts) as well as on the results of the historic maps analyses.
- Project of the General Revitalization of Křemže brook basin by Daphne Ecological Institute will be the acid test of communities, their will to understand and preparedness to follow up such reforms of disturbed landscape that is part of the protected area and should be under more special and strict limitations. It should not be a burden to live in the protected area. It naturally brings responsibility, but it is also a pride, luxury and certain privilege.
- Value of the cultural landscape within the basin is downgraded as much as the aesthetic value of its nature is impaired. The relation between the aesthetic and ecological value clearly reflects and accompanies each other in equal relation. If we lose the landscape aesthetics, we will lose more than a tree; we will lose a culture and in our view the future as well.
- The ecosystem services and such evaluation systems should also include the ecosystem aesthetic and heritage values as its essential part. If we are about to protect the traditional landscapes and its healthy environmental nature, we also need to protect the traditional nature of urban developments.
- The work and proposals submitted are based upon principles, policies and strategies of the sustainable territorial development. The work is a potential basis for setting limits and development possibilities at the level of regional landscape policy, development policies and a land use plan of a large territorial unit, development policies and land use plans of municipalities; their regulations and is a basis for area management on the change of landuse.
- Sensitive landscape designing, based on the historic information from old maps, could help to solve many of the arising ecological problems on the local scale, cadastre by cadastre. Especially when used in the current process of the consolidation of plots and land layouts.
- Everyone dealing with history will like it as much as will fall in love with it. Old chroniclers, including the author of our oldest Kosmas' Bohemian Chronicle, written at the beginning of the 12th century, mention something long ago as a blessed and overjoyed age. In the chronicles, Arcadia is called so. We are captivated by the logical, organic and harmonic organization of the nature and villages whose structures can be looked into in detail through this Work. We do not much realize the primitive and often destitute conditions of the then life such as hunger, epidemics and cruel servitude. The present time cannot be so crystal clear and simple; otherwise we would fail in our life. But let's learn from this picture of the past and endeavor after management close to the nature that is enabled by the new technologies and in a relatively rich society. After all, life modesty and humility would liberate us from the current time commotion and bring us to the simple zest of life and harmony of every well done work.

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# LANDSCAPE CHANGE ANALYSIS OF THE NOVÉ DVORY – ŽEHUŠICE REGION

# ANALÝZA VÝVOJE KULTURNÍ KRAJINY NOVODVORSKA A ŽEHUŠICKA

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**Abstract**

The main goal of the paper is to introduce the results of the research on historical development of cultural landscape, which has been made as a part of the project dealing with the implementation of the European Landscape Convention on the local level. The research has been realized in the area of „Nové Dvory – Kačina Chateau – Žehušice" in the Central Bohemia. The area under investigation represents an excellent example of an intensively utilized agricultural landscape with significant marks of the Baroque and the Classicistic landscape design activities. The paper aims to give a frame overview of the landscape changes within the area of Nové Dvory and Žehušice based on the study of old maps, aerial photographs and archive documentation. The archive documents were used to investigate particularly earlier period up to the mid of the eighteenth century. The landscape changes since the second half of the 18th century have been traced and evaluated up using old military survey maps and aerial photographs.

**Abstrakt**

Hlavním úkolem tohoto příspěvku je představit výsledky studia historického vývoje krajiny, dosažené v rámci výzkumného projektu, jenž se zabývá implementací Evropské úmluvy o krajině na lokální úrovni. Výzkum je realizován v území Nových Dvorů – Kačiny – Žehušic ve středních Čechách. Toto území představuje výborný příklad intenzivně zemědělsky obdělávané krajiny se stopami barokních a klasicistních krajinářských úprav. Cílem příspěvku je podat rámcový přehled o vývoji krajiny v okolí Nových Dvorů a Žehušic, zjištěný na základě studia starých map, leteckých snímků a archivních materiálů. Archivní prameny jsou využívány především pro starší období do poloviny 18. století. Vývoj krajiny od poloviny 18. století je hodnocen zejména na základě map vojenských mapování a historických a současných leteckých snímků.

**Keywords:** cultural landscape, periodization, landscape changes, Novodvorsko, Žehušicko, European Landscape Convention

## 1 INTRODUCTION

Monitoring and study of landscape changes and their consequences belong to traditional themes of both geographical and historical researches. Cultural landscape is perceived and understood as both natural and cultural heritage created by natural and anthropogenic processes. The cultural landscape has been changed many times by various human activities during its long-term development. To understand this development is a starting point for understanding the present state of the landscape and for landscape policies.

