SPATIAL AND TEMPORAL TRENDS IN LAND-USE CHANGES OF CENTRAL EUROPEAN LANDSCAPES IN THE PAST 170 YEARS: A CASE STUDY FROM THE SOUTH-EASTERN PART OF THE CZECH REPUBLIC

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Abstract

A quantitative evaluation of the dynamics and trends in changes of typical Central European landscapes in the Czech Republic is presented in this paper for the period 1836–2006. This study applied the technology of geographical information systems (GIS) to explore land-use changes using computer-aided analysis of historical and contemporary large-scale topographic maps. The area of study in the south-eastern part of the Czech Republic covers 4,187 sq. km. The analysis of a number of landscape changes from 1836 to 2006 showed that for 56% of the study area, the land-use did not change and thus the landscape remained stable. This quantitative approach, based on computer-aided interpretation of old and contemporary maps, provides valuable results relevant for planning processes and nature conservation for the changing cultural landscapes of Central Europe.T

Shrnutí

Prostorové a časové trendy ve využívání krajiny ve Střední Evropě v posledních 170 letech: případová studie jihovýchodní části České republiky

Článek se zabývá kvantitativním vyhodnocením dynamiky a trendů změn v typických krajinách střední Evropy v období 1836–2006. V práci je použita metoda počítači podporovaného studia historických a současných topografických map v prostředí geografických informačních systémů (GIS). Studované území se nachází v jihovýchodní části České republiky a zaujímá plochu 4 187 km2. Analýza prokázala, že využití krajiny se v období 1836–2006 nezměnilo na 56.0 % plochy a krajinu je tak možné považovat za stabilní. Tento kvantitativní výzkum, založený na počítači podporované analýze starých a současných map poskytuje cenné výsledky využitelné pro krajinné plánování a ochranu přírody v měnících se kulturních krajinách střední Evropy.

Key words: *spatial and temporal analysis of landscape patterns, trends of cultural landscape changes, landscape diversity, landscape stability, land-use, GIS based analysis of historical and contemporary topographic maps*

1. Introduction

Contemporary landscape ecology as an interdisciplinary science between biology and geography focuses on the analysis of spatial and temporal landscape patterns and their relationships to natural and socioeconomic processes. As a scientific discipline, landscape ecology has grown rapidly in recent years, supported by developments in geographical information systems (GIS) and spatial analysis techniques. A variety of ecological questions now requires large regions to be studied and spatial heterogeneity, disturbances, response, landscape changes and landscape stability to be understood (Turner, 1990). This study applied the technology of geographical information systems (GIS) to explore land-use changes using mainly the computer-aided analysis of old and contemporary large-scale topographic maps. Information derived from large scale topographic maps has an advantage in that they show land use spatial distribution together with the landscape micro-texture. Processing in the GIS-milieu enables also the quantitative evaluation of landscape metrics. On the other side, cartographers could over- or underestimate actual values of land-use categories. This type of errors is connected with the

accuracy of map sources and their processing. The aim of this paper is to explore the relationships between land-use spatial patterns and landscape-forming processes of a typical Central European cultural landscape in the last 170 years.

Land use changes are ones of the far-reaching effects of human activities on modern landscapes. Among other things, many of European cultural landscapes have experienced a remarkable change since the early 19th century, particularly during the 20th century (Bender et al., 2005; Bičík et al., 2001; Boltižiar, 2007; Boltižiar, Brůna, Křováková, 2008; Cousins, 2001; Haase et al., 2007; Houghton, 1994; Lipský, 2007; Palang et al., 1998; Petit and Lambin, 2002; Stránská et al., 2008a, 2008b, 2008c; Vuorela et al., 2002).

All landscapes are historically contingent geosystems the structure and dynamics of which reflect continuous modification of pre-existing systems. Data about land-use can be used to discriminate between natural and cultural causes of environmental change. Environmental variability and trends have regional and local components. Land in the south-eastern part of the Czech Republic is used in many different ways, from high-density cities and sprawling suburbs to various types of agriculture and forestry. The changes of land-use reflect complex nature-society interactions and the development of natural environment and human society over time (Boltižiar, Brůna, Křováková, 2008; Žigrai, 2004).

2. Location

The studied area is situated in the south-eastern part of the Czech Republic near the border of Slovakia (map sheets of the Army of the Czech Republic on a scale 1:200 000 M-33-XXX Zlín and M-34-XXV Žilina) and covers an area of 4,187 sq. km (Fig. 1). The area of study is in the southeast and south limited by the

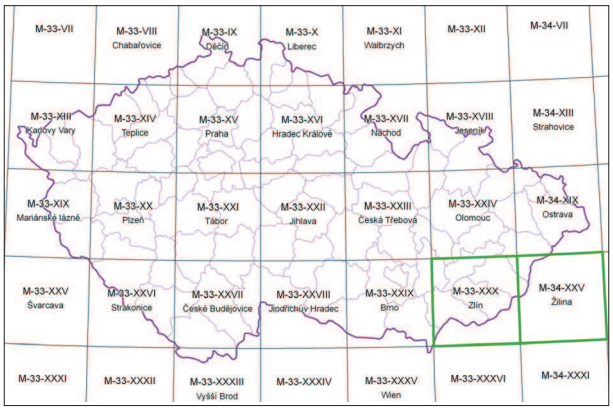


Fig. 1: Study area location (map sheets M-33-XXX Zlín and M-34-XXV Žilina) in the territory of the Czech Republic

border of Slovakia. The northern boundary of the region connects the town of Vyškov in the west, the town of Kroměříž in the middle and the town of Vsetín in the east. The western boundary runs from Vyškov in the north, the town of Bučovice in the middle and the village of Moravská Nová Ves in the south. The north-south axis of the studied area is formed by the middle reach of the Morava River.

In geological terms, the small north-western part of the studied area is formed by the Proterozoic Moravo-Silesian terrane and the southernmost part of the region between the towns of Hodonín and Napajedla is formed by Neogene deposits of the Vienna Basin. A predominant part of the region is composed of Mesozoic and Tertiary rocks of the Outer Western Carpathians with a typical nappe structure (Moravian-Silesian Flysch Carpathians: Stráník et al., 1993). Due to the direction of overthrusting and mostly nearly horizontal overthrust planes, the individual groups of nappes are arranged from the base to the top as follows: the older Magura group of nappes (Rača Unit, Bystrica Unit and White Carpathians Unit) on the top and the younger Outer group of nappes (Pouzdřany Unit, Ždánice Unit, Subsilesian Unit, Zdounky Unit and Silesian Unit) at the base (Chlupáč et al., 2002).

In the front of the Carpathians nappes developed a Neogene Carpathian Foredeep. The great ecological diversity of landscapes in the studied region results from combinations of the underlying patterns of topographic complexity, climatic variability, and environmental history. The great variety of relief types is typical for the studied area – from the plains and lowland hilly land of the Vienna Basin through the piedmont hilly land up to the flysch highlands and mountains on the Slovak border. According to the regional geomorphological division of the Czech Republic, the very small NW corner of the studied area belongs in the geomorphological subunit of Konická vrchovina Highland, classified in the subsystem of Brněnská vrchovina Highland, Province of Česká vysočina (Bohemian Highlands).

The larger part of the studied region is part of the geomorphological province of the Western Carpathians. Between the towns of Vyškov in the west and Holešov in the east, depressions developed in the geomorphological system of the Western Outer Carpathians Depression (Vyškovská brána Gate and the south-eastern part of the Hornomoravský úval Graben).The main part of the studied area belongs in the geomorphological system of the Outer Western Carpathians. The north-eastern part of the territory belongs in the subsystem of the Central Moravian Carpathians. The gentle rounded relief of

the agricultural landscape of Litenčická pahorkatina Hilly land on the uplifted Neogene deposits of the Carpathian Foredeep rises above the depression of the Vyškovská brána Gate. Two forested flysch ridges of the highlands of Ždánický les Forest and Chřiby (Mt. Brdo 586.7 m a.s.l.) form the axis of the Central Moravian Carpathians. The extensive agricultural landscape of the Kyjovská pahorkatina piedmont hilly land with vineyards partially on flysch deposits and partially on Neogene deposits of the Vienna Basin lies more to the south. Forms of disastrous rill and gully soil erosion are common after heavy rains in this subregion (Stehlík, 1954).

The south-eastern part of the studied area belongs geomorphologically to manifold units of the subsystem of the Moravian-Slovak Carpathians, explicitly to the Vizovická vrchovina Highland on the rocks of the older Magura nappe. The highest part and the axis of the Vizovická vrchovina Highland is formed by the forested mountain ridge of the Komonecká hornatina Mts. (Fig. 9). The mountain relief of the Komonecká hornatina Mts. is surrounded by the lower Zlínská vrchovina Highland in the north and by the Luhačovická vrchovina Highland in the south. Transition to the lowlands of the Vienna Basin forms the piedmont of Hlucká pahorkatina Hilly land. On the border with Slovakia is the mountain ridge of the flysch White Carpathians (Mt. Velká Javořina 970.0 m a.s.l.) with typical protected herb-rich meadows (White Carpathians Protected Landscape Area). The Lyský průsmyk Pass divides the White Carpathians from the forested mountain ridges of the Javorníky Mts. (Mt. Malý Javorník 1019.2 m a.s.l.). A part of these flysch mountains is situated in the Protected Landscape area of Beskids. The Walachian type of landscape (fields on mountain slopes) with dispersed farm houses on clearings in fir-beech stands is typical of the Javorníky Mts. Forested ridges of the Hostýnsko-vsetínská hornatina Mts. (a part of the Western Beskids subsystem) rise in the north-east part of the studied region. Slopes of the flysch Carpathians are often deformed by landslides and mud flows (Krejčí, 1944; Záruba, 1938). Föhn-like winds from the White Carpathians cause aeolian soil erosion in the Hlucká pahorkatina Hilly land (Hrádek, Švehlík, 1995). This aeolian soil erosion is emphasised in spring on fields in the vicinity of the villages of Bystřice pod Lopeníkem and Bánov (Nekuda [ed.], 1992). The southern part of the studied region between the town of Napajedla in the north and Hodonín in the south forms a part of Vienna Basin called the South Moravian Basin. The axis of the Basin forms the Dyje-Morava Floodplain (Dyjsko-moravská niva). A part of the floodplain around the Lower Morava River is called the Lower Morava R. Floodplain (Dolnomoravská niva) and is up to 6 km wide (Fig. 10).

