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CONTENTS

CHANGES IN THE EXTENT OF NON-FOREST WOODY VEGETATION IN THE NOVODVORSKO AND ŽEHUŠICKO REGION (CENTRAL BOHEMIA, CZECH REPUBLIC)

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ABSTRACT

Changes in the extent and occurrence of non-forest woody vegetation in the agricultural landscape of the Novodvorsko and Žehušicko region in the Central Bohemia during the last 60 years are presented in the paper. The study is based on a comparison of data (landscape structure indicators) from two time horizons – 1950 and the present (2011). Historical black and white aerial photographs from 1950 and color orthophotomaps from 2006 were used as data sources. Furthermore, the present state of the vegetation was investigated and specified by field mapping in 2011. The extent and changes of non forest woody vegetation were observed in natural (biochores) and cultural (landscape character areas) units with the aim to find out differences dependent on natural and cultural conditions. Results confirm that the quantity as well as the distribution of elements of non-forest woody vegetation changed during the last 60 years in an important way. Significant decrease in the area of non-forest woody vegetation and extinction of many important biotopes are among the main results of the work. The study provides strong evidence that changes in land use and landscape structure have a great influence on non-forest woody vegetation in all aspects. At the end of the paper, the reasons for the changes are discussed. In general, intensification and mechanization of agriculture has caused extinction of fine-grained landscape microstructure especially as to arable lands connected with removal of dispersed vegetation structures. Straightening of watercourses and destruction of meanders with their riparian vegetation has had the same effect.

Key words: non-forest woody vegetation, landscape changes, landscape structure indicators, landscape units

1. Introduction and literature review

Non-forest woody vegetation (NFWV) is an important part of landscape structure and a determining feature of landscape character. However, it has not received as much attention in recent years as topics such as land use or land cover changes, and also landscape character assessment. Hedges or hedgerows, linear features, are paid traditionally more attention especially in western European countries, for example Burel, Baudry 1995; Barr, Gillespie 2000; McCollin 2000; Jongman 2002.

Non-forest woody vegetation, or *scattered greenery*, in other words, is stable woody vegetation including the herbal floor, which is neither a forest, agricultural crop, nor, a part of vegetation of built-up areas in municipalities or in landscape (Bulíř 1981; Mareček 2005). Natural elements growing spontaneously as well as vegetation planted by human are included (Bulíř, Škorpík 1987; Machovec 1994).

Non-forest woody vegetation is divided according to shape into three categories (Sláviková 1984; Supuka et al. 1999; Trnka 2001):

- *Patches* – maximum area of 0.3 ha (small woods, groves, vegetation on wet sites, on abandoned lands or localities unsuitable for any economic use);
- *Linear elements* – minimal length of 30 m, width maximum 30% of length (alleys, riparian vegetation, linear vegetation along railways, on balks etc.);
- *Point elements* – one, up to three individuals of tree or shrub (solitairy, group of trees, shrubs).

Non-forest woody vegetation is a typical feature of many European agricultural landscapes (Meeus 1995; Burel, Baudry 1995). From a historical point of view, it was formed in following ways (Sklenička 2003):

- Retreat of forest – non-forest woody vegetation is a remnant of the original forest stands;
- Natural raid – (spontaneous) spreading of woody vegetation outside forest stands;
- Planting – intentional spreading by humans.

NFWV plays a crucial role in agricultural landscape. It provides many important functions such as soil-protective, stabilizing, hygienic, aesthetic, productive etc. Many studies focused on the importance and function of non-forest woody vegetation, for example Pollard et al. 1974; Forman, Godron 1986; Sláviková 1987; Supuka et al. 1999; Baudry et al. 2000; Trnka 2001; Sklenička 2003; Špulerová 2006 etc. In general, it has a positive influence on visual aspects of landscape structure and landscape character, because it makes landscapes more divergent and as a consequence the pattern (mosaic) is more varied as well. Furthermore, NFWV causes also increase of biodiversity due to providing food and refuge for many animal species in agricultural landscapes. So the impact of NFWV on landscape is generally very positive from biological and landscape-ecological point of view.

Forests, tree-lines (alleys), groves, riparian vegetation, windbreaks etc. are considered as important landscape features that complete the landscape image (Benčať, Jančura 2008) or landscape character (Flekalová 2010).