The cultural landscape represents an integrating object of an interdisciplinary research. The Research of cultural landscape executed in the mind of the European Landscape Convention (ELC) (Council of Europe 2000) needs a complex involvement of a range of different research methods. Our research has been made as a part of the research project of the Ministry of Education of the Czech Republic: *The implementation of the European Landscape Convention in intensively utilised type of agricultural landscape with signs of historical landscape design activities – the pilot study at the Nové Dvory – Kačina area.*

The project serves as the first example of the implementation of the ELC on local level.

The research project has been solved at two institutions: The Silva Tarouca Research Institute for Landscape and Ornamental Gardening, Publ. Res. Inst., in Průhonice and the Faculty of Science of the Charles University in Prague. The paper deals with historical development of the old cultural landscape and its changes in the context of historical, economic and environmental development.

The paper presents our research results collected by historical methods. The archive research has been made; the archive files, the old pictures and maps have been collected, criticized and interpreted. These methods are almost the only possible ones to study the history of the landscape before the second half of the 18th century when the maps of the first military survey were made. However, they are useful for the 19th and 18th centuries landscape history study as well.

The GIS methods were helpful at the analysis of the military surveys maps, the old aerial photographs and the old cadastral maps, but they could not describe the whole reality within the study area. The historical research has been necessary for the study of social conditions and their impacts on the landscape. Of course, we have used the GIS methods for interpretation of the old military maps and aerial photographs too. The paper mainly presents the results of the historical research.

## 2 STUDY AREA

The research has been carried out in the area of Nové Dvory and Žehušice. The area is located in the Central Bohemia, to the east from the former wealth mining town of Kutná Hora (Kuttenberg), which is a part of the UNESCO' s list of the cultural heritage. The model area is situated in the lowland along the lower reaches of the Doubrava and Klejnárka rivers, in the altitude about 200 m a.s.l. (near the river Labe). It represents an intensively utilized agricultural landscape with the landscape matrix formed by large-scale collective open fields and small patches of woods and rural settlements. Although the area has been intensively used for agricultural production, a number of historical landscape structures from 15–19th centuries, as relics of a former landscape design, are among characteristic landscape features increasing its cultural, aesthetic as well as natural values. The area consists of of 21 cadastral units. The total area is 113 square kilometres (Lipský et al., 2008).