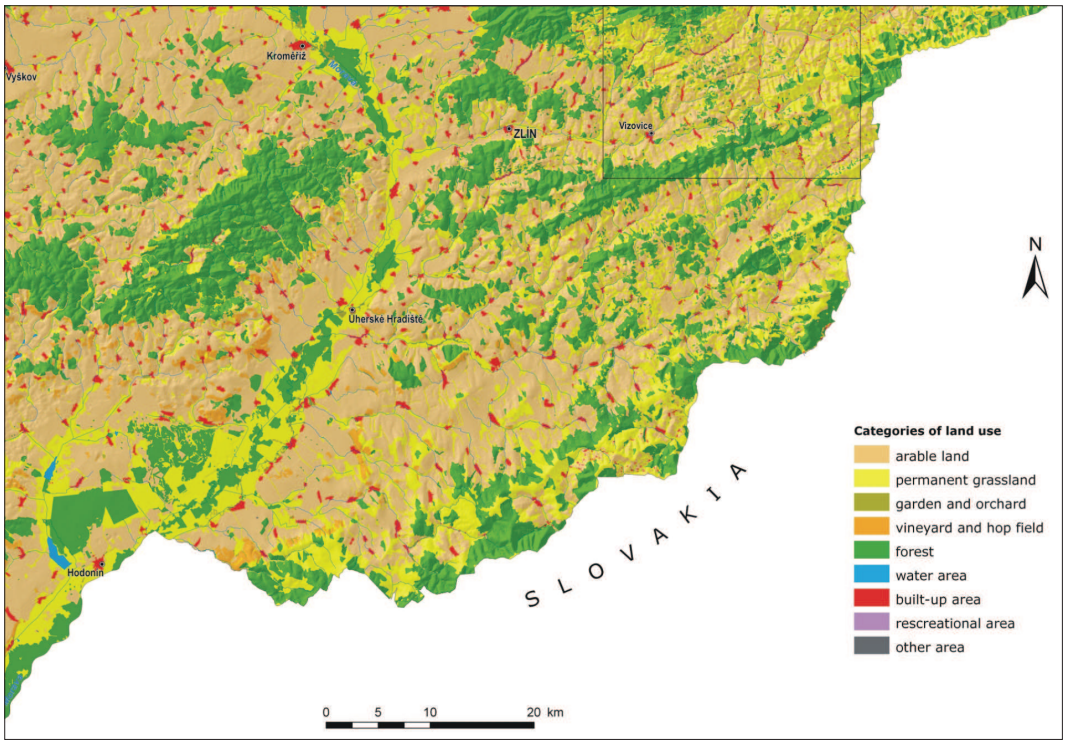


Fig. 2: Basic land-use map sheets M-33-XXX Zlín and M-34-XXV Žilina (1836), covering a part of the Moravian-Silesian Carpathians and the northern part of the Vienna Basin. This general legend is valid also for other basic land-use maps in this paper.
Source: Mackovčin et al., 2011

A typical feature of Southeast Moravia is climatic zoning. The climate is changing from very warm and dry Central European lowland type in the south, through warm climate of piedmont hilly lands up to mild warm climate of highlands and cold and wet climate of the Javorníky Mts. in the north-eastern part of the study region. The relief dissection and the active surface influence the atmospheric boundary layer and the ground layer of the atmosphere in the region.

The studied region drains into the Black Sea and mostly belongs in the Morava River catchment area. Only several watercourses on the Slovak border flow into the Váh River in Slovakia.

Vertical zones are obvious in the soils too. Typical soil types for warm plains and flat hilly lands in the south are black soils (chernozems). Brown soils and luvisols developed in piedmont hilly lands and highlands. Cambisols are soils of dissected highlands and mountains. Fluvisols are typical of floodplains. The whole Lower Morava Floodplain was flooded during the flood disaster in 1997.

The south-western part of the study region belongs to the old settlement areas. The Neanderthals had passed through the region 40,000 years ago. The settlements of Mikulčice and Staré Město u Uherského Hradiště were important centres of the Great Moravian Empire from the 8th to 10th century A.D. The Slavonic Empire collapsed in the early 10th century. Important trade routes followed the Morava River and the Olše River. Major villages were promoted to towns in medieval times, which launched the development of urbanized landscapes. The Slavonic village of Kroměříž in the southern part of the Hornomoravský úval Graben was granted town status in 1260, as well as the village of Holešov in 1272. In the Dolnomoravský úval Graben, the village of Hodonín was promoted to town in 1228, Uherské Hradiště in 1257, Strážnice in 1302, Uherský Ostroh in 1371 and Veselí nad Moravou in 1375. Colonization gradually spread from the core settlement area in the lowlands into the Carpathian highlands and mountains (Peřinka, 1905). In the Vizovická vrchovina Highland, the village of Uherský Brod was promoted to town status in 1272 and Zlín in 1397. At the foot of the Javorníky Mts., the village of Valašské Klobouky became a town in 1356 (Růžková, Škrabal et al., 2006). At the end of the 15th century and during a larger part of the 16th century, the forested frontier flysch mountains were colonized by Walachian pastoral tribes from Romania. Due to new methods of exploiting mountains, the pastoral tribes changed the natural, economic and cultural conditions of the mountain landscapes in the region. Although natural processes are still very much in play in the Flysch Mountains, human impacts connected with the Walachian colonization clearly show in this subregion (type of landscapes with fields on mountain slopes – so-called "kopanice"). Deforestation and grazing accelerated soil erosion and gravitational movements on steep flysch mountain slopes as well as accumulation in the valleys. Anthropogenic landscape changes in Central Europe occurred at several stages within the last 170 years. Characteristic features include acceleration in the sequence of changes, continual increase in the scope and complexity of ecological problems, growing destabilization of natural settlement and a rising proportion of irreversible changes. Great landscape changes took place in the 20th century.

3. Material and methods

3.1 Data acquisition and database

The long-term dynamics of land-use change are important for the evaluation of human impacts on the landscape. This authors' research is based on the computer-aided analysis of land-use changes on historical and contemporary large-scale topographic maps, namely on the

a) historical military maps created for the territory of the Czech Republic by the Austrian Military Geographical Institute in Vienna in 1836–1880 (2nd and 3rd Austrian Military Mapping),
b) post WWII military maps surveyed by the General Staff of the Czechoslovak People's Army and its successor organisation – the General Staff of the Army of the Czech Republic (military mappings 1952–1995), and
c) detailed civil maps 1:10 000 created by the Czech Office for Surveying, Mapping and Cadastre in Prague (Base Maps of the Czech Republic – digital version Zabaged 2002–2006).

Likewise, the continuity of the sources is of great importance. This means several time periods and corresponding landscape conditions must be represented by common attributes that were collected and recorded using a standard procedure. Topographic maps were geo-referenced. GIS processing and digital map creation were carried out using the ESRI ArcGIS 9.3 software.

3.2 Methods

Land-use categories (see Mackovčin, 2009) used in the study are as follows (Tab. 1). The categories are defined as follows:

1. Arable land – this category includes lands used mainly for agricultural production (principally fields with crops);
2. Permanent grassland – mainly meadows and pastures;

3. Garden and orchard – this category includes gardens, orchards, tree nurseries and ornamental gardens, Orchards are vectorized as a separate category outside of residential areas. Vegetable gardens distinguished on the maps from the 2nd Austrian military mapping are vectorized as parts of orchards;
4. Vineyard and hop field – include related objects outside of residential area (e.g. wine cellar, groups of wine cellars);
5. Forest – a large area of land that is densely covered with trees; in this category, the authors included also structures directly related to forestry (e.g. gamekeeper's lodge);
6. Water body – includes fishponds, lakes, water reservoirs, gravel pits filled with water, etc.;
7. Built-up area urban – artificial environment of dwellings as a part of town or city with multi-storey buildings and urban infrastructure;
8. Built-up area rural – connected with small settlements located in the countryside (outside a town or city);
9. Recreational area – land connected with leisure activities (incl. allotments and weekend homes), and
10. Other area – this category includes unused land, transport structures, mining sites, waste dumps, military objects (outside intravilan), etc.

In order to study the landscape changes, an interdisciplinary approach that integrates landscape ecology and history is vital (Bürgi, Russell, 2001).

Code	Name
1	Arable land
2	Permanent grassland
3	Garden and orchard
4	Vineyard and hop field
5	Forest
6	Water area
7	Built-up area urban
8	Built-up area rural
9	Recreational area
0	Other area

Tab. 1: Categories of land use
Note: For technical reasons, categories 7 and 8 are in the final basic land-use map 1:200 000 mapped together as built-up areas (Mackovčin, 2009). Category 9 –Recreational areas appears first in the post WWII land-use maps

Therefore, the authors studied the landscape changes in GIS milieu in four time periods 1836–1875, 1875–1955, 1950–1990 and 1990–2006.