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Vorel (2007) concludes that NFWV belongs to the most significant landscape components because it supports diversity as well as creates aesthetically delightful points, areas and landscape sceneries (Demková 2011).

From recent studies, Molnárová (2008) evaluates structural attributes of hedgerows such as density, relative area, connectivity and other characteristics in three cadastres in the Plzeň Region, Southwestern Bohemia. The most recent work (Flekalová 2010) proposed how to include non-forest woody vegetation into the process of landscape character assessment.

Landscape features formed by humans in the past and still exist in the landscape are called *historical landscape structures (HLS).* They are defined as a physical (material) part of immovable cultural heritage (Huba et al. 1988). Such relicts, remnants with long-term stability, identify not only the spatial structure but also the temporal structure of the landscape (Supuka et al. 1999). They represent a significant part of landscape memory.

Official reports on the state of the environment and a negative influence of socialist agriculture on the landscape specify early after 1990 drastic figures giving the evidence about the clearing and liquidation of non-forest woody vegetation from agricultural landscape: "4,000 km of lines of wood vegetation, 3,600 ha of scattered greenery, 49,000 km of balks and 158,000 km of field roads were removed from the Czech rural landscape" (Moldan et al. 1990). In the mid-eighties the total area of non-forest woody vegetation in the Czech Republic was only about 0.3–0.5% of the country's territory (Trnka 2001).

The rapid decrease in the area of non-forest woody vegetation in open agricultural landscape concerns not only former socialist countries. Increased intensification of agriculture including mechanization, the use of agrochemicals etc. after World War II was recorded in Eastern as well as Western Europe (Pollard et al. 1974; Barr et al. 1986). McCollin (2000) points out the loss of 158,000 km of hedges in England between 1984 and 1994, i.e. one-third of the total length existed in 1984. Jongman (2002) remarks that the total length of linear vegetation decreased by 80% in the Netherlands in 80 years (1900–1980).

The main aim of the paper is to compare the distribution and areal extent of non-forest woody vegetation in 1950 and in the present. According to the literature review and previous works (Demková, Lipský 2012; Lipský 1995 and others) we suppose that its areal extent has decreased and spatial distribution has changed (some elements disappeared and new ones originated). The partial aim is to find out how much has proportion of NFWV changed in the relation to natural conditions as well as evaluate if the amount or areal extent of NFWV depends on some kind of territorial nature and landscape protection. Since NFWV is a determining feature of landscape character (Vorel 2007; Benčať, Jančura 2008) we suppose also that landscape character units will differ from each other in proportion of NFWV. Finally we assume that few elements of NFWV preserved until today, could be considered as historical landscape structures.

2. Methods and study area

Non-forest woody vegetation was identified by the method of manual interpretation on orthophoto-air photographs from 2006 (CENIA) and on historical black and white aerial photos from 1950 (VÚKOZ Průhonice) on the basis of an application of visual criteria and size parameters (defined below). All elements of NFWV identified on the orthophotomaps from 2006 were mapped and investigated in the field during vegetation periods 2010 and 2011 according to proposed mapping methodology in order to obtain information about the current state and species composition of vegetation (Demková, Lipský 2012).

Non-forest woody vegetation was divided by shape into three categories (Sláviková 1984; Trnka 2001; Supuka et al. 1999):

- Point elements – one, up to three individuals of tree or shrub;
- Patches – minimal area of 50 m^2, maximum area of 0.3 ha;
- Linear elements – minimal length of 30 m, width maximum 30% of length.

The area of NFWV was set down as a projection of the tree or the shrub crown. In the case of the linear elements their lengths were counted. The area of linear vegetation was calculated from width estimated from orthophotomaps. In addition to size parameters (area, length), basic indicators of landscape structure such as quantity (number), average size and density (porosity) of spatial elements as well as share of single categories of NFWV were counted. Density (porosity) was calculated as the area of point and patch elements (m^2) and length (m) of linear vegetation per 1 square kilometer of the study area.