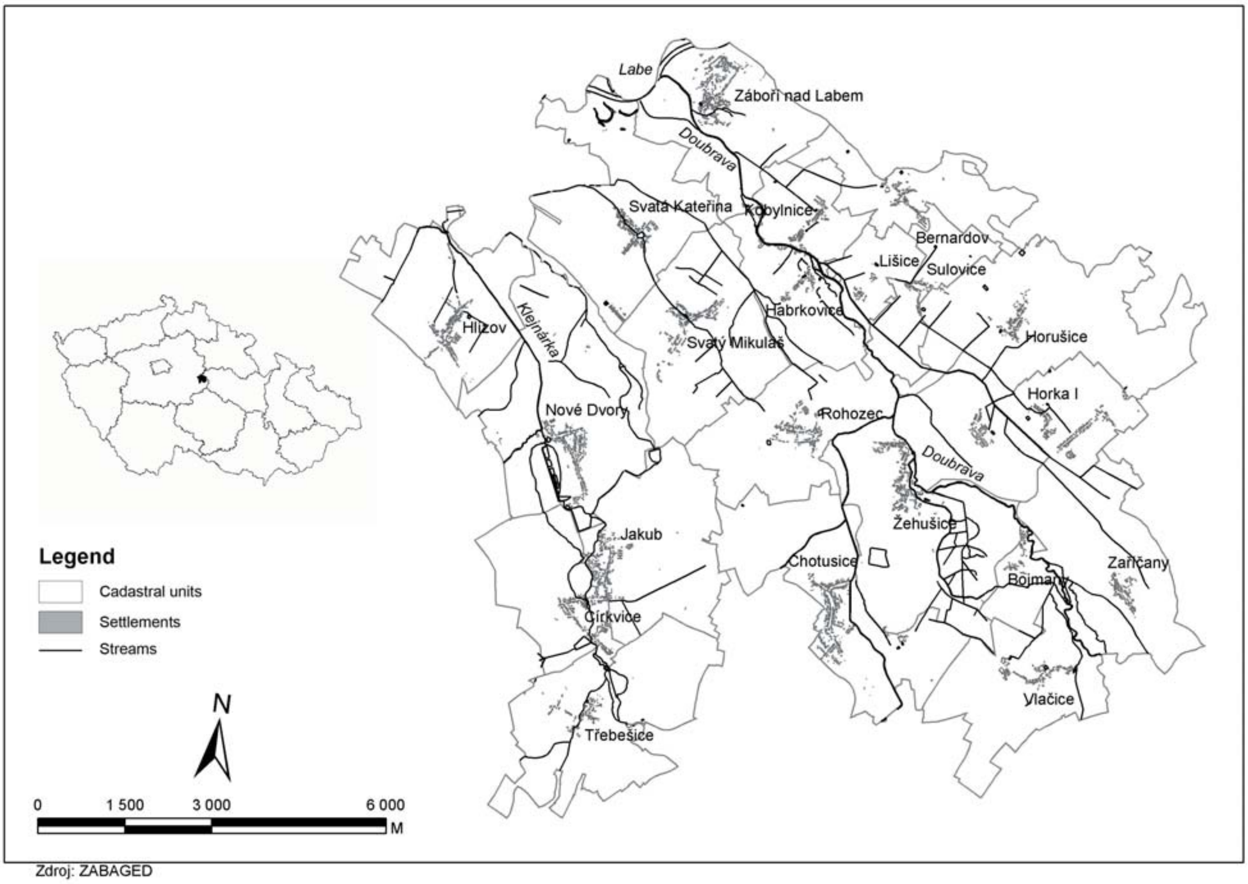



**Fig. 1 The sketch map of the researched area**

**Tab. 1 Cadastral units within the research area (Source: ZABAGED)**

| Name of the cadastral units | Cadastral area (ha) | Name of the cadastral units | Cadastral area (ha) |
|---|---|---|---|
| Bernardov | 345.06 | Nové Dvory | 910.75 |
| Bojmany | 137.77 | Rohozec | 531.71 |
| Církvice | 411.91 | Sulovice | 247.98 |
| Habrkovice | 332.89 | Svatá Kateřina | 717.05 |
| Hlízov | 589,29 | Svatý Mikuláš | 643.76 |
| Horka I | 696.93 | Třebešice | 716.37 |
| Horušice | 850.61 | Vlačice | 525,79 |
| Chotusice | 700.80 | Záboří nad Labem | 563.54 |
| Jakub | 595.07 | Zaříčany | 641.26 |
| Kobylnice | 235.25 | Žehušice | 756.08 |
| Lišice | 172.74 | | |

## 3 METHODS

We have analysed the changes and development of the cultural landscape of the model area from the beginning of its settlement to present days. The used methods have been chosen according to data and their information value. The archaeological and historical research works, old tax lists, old maps and plans, pictures and other archive files have been used.

The major amount of archive data sources are those dating back to 18th and 19th centuries. They are divided into written and non-written sources. The old maps represent the non-written sources and pictures, the written sources are those of the archive files. The researched area files are deposited in the State Regional Archives in Prague and could be divided into institutional and personal. The institutional files are saved in the collections of Velkostatek Nové Dvory (Nové Dvory Manor Farm Estate) (Tywoniak, 1968) and Velkostatek Žehušice (Žehušice Manor Farm Estate) (Roubíček, 1963). The personal files are saved in the collection of Rodinný archiv Chotků (Chotek' s Family Archiv) (Baštář, Tywoniak, 1999). The common methods of the historical research were applied to these files, so we collected the relevant files concerning the landscape and its changes, criticized, compared and interpreted them.

The cadastral files are useful for the investigation of changes in land utilization by population since the second half of the 17th century. The Berní rula (Tax decree, 1653–1655) and The Tereziánský katastr (Cadastre of Maria Theresia, 1757) are at disposal in the modern printed edition (Beneš, 1955; Burdová et al., 1970; Chalupa et al., 1964). The original manuscripts of Josefský katastr (Cadastre of Joseph II, 1780ies) and The Stabilní katastr (Stable Cadaster, 1824–1843) are deposited in The National Archives (Josefský katastr, Stabilní katastr).