4. Results

4.1 Landscape structure in the first half of the 19th century

Due to the fact that European landscapes achieved their greatest diversity in pre-industrial times (Antrop, 1997; Bender et al., 2005), it was very important to obtain data that originate from the first

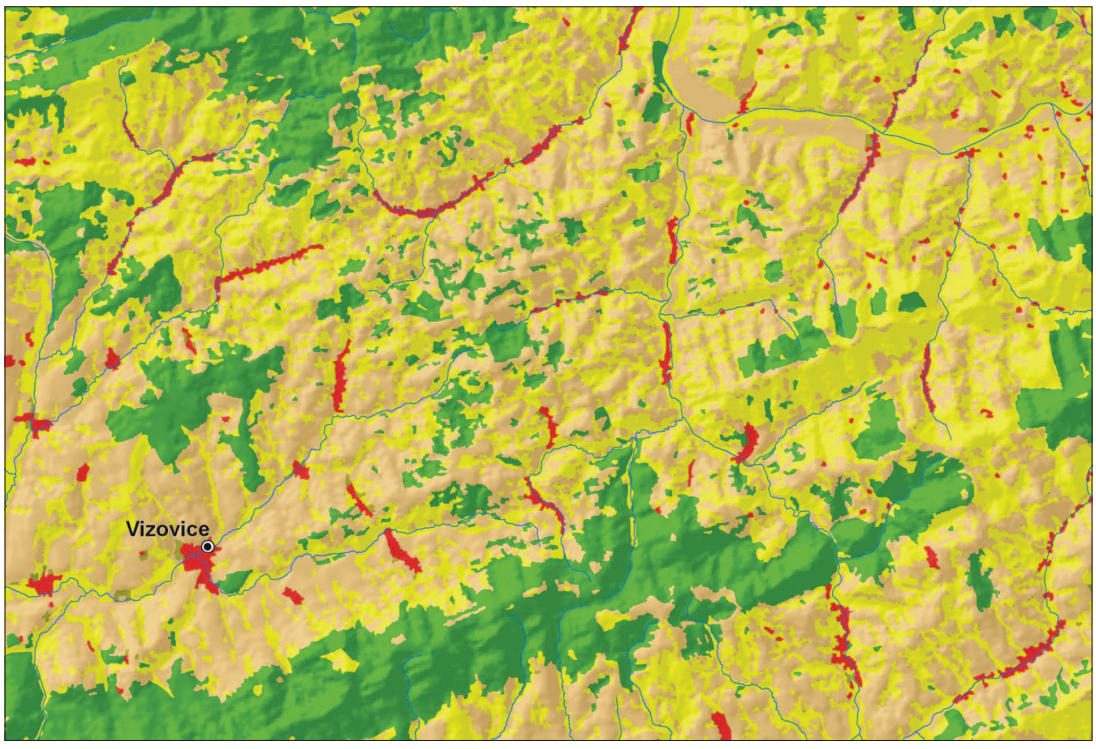


Fig. 3: Example of basic land-use in the Moravian-Silesian Carpathians nearby the town of Vizovice – the situation in 1836. For location of the territory and legend see Fig. 2
Source: Mackovčin et al., 2011

half of the 19th century. The landscape condition and structure in the first half of the 19th century is well represented on the map sheets from the 2nd Austrian Military Mapping. This survey was carried out in Moravia on a scale 1:28 000 in 1836–1841. Map sheets from this mapping already contain the triangulation net and therefore could be geo-referenced and processed in the GIS environment. As an example of the quantitative evaluation of land use based on these maps, the authors present results in Fig. 3 and Tabs. 2a and 2b.

The technical revolution during the 2nd Military Mapping resulted in the demolition of town walls and construction of factories, which resulted in the opening of towns. In about the middle of the 19th century, urbanized landscapes spread into surrounding rural landscapes. The town walls of Uherské Hradiště were already demolished and the newly obtained space was used to create town parks. The growing of sugar beet spread in the lowlands and on the bottoms of dried-out fishponds. Manufacturing in the Napajedla sugar refinery started in 1845 and in Kyjov in 1846. Iron ore (pelosiderite) mining from the flysch deposits began in 1838 and the first blast furnace was constructed in the town of Bojkovice in 1840. Large feudal estates still predominated in the agricultural landscapes. Nearly 70% of the land was devoted to agricultural production.

The trend of drying out fishponds that started after the beginning of the 1st agrarian revolution continued. For instance, fishponds around the village Záhlinice in the Middle Morava River Floodplain were no longer plotted on the maps from the 2nd Military Mapping (Fig. 2). The same occurred with the fishpond in the village Bilany near the town of Kroměříž. Now, during the floods in Kroměříž, waters of the Morava River flooded the Middle Morava R. Floodplain in the section called Bilanské trávníky (Grasslands of

Code	Categories	1836	1876	1956	1990	2006
1	Arable land	1,907.5	2,215.9	2,291.9	1,889.8	1,727.1
2	Permanent grassland	1,010.2	640.3	292.0	373.4	477.0
3	Garden and orchard	19.7	24.5	37.3	68.0	68.0
4	Vineyard and hop field	53.7	41.3	27.7	54.5	38.1
5	Forest	1,089.5	1,153.2	1,317.7	1,430.1	1,475.1
6	Water area	5.3	0.6	6.7	19.3	20.9
7	Built-up area	101.2	111.1	209.8	331.1	354.9
8	Recreational area	–	–	2.1	17.5	22.4
0	Other area	0.2	0.4	2.1	3.6	3.8
Total		**4,187.3**	**4,187.3**	**4,187.3**	**4,187.3**	**4,187.3**

Tab. 2a: Land-use changes in the study area in the period 1836–2006 (km²)
Source: VÚKOZ, v. v. i.

Code	Categories	1836	1876	1956	1990	2006
1	Arable land	45.6	52.9	54.7	45.1	41.3
2	Permanent grassland	24.1	15.3	7.0	8.9	11.4
3	Garden and orchard	0.5	0.6	0.9	1.6	1.6
4	Vineyard and hop field	1.3	1.0	0.7	1.3	0.9
5	Forest	26.0	27.5	31.5	34.2	35.2
6	Water area	0.1	0.0	0.2	0.5	0.5
7	Built-up area	2.4	2.7	5.0	7.9	8.5
8	Recreational area	–	–	0.0	0.4	0.5
0	Other area	0.0	0.0	0.0	0.1	0.1
Total		**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Tab. 2b: Land-use changes in the study area in the period 1836–2006 (%)
Source: VÚKOZ, v. v. i.

Bilany), covered the bottom of drained fishpond, the village green in Bilany and flowed into houses. Two fishponds were drained in the village of Mysločovice in the Tlumačovské vrchy Hills. Also, in the Lower Morava River Floodplain, several fishponds were drained and their beds used for meadow or arable land. On the map from the 2nd Military mapping, no more fishponds are plotted around the town of Strážnice. The Nesyt fishpond near Hodonín (earlier the second largest fishpond in Moravia) was drained too (Fig. 4).

The large unnamed fishpond on the junction of the Kyjovka River with the creeks Hruškovice and Zamazaná was also drained. The same happened to a smaller Mokronovský rybník Fishpond on the Kyjovka R. near the village of Svatobořice-Mistřín. Overleaf the map shows the (Horní) Jarohněvický rybník Fishpond (Jaranowitzer Teich with the area larger than today) and the Písečenský rybník Fishpond (Sand Teich – Fig. 5 – see cover p. 2). The millrace named Mühlbach still runs from the Kyjovka River bed to the mill on the dam of the Jarohněvický rybník Fishpond (Jaranowitzer Teich on the map – Fig. 5 – cover p. 2). However, the Nadýmák fishpond was already drained. Feudal estates were built in place of the former fishponds (Hlavinka and Noháč, 1926, p. 11).

The river pattern in the Lower Morava River Floodplain experienced a substantial change. The main river bed of the Olšava River no more led to the town of Uherské Hradiště, but from the town of Kunovice to the west and then parallel with the main Morava River bed to the south (contacts Yazoo). Thus, the Olšava R. opened into the Morava R. more to the south in the town of Uherský Ostroh. The Morava R. anastomosed to the south of Hodonín. Although its main channel continued freely to meander, the map showed a system of nicely anastomosing river fleets of the Morava River in the Lower Morava River Floodplain. The pattern of river fleets was a typical feature of the floodplain south of Lanžhot between the river beds of Dyje, Kyjovka and Morava. The overall patterns of the channel network included numerous smaller meandering or straight river fleets that diverted and again re-joined the main channels of the Morava and Dyje rivers and/or in some cases crossed the floodplain and connected the channels of the two main rivers. The higher flood activity on the Morava River is recorded in the decade of 1831–1840 (Brázdil et al., 2011).

The bed of the Kyjovka River led from the Písečenský rybník Fishpond towards the village of Mikulčice when the large Nesyt fishpond was drained and the fishpond bed was converted into arable land and meadows (Figs. 4 and 5). The Kyjovka River followed the western border of the floodplain to the south and fed into the Dyje River (Figs. 4 and 5). The degree of connectivity in the floodplains of south-eastern Moravia was still very high in this period.