Within the digitalization a special classification of development of non-forest woody vegetation was created to obtain information about its existence during the last 60 years. The following classes were distinguished, inspired by Elznicová, Machová (2010):

a. elements existing both in 1950 and 2011 as NFWV;
b. new elements of NFWV (existing only in 2011);
c. extinct elements of NFWV(existing only in 1950);
d. elements existing in 1950 as NFWV, changed into forest or other continuous vegetation by 2011;
e. elements existing as a part of other continuous vegetation in 1950, changed into NFWV by 2011.

In the second section of the paper, changes in the share of non-forest vegetation in selected natural and cultural units such as biochores, Landscape Memorial Zone Žehušicko and landscape character areas are analyzed. Biochores (Culek et al. 2005) are typological biogeographical units representing similar geomorphological, geological and vegetation conditions of the territory, whereas landscape character areas are individual territorial units delimited on the basis of geographical maps and subjective visual characteristics (see Lipský et al. 2013). The Landscape Memorial Zone Žehušicko was declared in 1996 with the aim to preserve a specific type of cultural landscape with signs of historical landscape design.

From 12 biochores presented in the study area, only 5 representative biochores with a share of more than 5% were chosen to analyze differences in the occurrence of NFWV depending on natural conditions:

2Nh – loam alluvia of the 2nd altitudinal vegetation zone (36%);
2RV – plains on blown sands of the 2nd altitudinal vegetation zone (13.7%);
2Do – waterlogged depression on neutral volcanic rocks of the 2nd altitudinal vegetation zone (8.3%);
2RN – plains on gravels of the 2nd altitudinal vegetation zone (7.4%);
2RE – plains on loess of the 2nd altitudinal vegetation zone (6.7%).

The source data were processed in the GIS environment and consequently adjusted using contingency table. Following statistical analyses were performed in software Statistica. Before performing statistical evaluations, all sets of data were checked for their normal distribution by the Shapiro-Wilk test (Shapiro, Wilk 1965) and by visual analysis of histograms. Since almost all of the datasets do not meet the criterion of normality, differences in the area and density (porosity) of elements of NFWV in individual landscape units between the defined time horizons were analyzed using Kruskal-Wallis one-way analysis of variance (Kruskal, Wallis 1952) (K-W test) at a confidence level p = 0.05.

2.1 Study area

The area under investigation is situated in the north-eastern part of the district Kutná Hora in the eastern part of the Central Bohemia. It is comprised of 12 cadastral units with a total area of 60.5 km^2 (Figure 1). From a geomorphological point of view, the territory is a part of the Čáslavská kotlina basin with an altitude of 200–239 m a. s. l. Železné hory Mts interferes into the north-eastern edge of the study area with a maximal elevation of 320 m a. s. l. The flat relief of the basin is formed by wide alluvial plains of the lower streams of the rivers Doubrava, Klejnárka and Labe in the north of the territory. Despite the simple geological and geomorphological structure, a mosaic of soil types has developed in the lowland depending on substrate. Fluvisols and Cambisols predominate, but also Chernozems and Rendzinas are represented in the area. The area is comprised of 10 biochores of the second vegetation degree and 2 biochores of the third vegetation degree in the spur of the Železné hory Mts (Culek et al. 2005).