The maps of the First Austrian Military Survey (1764–1768, rectified 1780–1783), the maps of the Second Military Survey (1836–1852), the maps of the Third Military Survey (1877–1880), the aerial photographs from the 1950ies, the maps of the General Staff (1953) and the present aerial photographs have been used to investigate the landscape changes in the entire researched area since the second half of the 18th century. The map of the Nové Dvory estate by Jan Glocksperger from 1734 and the maps of the Stable Cadaster have been used for a detailed investigation of the core area. These maps were georeferenced and analyzed using the GIS methods. The detailed handwritten maps of the surrounding of the Kačina Castle from the end of the 18th century and the beginning of the 19th century have been used to investigate the landscape designs by Johann Rudolph Chotek.

The second large group of the non-written sources is represented by old paintings and drawings. We have used the painting of Nové Dvory in the Baroque Age with the magnificent Baroque garden. This painting dates back probably to the first half of the 18th century. Several drawings and graphics from the 19th century show us the landscape of the Classicistic Period, especially the Kalian Castle and its surroundings and pavilions in the landscape. These drawings and paintings have been criticized very strictly and compared to other sources if they depicted the real or only an ideal planned state.

## 4 RESULTS

The landscape under investigation belongs to the most ancient settlement area in Bohemia. During the Late Stone Age (6 000–3 000 BC), the most of the area was settled and people began to change the woody and marshy ground by their agricultural activities. The recent network of seats was formed mainly during the Middle Ages colonization. In 1142/1143 the Cistercian Monastery in Sedlec was founded. As the first Cistercian Monastery in Bohemia, it influenced its surroundings in a significant way. New granges and villages belonging to the monastery were founded there. The large forest of Bor was cleared and marshy ground there was dried. The second part of the 13th and the first half of the 14th century when rich silver mines were discovered near Sedlec were the periods of high importance. A new royal town of- Kutná Hora arose and almost immediately became wealthy and huge peopled. It influenced its surroundings by needs for food and wood. The forests were cleared and farming became more intensive (Novák, 2001; Nožička, 1957).

The mining boom finished at the beginning of the 15th century. At first, the richest mines were exhausted; then, the Hussite (religious) wars flamed out in Bohemia. The monastery of Sedlec was burned out and its estate was seizured by noblemen and by the King Zikmund. The Sedlec Monastery had owned the greatest part of the lands in this area before the Hussite wars, after different noblemen owned that many small estates. Systematically the estates were united in the hands of richer families. The Žerotín family who founded Nové Dvory and Žehušice estates in the second half of the 16th century was the wealthiest. Growing grains, fishery and sheep farming became the most important parts of the economics. Many fish ponds were were built up during the 15th–16th centuries. The artificial water bodies covered more than 10 % of the model area (in the Žehušice estate situated in the alluvial plain along the Doubrava river it was about 30 % of the area) and changed the landscape character of the area completely (Ledr, 1884; Lipský et al., 2008; Novák, 2001).

The Thirty Years War interrupted the economic growth in the first half of the 17th century. After the war, especially the aristocratic economics grew and farms were very rich. The woods went back to the landscape in the form of peasantries and hunting grounds (these woods are mainly preserved until the present, Nožička, 1957). Around Nové Dvory and its castle, a spectacular Baroque garden with flower parterres, alleys and a water channel was built up. The remains of the Baroque landscape, which appearance was mainly worked by Bernard Věžník (1679–1714), still exist (Ledr, 1884; Šantrůčková et al., 2007).

The period of Classicism when Jan Rudolf Chotek (1787–1824) ruled there, was the second very important period, which influenced the character of the landscape. The new castle of Kačina, as a representative seat of the Chotek family, was built up in the Empire style in the central location of the domain, and a large landscape park was founded around it. The park was designed as an ornamental farm and included fields, patches of grasslands, small woods, solitary trees and water bodies. The whole landscape of the estate was designed. New follies were built up to please of the visitors of the park