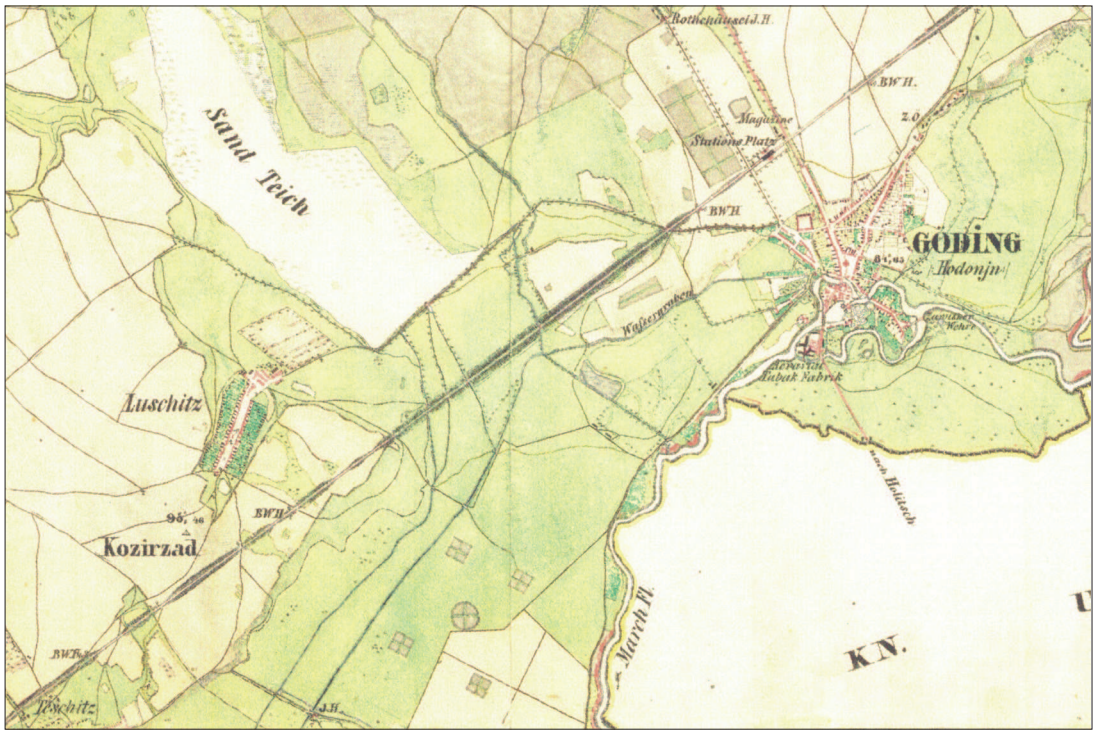


Fig. 4: The Lower Morava River Floodplain near the town of Hodonín on the map from the 2nd Austrian Military mapping in 1838. The large Nesyt fishpond was already drained, the Kyjovka River was flowing parallel with the Morava River and joined the Dyje River. Source: Ministry of the Environment of the Czech Republic

Fallow land farming in agricultural landscapes when farmers kept at least one-third of their arable land temporarily under relatively permanent grass was gradually abolished.

Maps of the 2nd Military Mapping show the beginning of reforestation of drift sands on the territory to the south of Bzenec (Dúbrava, Doubrava) that was launched in 1823 (Vitásek, 1942, p. 1).

The Northern Railway of the Austrian Emperor Ferdinand from Břeclav to Přerov was built in 1838–1841 (Figs. 4 and 5).

4.2 Landscape structure in the second half of the 19th century

During the second half of the 19th century, an entirely new industrial, demographic and transportation system came into existence. The authors used map sheets from the 3rd Austrian Military mapping for the evaluation of landscape development and landscape structure in the second half of the 19thcentury. The 3rd Military Mapping was carried out in the years 1875–1877 in Moravia on a scale 1:25 000. The period between the 2nd and 3rd Military Mapping was a phase of very rapid development of the cultural landscape, which experienced far-reaching changes. For instance, the number of plots showing a land-use change amounted to 22.53% in the Dolnomoravský úval Graben. The continuing agricultural revolution intensified agricultural production based on the increased share of arable land in the landscape (Bičík, Jeleček, Štěpánek, 2001). In this period, total abolition of fallow farming occurred. The share of arable land increased at the expense of permanent grassland (Tabs. 2a and 2b).

From the 1880s, feudal estates and private farmers in the studied area began to concentrate on intensive tillage of better soils, use of agricultural machinery, artificial fertilizers and the introduction of new systems of land management. In lowlands and flat hilly lands, plantations increased of sugar beet, which depleted arable land and gave rise to an increase of not only manuring, but also fertilization with the use of artificial fertilizers. The use of agricultural machinery was spreading. Also the number of sugar refineries was growing.

Agriculture in highlands and mountains, namely in "kopanice" areas (Fig. 6), remained slow. Landscape fragmentation increased due to the Austrian Law on free subdivision of fields from the year 1868.

The share of floodplain forest decreased in floodplains and arable land spread from hilly lands into floodplains. Cessation of natural avulsions, abandonment of many smaller channels and the concentration of discharge into one or two main channels were the main trends in the Morava River channel development in the Middle and Lower Morava River Floodplains in the second half of the 19th century (Grygar et al., 2011).

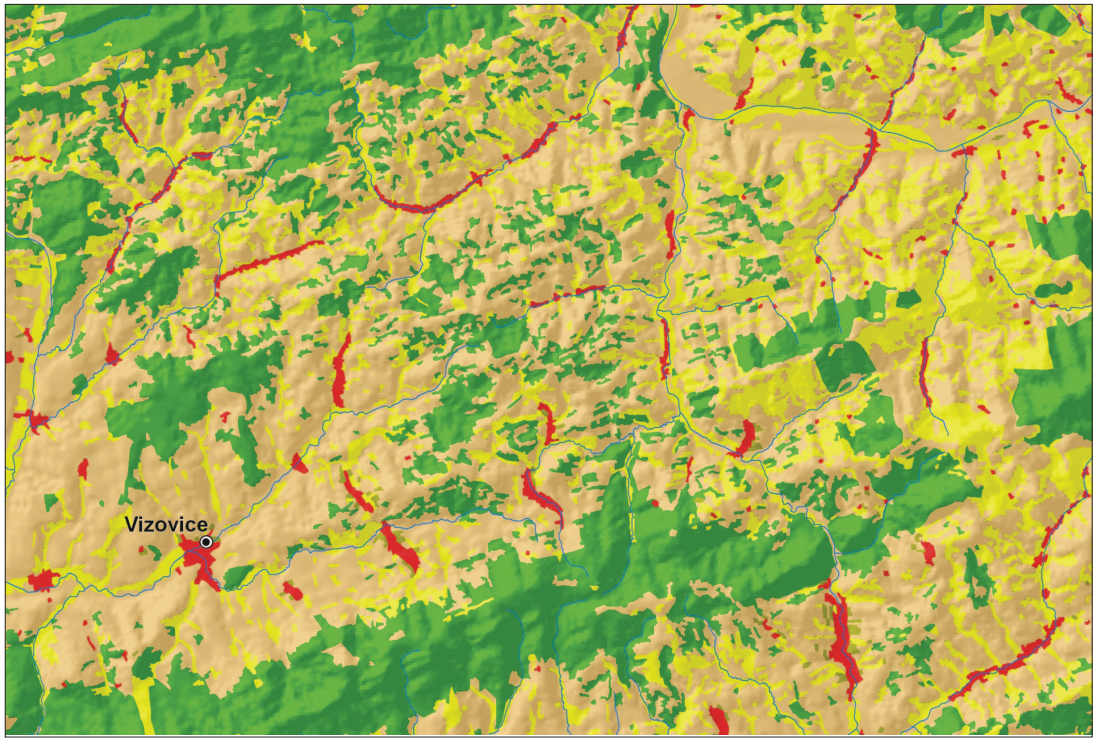


Fig. 6: An example of basic land-use in the Moravian-Silesian Carpathians with the "kopanice" areas nearby Vizovice – the situation in 1876. For location of the territory and legend see Fig. 2
Source: Mackovčin et al., 2011

The trend of draining fishponds further continued. For instance, the share of water areas decreased by about one half in the Dolnomoravský úval Graben (from 1.42% on map sheets from the 2nd Military Mapping to 0.74% on map sheets from the 3rd Military Mapping). The large fishponds (Horní) Jarohněvický rybník and Písečenský rybník were drained in the Kyjovka River valley. The Stonáč Creek channel near the village of Bilany was regulated in the Middle Morava River Floodplain in ca. 1880 (Peřinka, 1911, p. 281). A small fishpond in the village of Sobělice to the southwest of Kroměříž was drained, too.

A severe flood in 1877 caused dam wall breakage on the Bečva River and flooding of the entire Middle Morava River Floodplain. A great flood in the studied area is also reported from 1894 (Peřinka, 1912, p. 577) on the Morava R. in the decade 1891–1900 (Brázdil et al., 2011).

The trend of the spreading of built-up areas was increasing near large towns. The construction of the network of imperial and royal roads was finished in 1850 (Musil, 1987, p. 175) that – together with the growing network of railways – contributed to the fragmentation of landscapes. The above-mentioned Emperor Ferdinand Northern Railway was the main transportation line in the studied area in this period. The Vlára Railway from the city of Brno to the town of Trenčianská Teplá in Slovakia was also constructed in this period. The individual sections received operational status in the following way: 1 April 1883 Kunovice–Uherský Brod, 2 July 1884 Kyjov–Bzenec, 4 June 1887 Bzenec–Kunovice, 10 October 1887 Brno–Kyjov and 28 October 1888 Uherský Brod–Vlárský průsmyk Pass and Trenčianská Teplá in Slovakia. Nevertheless, wagoner services were still used for the local and long-distance transport of goods and mail. The imperial and royal roads were in a relatively good condition; other roads were dusty and not maintained (Nekuda, [ed.], 1992, p. 254). On 8 October 1899, the railway line Otrokovice–Zlín–Vizovice received operational status.