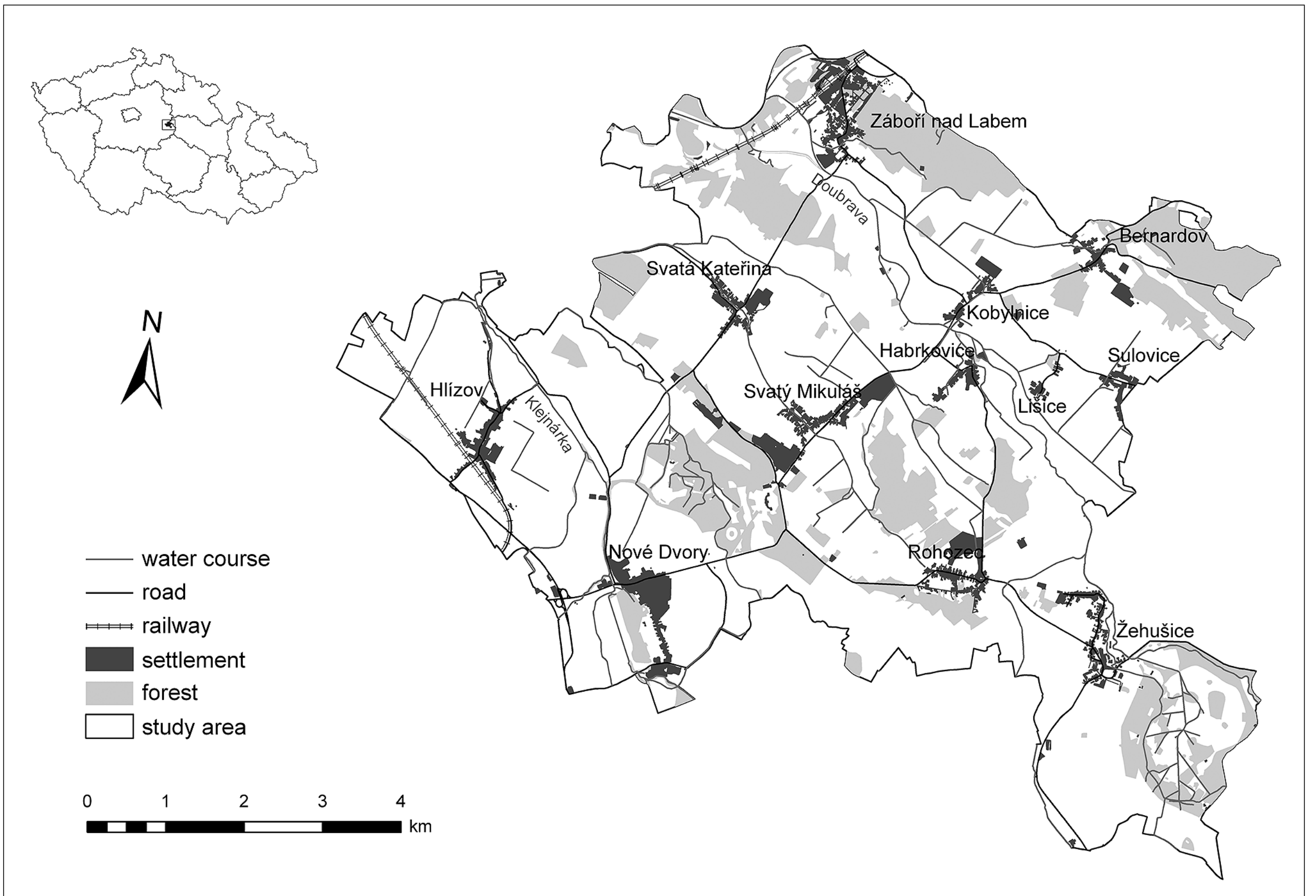

Fig. 1 Map of the study area

At present, an intensively used agricultural landscape with a dominant share of arable land prevails in the study area. However, in comparison with the rest of the Čáslavská kotlina basin, most of the study area has a specific landscape character with a more varied landscape structure due to a higher proportion of forest as well as aesthetically motivated landscape formations around the Kačina and Žehušice castles in the 18th and 19th centuries (Lipský et al. 2011). Consequently, the Landscape Memorial Zone Žehušicko was declared in 1996 in the southern and central part of the study area. Recently, the park and game preserve around the Kačina castle with a total area of 196 ha became a NATURA 2000 site as well.

3. Results

The distribution of non-forest woody vegetation changed in the last 60 years. As it was supposed, the number of elements of NFWV as well as their areal extent decreased in all categories. The total area of point elements and patches decreased together by more than 40 thousands of square meters and the total length of linear elements decreased by 32 km (Table 1). Although the length decreased by 20% in comparison to present, the area sank only by 4%. This is caused by enlarging of their width due to changes in practice of agricultural management on surroundings agricultural plots and no maintenance of the greenery. According to K-W test only changes in the area of linear and patch elements are statistically significant.

Due to the changes a lot of point elements disappeared, especially those which were situated on the plot boundaries. The original trees, probably fruit trees, were replaced by shrubs of elder near extra high voltage towers. Point elements of NFWV in the alluvial plain of the Klejnárka river in cadastral territory Hlízov and the Brslenka stream in the cadastral territory Žehušice disappeared completely.