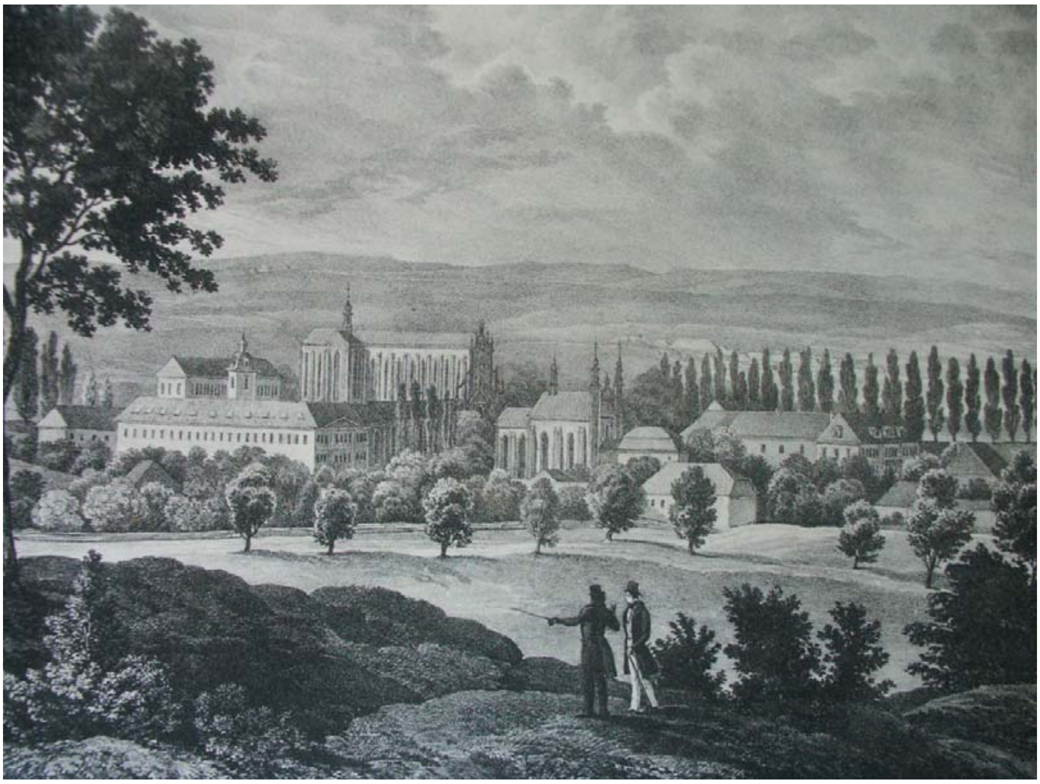


**Fig. 2 The Sedlec Monastery – a medieval centre of culture and colonization of the landscape. The visual effect of the hills on the right side of the stream Vrchlice is not in reality so conspicuous as we could see on this graphics. (Source: National Museum of Agriculture, Kačina, first half of the 19th century, unknown author)**

**Tab. 2 Settled and abandoned homesteads in 1650ies according to the Tax decree (Beneš ed., 1955)**

| Name | Settled Homestead | Abandoned Homesteads |
|---|---|---|
| Bernardov | - | - |
| Bojmany | 5 | 2 |
| Církvice | 7 | 5 |
| Habrkovice | 12 | 5 |
| Hlízov | 12 | 10 |
| Horka | 4 | 3 |
| Horušice | 2 | 0 |
| Chotusice | 16 | 16 |
| Jakub | 4 | 12 |
| Kobylnice | 4 | 6 |
| Lišice | 2 | 6 |
| Nové Dvory + Ovčáry | 3 | 0 |
| Rohozec | 5 | 10 |
| Sulovice | 0 | 5 |
| Svatá Kateřina | 7 | 13 |
| Svatý Mikuláš | 0 | 13 |
| Třebešice | 6 | 0 |
| Vlačice | 3 | 1 |
| Záboří nad Labem | 5 | 13 |
| Zaříčany | 12 | 0 |
| Žehušice | 16 | 10 |
| Σ | **125** | **130** |