The maps from the 3rd Military Mapping show reforestation in the western part of the area of drift sand dunes (Dúbrava, Doubrava) to the south of the town of Bzenec. The construction of the transport network and the sprawling of settlements required a large amount of construction materials. Many gravel and sand pits were opened in the floodplains. Brick earth (loess, clay) was extracted in the surrounding hilly lands. Construction stones were extracted in many quarries in the flysch highlands and mountains.

4.3 Landscape structure in the first half of the 20th century

There is no coherent set of large-scale topographic maps for studying landscape development in the first half of the 20th century. Czechoslovak authorities mostly carried out the revision of maps from the 3rd Austrian Military Mapping only. In this relatively long period, the land-use of many plots changed (e.g. approximately one quarter of the plots in the Dolnomoravský úval Graben changed their use).

The first Czechoslovak agrarian reform after World War I restricted feudal estates and sold land to small farmers. Thus, a mosaic of small fields formed in rural landscapes. The average size of arable parcels was a few hectares in the first half of the 20th century.

Very high flood activity on the Morava River was reported in the period of 1911–1920 (Brázdil et al., 2011). This is why the Morava River channel regulation was launched in 1906 near the town of Otrokovice and on the lower reaches of its left tributary Dřevnice River in floodplain forests of the southern part of the Middle Morava River Floodplain. Draining of the other part of the Morava R. channel in the southern part of the Hornomoravský úval Graben between the town of Kojetín in the north and the village of Kvasice in the south was launched in 1911 (Peřinka, 1911, p. 5). Then there was stream channel regulation of the Morava River in the Dolnomoravský úval Graben between Napajedla and Lanžhot. The regulation measure shortened the Morava R. bed between these two towns from 82 km to 52 km (Kilianová, 2000, p. 30). The topographic map on a scale 1:75 000 revised in about 1930 shows the river bed regulation of the Morava River and cut-off free meanders between Napajedla and the village of Spytihněv. The river bed was also regulated around the town of Uherské Hradiště. The transformation of the anastomosing system into a single channel meandering system was completed in this period. The regulation considerably reduced the width of the regularly inundated area. Floodplain aggradation reflected the change and the area referred to as distal floodplain was much reduced.

Regulation was also the reason for a rectilinear bed of the Syrovinka River in the western part of the Lower Morava River Floodplain. The bed of the Kyjovka (Stupava) River is also of the artificial origin. This river runs parallel with the main bed of the Morava River. The Bata navigation and irrigation canal was constructed between the village of Sudoměřice and the town of Otrokovice in years 1935–1938.

The river bed of the Dřevnice River was regulated around the Bata Factories in the town of Zlín in the years 1919–1921. In the 1920s, the Olšava River (left tributary of the Morava River) was regulated too. The water reservoir on the Luhačovický potok

Brook situated about 3 km from the Luhačovice Spa was finished in 1930: The topographic map 1:25 000 produced in 1944 shows the beginning of restoration of the Mutěnické rybníky Fishponds.

The area of drift sands (Doubrava) to the south of Bzenec was already completely forested.

The intravilan of settlements was spreading in this period, especially the share of urbanized landscapes increased (see Tabs. 2a and 2b). The regulation of rivers was a trigger for the accelerated development of residential landscapes in the floodplains.

The local railway Kunovice–Staré Město connected the railway lines Břeclav–Přerov and the Vlára railway. The railway line from Veselí nad Moravou–Nové Město nad Váhom in Slovakia was constructed in the period from 1923 to 1928. This railway line connected the south-eastern Moravia with Slovakia. The railway section from the town of Vsetín to the village of Horní Lideč and further to Slovakia was finished in 1937.

4.4 Landscape structure in the second half of the 20th century

A typical feature for the second half of the 20th century is the impact of technological and scientific revolutions on the landscape. The cultural landscape in the studied territory experienced essential changes by changing agricultural practices, housing development and increasing landscape fragmentation. A rapid increase was recorded in the proportion of landscapes that had suffered irreversible change (Bastian, Bernhardt, 1993). After a long break of about 75 years, a new integrated set of large scale topographic maps was published by the Czechoslovak Army in 1952–1955 (S-52).

The second Czechoslovak agrarian reform passed after World War II. Industrialization and collectivization of agriculture was launched after 1955. The structure of agricultural land changed due to land consolidation. The matrix of individual fields disappeared completely. The mosaic of small fields of private farmers was gradually replaced by extensive fields of cooperative farms or state farms. The new single field size was approximately 50–100 hectares. Thus, the intensification and collectivization of agriculture generated a new type of simplified rural landscape, which is apparently less appealing than the traditional one. As a result of the intensification of agricultural production on the one hand, and the retreat of agriculture from unfavourable sites on the other hand, many of the extensively managed traditional land-use systems disappeared. Cropland expanded so much that natural ecosystems started to become rarer. The continued retreat of natural habitats and the growth of cooperative farms greatly simplified the landscape. The landscape simplification led to an increased abundance of crop pests and hence higher use of insecticides. The size of individual field plots grew further during the 1970s in the following wave of land consolidation. A larger part of the dispersed greenery (hedgerows, balks) disappeared from agricultural landscapes due to land consolidation. The removal of dispersed greenery caused consequently the disappearance of traditional medieval field patterns in rural landscapes (Sklenička et al., 2009). Agricultural production reached its peak in this period. The share of arable land decreased (Table 2a and 2b). The share of forested plots increased. Agrochemical inputs into the farmland markedly decreased after 1989.

Differences between the physical environment in towns and villages were largely reduced due to the 2nd Czechoslovak agrarian reform, following industrialization and collectivization of agriculture and the growth of urbanized landscapes sprawling from towns into villages in the second half of the 20th century.

Important features were trends in the restoration and construction of fishponds. The Pláňavský rybník Fishpond (44 hectares) on the left tributary of the Rusava River near the village of Záhlinice (Vlček et al., 1984, p. 217) and small fishponds in the village were restored. The Svárov fishpond (also called Nový rybník) on the Mojena and Rusava Rivers was constructed in 1964. Map S-52 from 1954–1955 shows the restoration of the large (Horní) Jarohněvický rybník Fishpond (150 ha) in the valley of Kyjovka (Stupava) River near the village of Jarohněvice. Downstream on the bed of the former large (Dolní) Jarohněvický (also Brodský) rybník Fishpond, the Mutěnice system of small fish hatchery fishponds was constructed (from the north: Bažantnice, Mlynářka, Srálkovský 11 ha, U křížku, Šilhánek, Hejdovský, Josef, Zbrodský 14 ha, Výtažník, U vrby, Za vrbou). On the bottom of the former large Písečenský rybník Fishpond between the village of Dolní Bojanovice and the town of Hodonín, the Hodonín fishpond system was constructed (from the north: Výtopa 11 ha, Bojanovický 20 ha, Novodvorský 21 ha, Dvorský 28 ha, Komárovský 19 ha, Nad sádkami 9 ha, Lužický 28 ha and the new Písečenský rybník Fishpond 32 ha). The consolidated Czechoslovak military map surveyed in 1991 shows that between the Mutěnice fishpond system and the Hodonín system, large sedimentation basins of the Hodonín power station were situated. This map also shows a new small fishpond situated on the right bank of the right tributary of the Prušánka River downstream of Dolní Bojanovice.

Construction of the Bojkovice water reservoir on the Kolelač Creek was finished in 1966, and the Ludkovice water reservoir on the Ludkovický potok Brook in 1968. The construction of other water reservoirs was finished as follows: Buchlovice (10 ha) on the Dlouhá řeka River in 1969, Ordějov (14.9 ha) on the Bystřička R. near Bánov in 1971, and Slušovice (77.7 ha) on the Dřevnice R. in the Hostýnské vrchy Hills in 1975.

The regulation of watercourses continued, especially in the floodplains of Morava and Dyje rivers (Dyjsko-moravská niva), in response to higher flood activity in the period 1961–1970 (Brázdil et al., 2011). The regulation resulted in disturbed connectivity. Nevertheless, the regulation of the Morava River and its tributaries was not able to protect the Lower Morava River Floodplain from complete inundation during the disastrous flood in 1997 (Demek et al., 2012).

Catastrophic landslides destroyed 12 houses (of 33) on flysch slopes in the village of Maršov near the town of Uherský Brod in 1967 (Nekuda [ed.], 1992, p. 570). The geohazard in this village continues. Extremely high precipitation in 1997 that caused the above-mentioned catastrophic flood caused also the rejuvenation of landslides on slopes of the Moravian-Silesian Carpathians as well as the development of new landslides and mudflows (Krejčí et al., 2002, Demek et al., 2012 b).

The areas of gravel pits flooded with groundwater increased in the Middle Morava and Lower Morava River Floodplain. Large gravel pits developed in the Middle Morava R. Floodplain to the south of the town of Hulín, between Tlumačov and Kvasice and near the town of Otrokovice (Bahňák). Gravel pits flooded with groundwater are situated in the Lower Morava R. Floodplain near Babice, Ostrožská Nová Ves and Moravská Nová Ves (Basic Water Management Map).

In that period, the built-up area began to grow rapidly (Tabs. 2a and 2b). Unfortunately, the residential landscapes in the floodplains were sprawling too. Consolidated Czechoslovak military maps produced in 1990–1992 provide documentary evidence about the rapid growth of urbanized and suburbanized landscapes in the studied area including the growth of this type of landscapes in the floodplains. Urban landscapes became more fragmented during the process of urban development. The growth of recreation landscapes growth can be documented too. The maps also show the growing degree of landscape fragmentation. Deficiency of the set of these maps lies in the underestimated area of permanent grasslands.