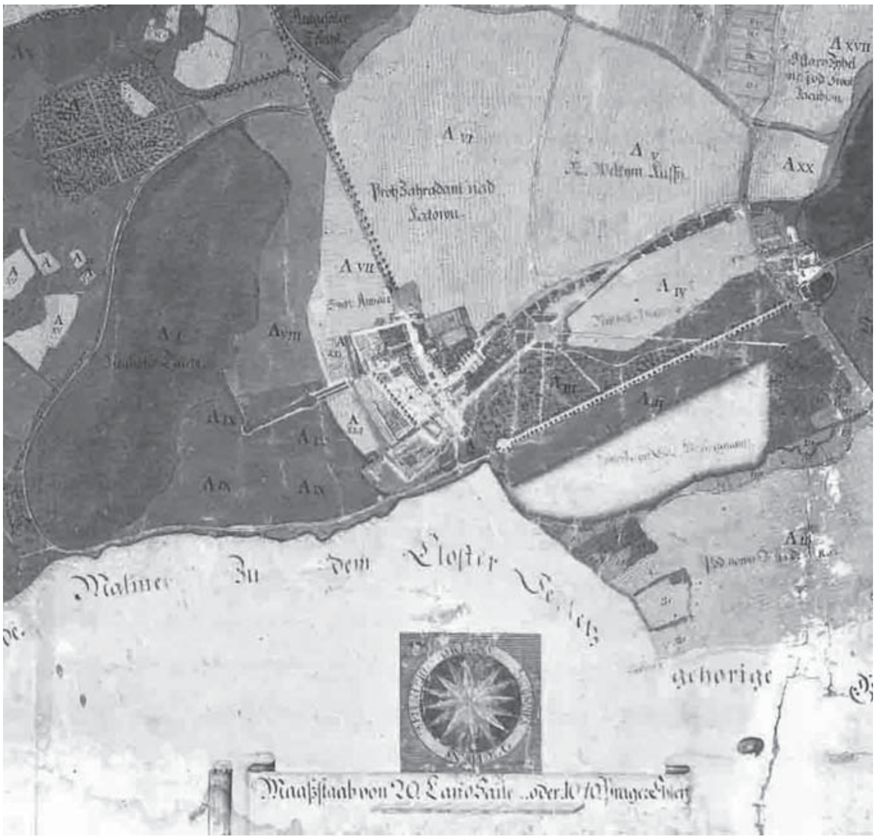


**Fig. 3 Nové Dvory on the Glocksperger´s map from 1734; the map is a unique source of information on the Czech Baroque landscape (Source: National Museum of Agriculture, Kačina, photo J. Vidman, 2007)**

**Fig. 4 The castle of Kačina was a representative seat of Johann Rudolph Chotek and the central point of the designed landscape since the period of Classicism (photo M. Weber, 2006)**

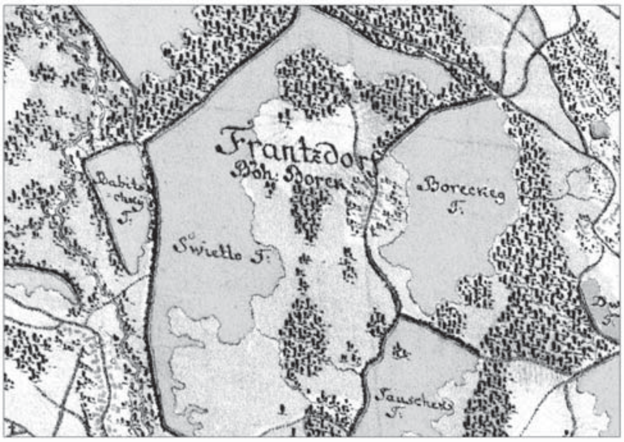
(Flekalová, 2004; Ledr, 1884; Kuthan, Muchka, 1999).

The landscape changed dramatically during the second half of the 19th and 20th centuries (Schaller, 1787; Sommer, 1843). It was connected with economic changes, industrialization, urbanization, later collectivization in the second half of the 20th century. Most fishponds vanished from the landscape within the 19th century. The area of former fishponds and meadows was turned into arable land, which became the largest and the most important land use category. Sugar beet and other supplies for the industry were grown here on rich soils. The law from the 1860ies allowed free inheritance and dividing of rural farms. The land reform in the 1920ies divided the bigger farms among small farmers. Therefore, the fields became very small forming a varied small-scale landscape mosaic (Skaloš et al., 2009). The streams were straightened up and wet meadows dried up (Lipský et al., 2008; Novák, 2001).

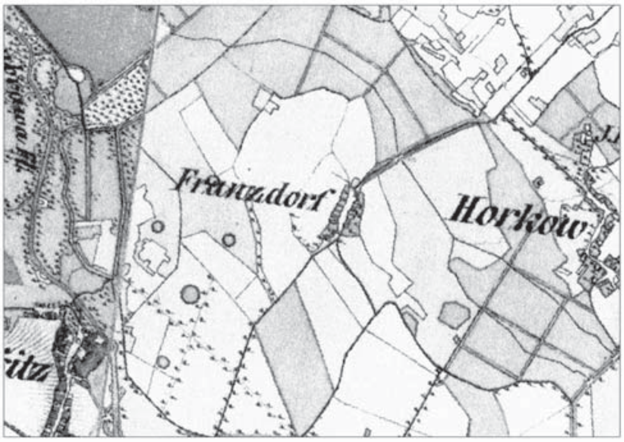
During the communists period in the second part of the 20th century fields were collectivized and united into large plots. The new big farm buildings arose outside of the traditional villages; some of them are still used but some are empty now and falling down. The arable land covers 67 % of the area, while meadows only 2.9 %. New large-scale fruit orchards were founded in some parts of the model area. However, the hard accessible land became overgrown after uniting the fields because heavy machines (Skaloš et al., 2009) could not cultivate them. The streams have been straightened up and man has changed their lines. The biodiversity and ecological stability of the landscape have decreased dramatically since the 1960ies (Lipský et al., 2008). The remains of the former landscape designs are still evident in the present intensively used rural landscape.