Toward the end of the 20th century, the regulation of the Morava River was accomplished (Kirchner and Nováček, 1999), which began to resemble a sewer, namely downstream of the town of Hodonín. Floodplain forests were maintained in the Lower Morava biosphere reserve at the junction of rivers Morava, Dyje and Kyjovka on the border with Slovakia and Austria.

The loss of arable land through rain-wash was increasing in the Dyjsko-moravská pahorkatina Hilly land between the town of Břeclav in the west and the town of Hodonín in the east (Fig. 2).

4.5 Landscape structures at the beginning of the 21st century

The present landscape structure is shown on the raster Base Maps of the Czech Republic 1:10 000 as well as on aerial and satellite photographs. The detailed maps reveal that in the recent decades, urban built-up activities have greatly increased impervious surfaces and resulted in remarkable urban sprawling in the study area. Built-up areas have reached their historical maximum (Tabs. 2a, 2b and Fig. 8).

Agricultural landscapes in lowlands and hilly lands represent a typical mosaic of large blocks of arable land and vineyards presenting the landscape of the study area as a special landscape type in the territory of the Czech Republic. Large blocks of fields of fertile soils from the socialist times still predominate in lowland agricultural landscapes. Another peculiar landscape type represents mountain landscapes with the Walachian type of settlements that extend in the mountainous parts of the White Carpathians and the Javorníky Mts. up to the summits of watershed ridges. The accession of the Czech Republic to the EU in 2004 supports trends to a more intensive use of fertile land in lowlands and to a gradual conversion of less fertile soils in highlands and mountains into permanent grasslands or forests.

A new type of landscape element is represented by large shopping malls with extensive "hardscapes" on the periphery of towns or on important road/highway crossings.

5. Quantitative evaluation of landscape changes

Construction of the sheets of digital land-use maps M-33-XXX Zlín and M-34-XXV Žilina (Czech part) by the public research institute VÚKOZ for the periods 1836–1875, 1875–1955, 1950–1990 enabled quantitative evaluation of landscape changes in the period 1836–2006. GIS enabled the development of digital maps of landscape changes, which were constructed by successively overlaying the four basic temporal layers according to categories of changes, beginning with the oldest layer from 1836.

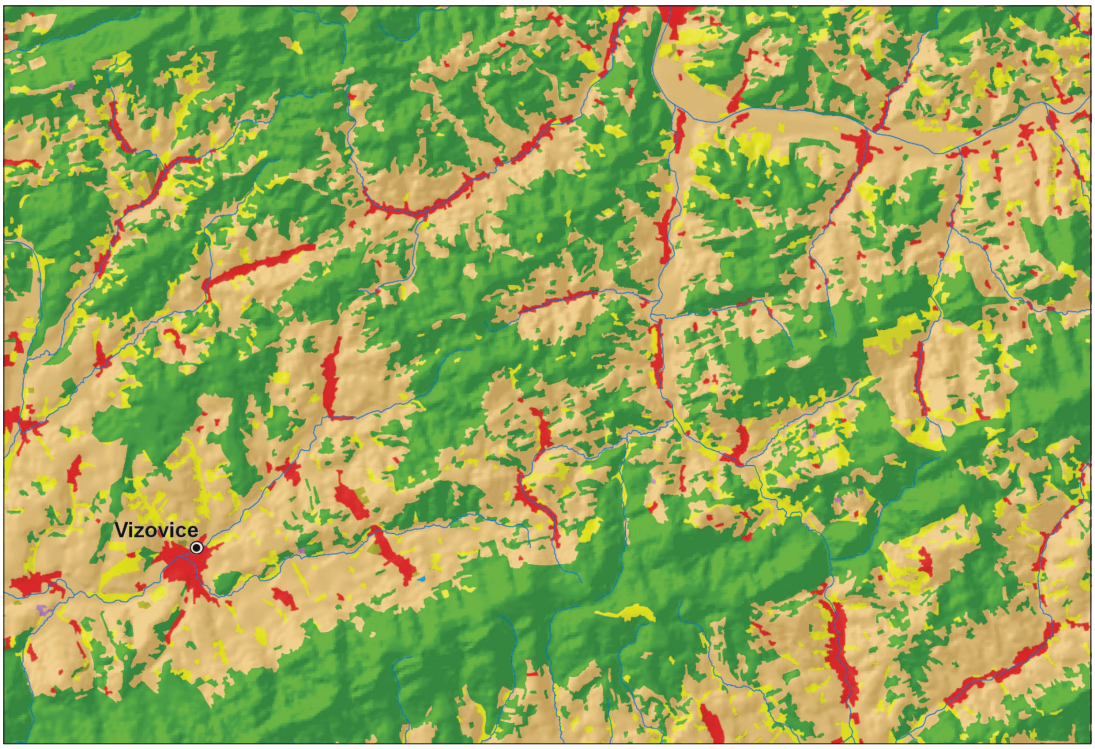


Fig. 7: An example of basic land-use in the Moravian-Silesian Carpathians nearby the town of Vizovice – the situation in 1955 before the collectivisation of agriculture. For location of the territory and legend see Fig. 2
Source: Mackovčin et al., 2011

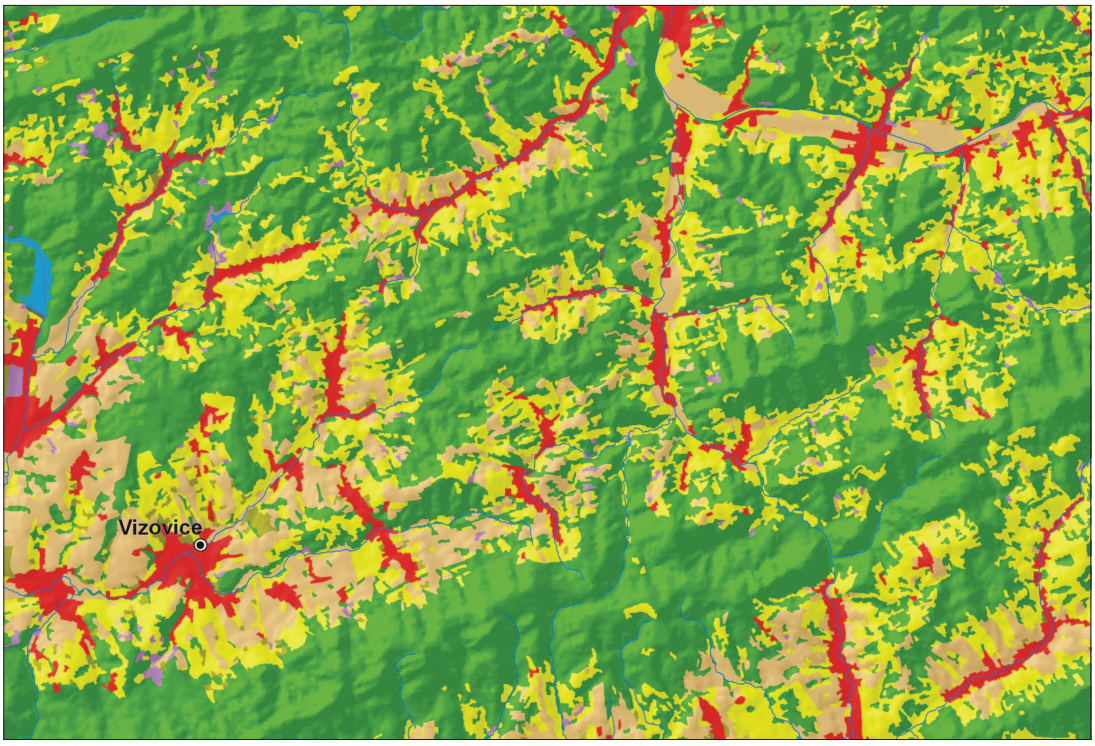


Fig. 8: An example of basic land-use in the Moravian-Silesian Carpathians nearby the town of Vizovice – the situation in 2006. Built-up plots (red) reached their historical maximum. For location of the territory and legend see Fig. 2
Source: Mackovčin et al., 2011

5.1 Landscape metrics

The digital database and the maps enabled a detailed evaluation of the landscape metrics. The following tables show the number of polygons, total area of individual land-use categories in hectares, average area of plots in the respective land-use categories in hectares and the share of the respective land-use categories in percent in four temporal layers.

5.1.1 Landscape structure in 1836

Table 3 shows the largest extent of permanent grasslands and the largest plots of permanent grasslands (24.9 ha) in the studied period 1836–2006.

5.1.2 Landscape structure in 1875

Tab. 4 documents the growing size of arable land as a result of the industrial revolution and the growing number of inhabitants resulting in the growing demand for food.

5.1.3 Landscape structure in 1955

Tab. 5 contains some surprising data. The first is a smaller number of the polygons of arable land despite the fact that the area of arable land was still growing and reached its maximum in the studied period (total area 54.7%) and despite the fact that the topographic maps depict the landscape before the socialist collectivization of agriculture. Also, the number of the polygons of permanent grassland is smaller. These differences could have resulted from the changed topographic map key. The growing number of water bodies is the result of the reconstruction of former drained fishponds and construction of new water reservoirs.

5.1.4 Landscape structure in 1990

The area of arable land is slightly decreasing to 45.1% and the number of polygons is increasing again despite the processes of collectivization of agriculture and formation of large parcels of arable land. The extent of permanent grasslands is slightly increasing.

5.1.5 Landscape structure in 2006

The area of arable land is further decreasing to 41.3% as well as the number of polygons. The area of permanent grassland is again slightly increasing. The area of forested land and built-up areas reached their maximum in the studied period.