According to the sketched landscape history of the Nové Dvory and Žehušice area we can describe 7 periods of its development:

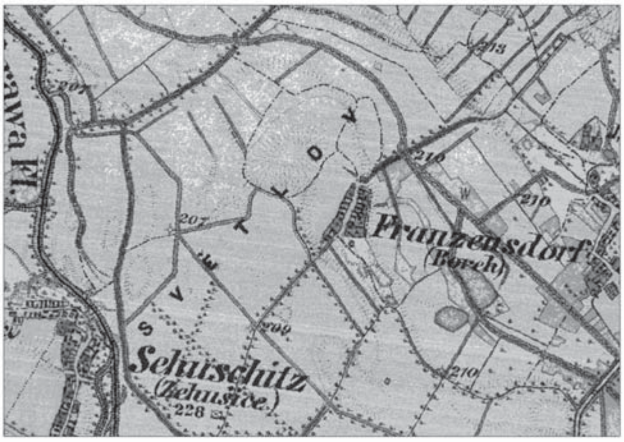
- Until the 12th century: a man influenced landscape only around his dispersed settlements; native forests prevailed in large parts of the landscape.
- From the 12th century to the beginning of the 15th century:




5a) 1st Military Survey from 1764–1768, 1780–1783

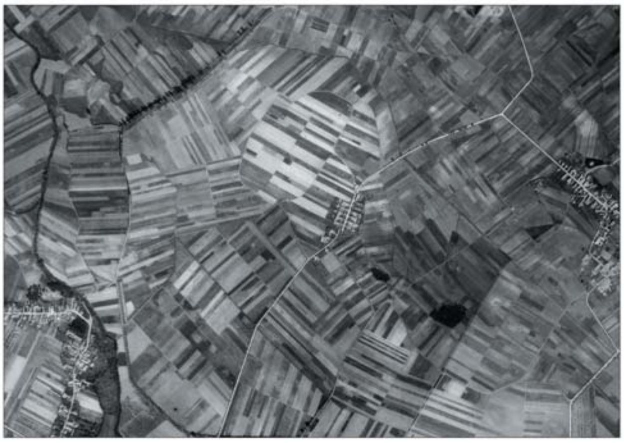



5b) 2nd Military Survey from 1836–1852




5c) 3rd Military Survey from 1877–1880


5d) Topography map of the General staff from 1953



5e) Aerial photograph from 1950

5f) Aerial photograph from 2003

Fig. 5 (a–f) Landscape changes from the second half of the 18th century to the present around the village Borek. Borek was founded in 1711 by Francis count Thun-Hohenstein so it is one of the latest villages in our research area. It was surrounded by large ponds until the end of the 18th century when the ponds were dried up (see the map of the 1st Military Survey). During the 19th century the landscape was intensively agriculturally used, former ponds were changed to the arable land. Fields were small and with small-scale landscape mosaic (see the map of the 2nd Military Survey, the 3rd Military Survey, the Topography map of the General staff and the aerial photograph from the 1950s). The other change happened during the second half of the 20th century due to collectivization and industrialization the the agriculture. Now large-scale landscape of collective openfields cover all research area (see the present aerial photograph). Sources: Ministry of the Environment of the Czech Republic 2003, depon in: VÚKOZ, v.v.i.; Map Collection of the Charles University in Prague, Faculty of Science; Maps from the Geo-Portal of the Czech Environmental Information Agency, CENIA http://geoportal.ceniacz; VGHÚ Dobruška, 2006