5.2 Number of landscape changes in 1836–2006

The computer-aided analysis of the number of landscape changes in the period 1836–2006 showed that land use did not change for 56% of the studied territory (Tab. 8). The analysis showed that some landscapes are more vulnerable to change than the others. Stable areas are forested mountain landscapes around the state border in the White Carpathians and in the Javorníky Mts (Fig. 13 – see cover p. 4). Some changes of land use were registered in the areas of specific Walachian colonization around the village of Starý Hrozenkov in mountain landscapes with alternating meadows and forests. Land use changes are also apparent in landscapes with alternating meadows and forests occurring in piedmont highlands of the White Carpathians (e.g. in the Suchovská vrchovina Highland and Komeňská vrchovina Highland). The forested ridges of the Komonecká hornatina Mts. in the Vizovická vrchovina Highland (Fig. 11), beech stands in the highlands of Ždánický les Forest and in Chřiby are also stable

In the agricultural landscapes of the Vyškovská brána Gate, Hornomoravský úval Graben, Litenčická pahorkatina Hilly land, Hlucká pahorkatina Hilly land and lowlands of the Hornomoravský úval Graben, there are stable plots of arable land sloping up to 5 degrees. Large flats of arable land with agrocoenoses of monocultures dominate on these plots. On the other side, frequent changes of land-use occurred on steeper inclined slopes over time. Indigenous, ecologically stable formations (e.g. fragments of forests, permanent grassland, bush, possibly orchards and vineyards) have been replaced by arable land. More frequent are changes in the landscape of the Mutěnická pahorkatina Hilly land with fields and forests at the foot of the Chřiby Highland. Changes of land-use in the more vulnerable Middle Morava River Floodplain (Fig. 14 – see cover p. 4) and Lower Morava River Floodplain landscapes were very common (up to 4 changes during the above mentioned period – Fig. 10).

5.3 Stable areas in the period 1836–2006

The authors classified the plots that retained the same land-use during the period of 170 years as stable plots. On these plots, the natural conditions were in balance with demands of the human society in the last 170 years.

Categories of land use	Number of polygons	Area (ha)	Average area (ha)	Share on total area (%)
arable land	2,665	190,745.6	71.6	45.6
permanent grassland	4,054	101,016.0	24.9	24.1
garden and orchard	499	1,972.6	4.0	0.5
vineyard and hop field	331	5,374.0	16.2	1.3
forest	1,126	108,954.6	96.8	26.0
water area	59	527.5	8.9	0.1
built-up area	828	10,120.3	12.0	2.4
recreational area	–	–	–	–
other area	13	21.0	1.6	0.0

Tab. 3: Landscape structure of the studied area in 1836

Categories of land use	Number of polygons	Area (ha)	Average area (ha)	Share on total area (%)
arable land	1,736	221,593.7	127.6	52.9
permanent grassland	4,055	64,030.1	15.8	15.3
garden and orchard	575	2,453.1	4.3	0.6
vineyard and hop field	356	4,127.7	11.6	1.0
forest	1,289	115,318.3	89.5	27.5
water area	17	60.0	3.5	0.0
built-up area	901	11,110.3	12.3	2.7
recreational area	–	–	–	–
other area	18	38.4	2.1	0.0

Tab. 4 : Landscape structure of the studied area in 1875

Categories of land use	Number of polygons	Area (ha)	Average area (ha)	Share on total area (%)
arable land	813	229,186.9	281.9	54.7
permanent grassland	2,512	29,196.1	11.6	7.0
garden and orchard	613	3,734.2	6.1	0.9
vineyard and hop field	226	2,772.0	12.3	0.7
forest	1,481	131,769.6	89.0	31.5
water area	76	664.4	8.7	0.2
built-up area	1,137	20,982.0	18.5	5.0
recreational area	68	212.2	3.1	0.0
other area	46	214.2	4.7	0.0

Tab. 5: Landscape structure in 1955

Categories of land use	Number of polygons	Area (ha)	Average area (ha)	Share on total area (%)
arable land	1,364	188,979.0	138.5	45.1
permanent grassland	3,639	37,337.8	10.3	8.9
garden and orchard	1,184	6,799.9	5.7	1.6
vineyard and hop field	191	5,449.2	28.5	1.3
forest	1,966	143,006.9	72.7	34.2
water area	177	1,933.1	10.9	0.5
built-up area	1,076	33,115.6	30.8	7.9
recreational area	466	1,748.4	3.8	0.4
other area	72	361.7	5.0	0.1

Tab. 6: Landscape structure in 1990

Categories of land use	Number of polygons	Area (ha)	Average area (ha)	Share on total area (%)
arable land	1,275	172,712.7	135.5	41.3
permanent grassland	3,704	47,694.4	12.9	11.4
garden and orchard	1,513	6,797.7	4.5	1.6
vineyard and hop field	249	3,811.0	15.3	0.9
forest	2,277	147,511.0	64.8	35.2
water area	191	2,087.7	10.9	0.5
built-up area	1,074	35,492.6	33.0	8.5
recreational area	568	2,244.0	4.0	0.5
other area	73	380.5	5.2	0.1

Tab: 7: Landscape structure in 2006

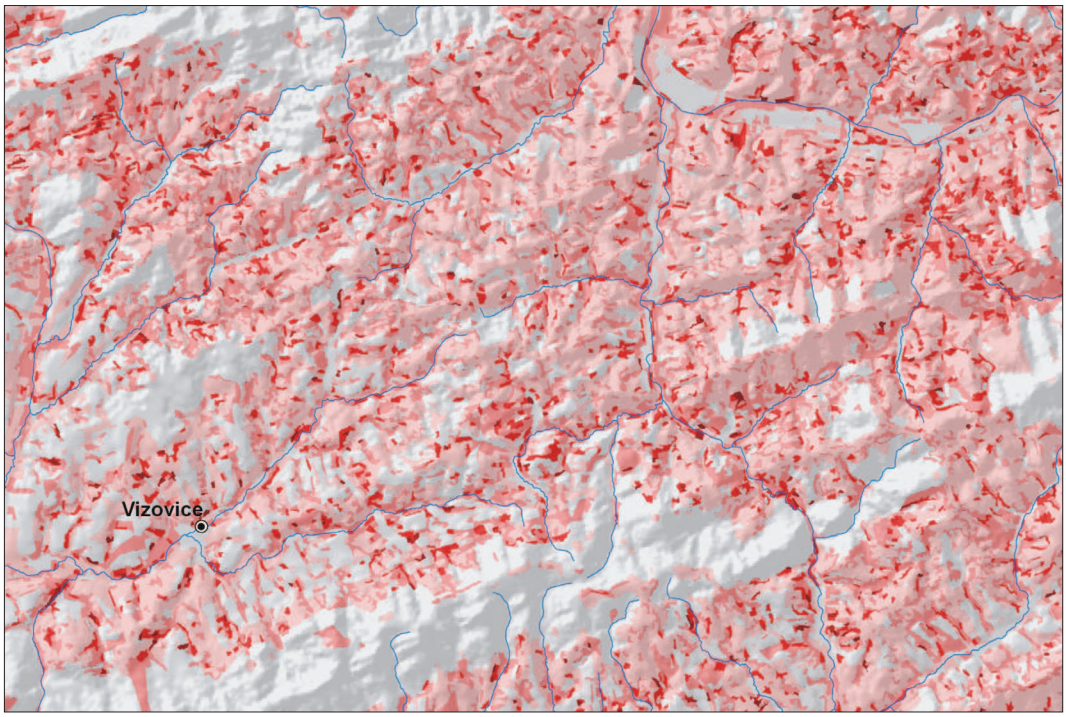
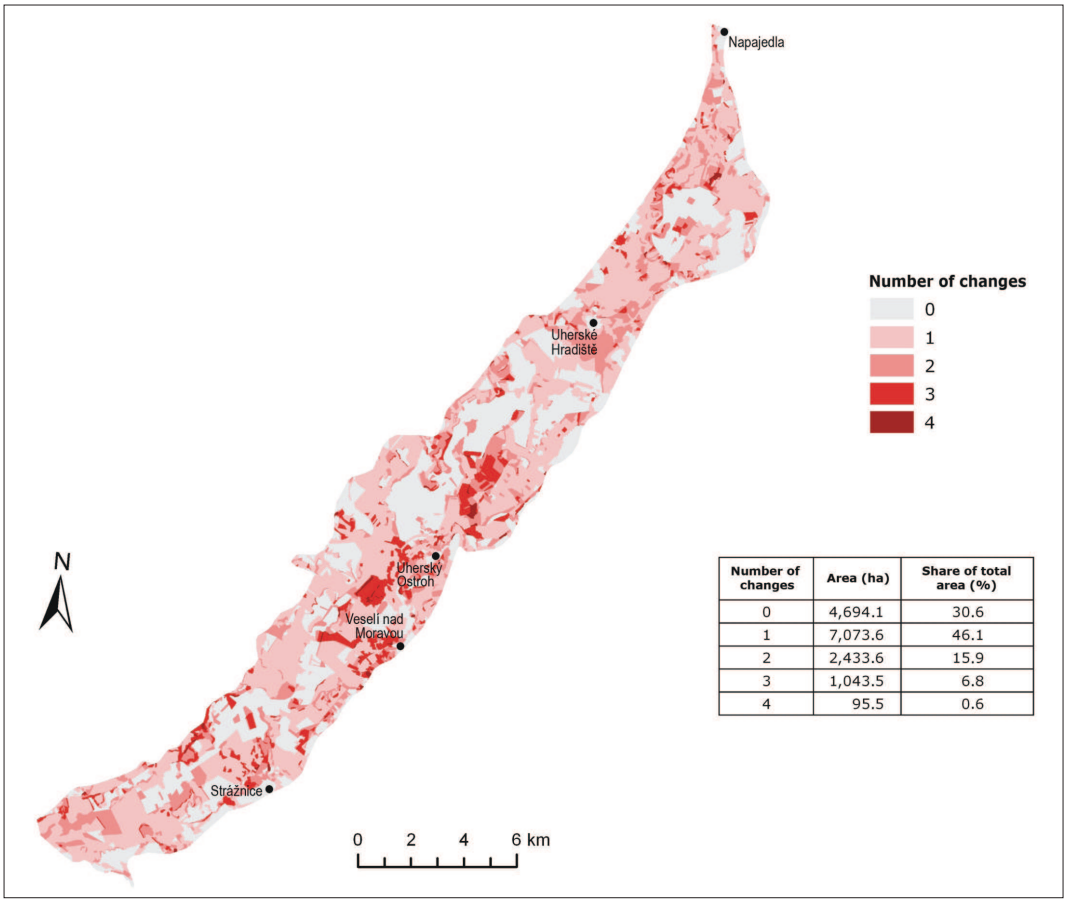