**Tab. 3 Development of number of houses in the researched area (Josefský katastr; Sommer, 1843, Chromý et al., 2008)**

| Name | Number of houses according the Cadastre of Joseph II (1780ies) | Number of houses in Sommer 1843 | Number of houses according the Cenzus 2001 |
|---|---|---|---|
| Bernardov | 18 | 33 | 83 |
| Bojmany | 32 | 36 | 46 |
| Církvice | 35 | 64 | 195 |
| Habrkovice | 23 | 28 | 50 |
| Hlízov | 80 | 85 | 154 |
| Horka | 27 | 39 | 59 |
| Horušice | 47 | 50 | 89 |
| Chotusice | 120 | 166 | 257 |
| Jakub | 40 | 60 | 172 |
| Kobylnice | 27 | 32 | 56 |
| Lišice | 12 | 16 | 22 |
| Nové Dvory + Ovčáry | 88 | 96 | 258 |
| Rohozec | 49 | 67 | 123 |
| Sulovice | 24 | 39 | 47 |
| Svatá Kateřina | 43 | 61 | 126 |
| Svatý Mikuláš | 41 | 52 | 135 |
| Třebešice | 38 | 53 | 81 |
| Vlačice | 12 | 13 | 13 |
| Záboří nad Labem | 41 | 50 | 263 |
| Zaříčany | 47 | 58 | 72 |
| Žehušice | 82 | 122 | 164 |
| Σ | **926** | **1,220** | **2,465** |

"medieval colonization" of the landscape, many villages were founded, beginning of intensive farming, silver-mining activities.

- From the 15th century to the beginning of the 17th century: forming of the noblemen's estates of Nové Dvory and Žehušice, large fish pond systems are built up in alluvial plains, sheep farming and farms owned by noblemen.
- From the 17th century to the half of the 19th century: The Baroque and Classicistic landscape designing, peasantries and hunting areas, wood lines and new roads in the landscape.
- From the half of the 19th century to the half of the 20th century: drying up of the ponds and wet meadows, meadows and pastures turned into arable, straightening of water streams, intensive farming on small fields, small-scale rural landscape.
- Since the half of the 20th century (1950ies–1980ies): socialist collectivization, origin of the large-scale landscape of collective open fields, using heavy machines, decrease in biodiversity and ecological stability of the landscape, damaging of former landscape design.
- Present period since the 1990ies: large-scale landscape of collective open fields continues, some huge buildings of large-scale animal husbandry are abandoned, some fallow lands (not too much in this area), landscape forming programmes supporting polyfunctionality of agricultural landscape, planning ecological networks, pressures on lands to build new resident buildings.

These periods are described in detail in the frame of the research and they are one of the starting points for the landscape review in our researched area.

## 5 DISCUSSION

The above-mentioned periods have been formulated for the researched area and its development. It will be very interesting to compare these periods to the periodization of the other localities from the Czech Republic. We can say the most important turning points were events like the medieval colonization, the Hussite wars, the Thirty Years War, industrialization or collectivization that influenced, but local activities were also important and often enhanced the results of these events.

The periodization is not only the result of one of the activities of our research but it is also used as a basis for other activities such as a detailed research of historical changes in river courses and water bodies; land use and land cover changes, changes in landscape character of the model area etc. Other activities of our research are concentrated to detailed study land use and land cover in the 19th and the 20th century. These acticities give precision to our historical research by using the LUCC database (activity 701A01) and by detailed study the land cover on the first, second and third military maps (activity 803A04).

The paper is based on the historical research and on the previous scientific papers too (Ledr, 1884; Novák, 2001; Flekalová, 2004; Nožička, 1957). We have added some new information and proposed the periodization.

## 6 CONCLUSIONS

The above-mentioned periods describe more than one thousand years long development of the cultural landscape, during which the original woody and marshy ground has been was changed to the present intensively used agricultural landscape. The landscape changes resulted in the landscape character changes, which represent the most frequent issue of the recent research works oriented to the practice of landscape protection and planning. The issue of cultural landscape has become a public matter. Knowledge of historical development of the model territory including wider territorial links, determination of evolutional steps and junction points of the landscape development is an important starting point of landscape policies on the local level according to the demands of the European Landscape Convention. The landscape planning and management should respect the continuity of human activities because cultural landscape is a result of long-term naturo-cultural interactions.

The historical methods have been proved useful for this kind of research. We gained information, which we could not gain by GIS methods or any other ones. The older history of the landscape must be studied by the historical research. Moreover, the social events, whose results were depicted on the maps, could be analyzed by them.

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