Fig. 9: An example of the number of land-use changes in the Moravian-Silesian Carpathians nearby the town of Vizovice in the period 1836–2006. The map shows the stability of the flysch ridge of Komonecká hornatina Mts. in the Vizovická vrchovina Highland. For the legend see Fig. 10
Source: Mackovčin et al., 2011.



Number of changes	Area (ha)	Share of total area (%)
0	4,694.1	30.6
1	7,073.6	46.1
2	2,433.6	15.9
3	1,043.5	6.8
4	95.5	0.6

Fig. 10: The number of land-use changes in the Lower Morava River Floodplain (Dolnomoravská niva) in the period 1836–2006. Floodplains were highly dynamic geosystems in this period
Source: Mackovčin et al, 2011

Number of changes	Number of polygons	Area (ha)	Share of total area (%)
0	2,650	234,585.2	56.0
1	6,977	116,417.8	27.8
2	10,499	52,409.2	12.5
3	5,849	13,805.8	3.3
4	1,044	1,513.6	0.4

Tab. 8: The number of landscape changes 1836–2006

Area in stable usage	Number of polygons	Area (ha)	Average area (ha)	Share on total area (%)
arable land	1,595	123,884.6	77.7	29.6
permanent grassland	867	5,990.1	6.9	1.4
garden and orchard	23	72.7	3.2	0.0
vineyard and hop field	81	718.5	8.9	0.2
forest	851	94,498.0	111.0	22.6
water area	2	7.1	3.5	0.0
built-up area	692	9,414.2	13.6	2.2
recreational area	–	–	–	–
other area	–	–	–	–
In total	**4,111**	**234,585.2**	**–**	**56.0**
Area in unstable usage	**2,284**	**184,146.4**	**80.6**	**44.0**

Tab. 9: Stable and unstable plots in the study area according to land-use type in the period 1836–2006

Fig. 11: Stable plots. The forested Klášťovský hřbet Ridge and the rock pediment in the depression of the Pozlovická brázda Furrow. Photo J. Demek

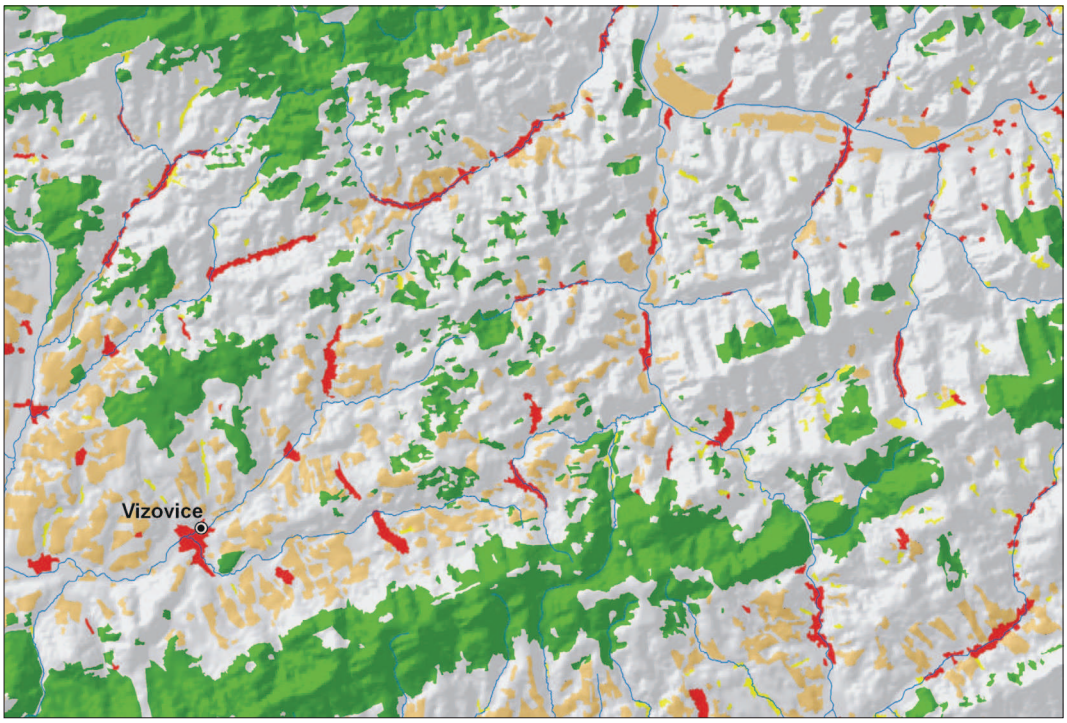


Fig. 12: An example of the map of stable and unstable plots in the Moravian-Silesian Carpathians nearby the town of Vizovice in the period 1836–2006. Legend see Fig. 2. Grey flats are unstable plots
Source: Mackovčin et al., 2011

These stable plots occupy 56% of the studied area (Tab. 9). Plots of arable land in lowlands and flat hilly lands (29.6% of the studied area) showed the stable land use. Stable large blocks of arable land occurred namely in the Vyškovská brána Gate, in the Hornomoravský úval Graben (with the exception of the Middle Morava River Floodplain), in lower parts of the Litenčická pahorkatina Hilly land, in the Mutěnická pahorkatina Hilly land (with the exception of floodplains) and in lower parts of the Vizovická vrchovina Highland (especially in the Hlucká pahorkatina Hilly land). Stable were also forest stands on the ridges of Ždánický les Forest, Chřiby, Hostýnské vrchy Hills and Klášťovský hřbet (Fig. 11). It is interesting that for the whole period forests also covered the highest parts of the flysch Litenčická pahorkatina Hilly land and Mladcovská pahorkatina Hilly land as well as some lower ridges of the Vizovická vrchovina Highland.

6. Conclusions

The development of new analytic and computing technologies and the higher demand for scientific guidance in decision making concerning future landscape transformation and restoration have propelled research on landscape changes in the Czech Republic over the past decade. The manual and computer-aided evaluation of historical and contemporary large-scale topographic maps allowed the authors to define some trends in land-use changes and transformation of Moravian landscapes in the last 240 years.

The first trend in the studied period was the drainage of a large number of fishponds shown on maps from the 1st Austrian Military Mapping connected with the agrarian revolution in 1764–1836. Fish farming was no more profitable in the 19th century and the growing population required a higher production of food. The beds of former fishponds changed into pastures, meadows, arable land or even in some places foundations for Feudal estates.

The second trend was increase in the area of water bodies, especially the restoration of fishponds drained in the past, mainly in the first half of the 19th century. This trend is especially apparent on the Czechoslovak Military maps S-52 produced in 1952–1955.

A third trend was an increasing share of arable land especially in the lowlands and hilly lands of the study area due to the agrarian revolution in the second half of the 19th century, progress in land cultivation and demand for food for the increasing number of inhabitants. The extension of arable land mostly proceeded at the expense of permanent grassland (compare Tab. 2a and 2b). Unfortunately, the data are deformed due to the change of the map key during the fourth consolidation of military maps of the Czechoslovak People's Army produced in the years 1988–1995 that underestimated the category of permanent grassland. The third trend is obvious until the year 1990. With the re-introduction of the capitalist economy after 1990, the area of arable land started to decrease.

The fourth trend is the gradually increasing area of forests. This trend results from the industrialization of agriculture. The agricultural use of steep slopes became uneconomical. Besides, the fields on these steep slopes were endangered by accelerated soil erosion. Industrialized agriculture guaranteed enough food for inhabitants and this is why the plots less favourable for mechanized agriculture or devastated were reforested. Balks (often constructed of stone blocks) between the former abandoned fields are still common in the contemporary cultural forests.

The fifth trend is the increasing area of urbanized plots, especially in the 20th century, and the decreasing differences between various environments in towns (urbanized landscapes) as well as in villages. Unfortunately, urbanized landscapes sprawl also into endangered areas, e.g. into regularly inundated floodplains or into landslide areas.

Finally, a sixth trend is the increasing area of recreation plots in the second half of the 20th century.

In order to predict the future of landscapes, an historical perspective is particularly important. Quantitative studies of historical and contemporary large-scale topographic maps in a GIS environment make it possible to elucidate the driving forces (natural and socioeconomic) in the landscape development in the last 170 years, the years of principal changes in the cultural landscapes of Central Europe. The exact knowledge of historical landscape conditions and landscape change over time and the related databases in GIS milieu facilitate and improve predictions about the future state of Czech landscapes.

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