Almost 60% of patches of NFWV existing in 1950 disappeared from the landscape (Figure 2). Approximately one-third of patches became a part of forest or other continuous vegetation, the rest (23%) disappeared completely because it was changed into arable land. More than 40% of all patches were preserved till present. Most of them are situated on localities not suitable for agriculture (waterlogged or elevated habitats). New patches appeared also due to land abandonment, mostly covered by ruderal vegetation.

In 1950 the relics of riparian vegetation of former meanders of water streams Doubrava and Stará Doubrava were observed in the landscape. These very significant biotopes were also destroyed due to the intensification and mechanization of agricultural production. Modification (straightening) of riverbeds caused extinction of line vegetation as well (especially the Labe river). Other linear elements existing in 1950 indicated the course of plot boundaries or boundaries of cadastral territories. There were also more field roads or roads accompanied by continuous vegetation in comparison with the present landscape.

New linear elements are observed along new roads, artificial water canals (very sporadically) or around the flooded sandstone pit near Žehušice. Modified water courses such as the Doubrava river are nowadays accompanied by new riparian vegetation.

Decrease in the number of point elements and patches of NFWV were observed (Table 2). But the average size of both categories increased, in case of point elements not as much as in case of patches. The majority of patches were smaller in 1950 (72% with the area up to 500 m^2) whereas in 2011 the ratio of the smallest patches sank to 50%. Only a half of large patches, with the area more than 1,500 m^2, existing in 1950 were preserved until the present. The others were removed. Density (porosity) decreased in all categories of NFWV as well.

Figure 3 demonstrates changes in proportion of NFWV in 5 representative biochores in 1950 and 2011. The highest proportion of linear elements in biochores 2Nh (alluvia) and 2RE (plains on loess) and the highest proportion of point elements in the biochore 2Nh were recorded in both observed time periods. This is caused by riparian vegetation along water streams and remnants

Tab. 1 Comparison of size parameters and percentage of non-forest woody vegetation in 1950 and in 2011

Category of NFWV	Area (m^2)		Share of the total area (%)		Change (m^2)	Change (%) (1950 = 100%)	Statistical significance of change (p)
	1950	2011	1950	2011	1950/2011	1950/2011	1950/2011
Point elements	20,953.5	17,285.0	0.035	0.030	−3,668.5	−17.5	0.7418
Patches	99,917.2	93,482.5	0.165	0.155	−6,434.7	−6.5	0.0001
Linear elements	799,992.0	768,294.0	1.32	1.27	−31,698.0	−4.0	0.0001

Tab. 2 Changes in landscape structural indicators of non-forest woody vegetation between 1950 and 2011

	Number of elements		Average size (m^2)		Density (area in m^2 and length in km) per 1 km^2 of the study area	
	1950	2011	1950	2011	1950	2011
Point elements	483	357	43.4	48.4	346.6	285.9
Patches	197	127	507.2	736.0	1651.5	1545.2
Linear elements	–	–	–	–	2.65	2.12

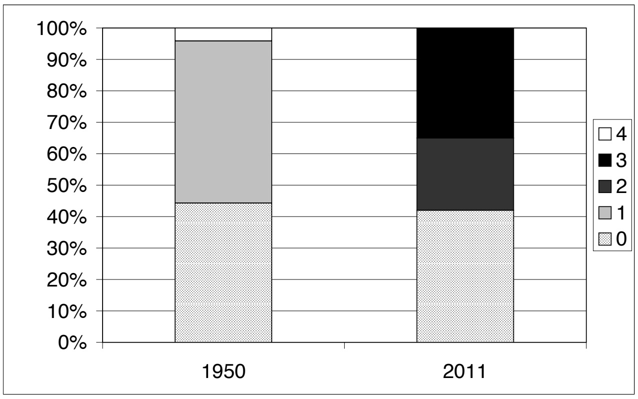

Fig. 2 Classification of development of patch elements in 1950 and 2011 in percentage
Explanatory notes to the figure: 0 – elements existing both in 1950 and in 2011; 1 – new element (existing only in 2011); 2 – vanished elements (existing only in 1950); 3 – elements existing in 1950, changed into forest or other continuous vegetation till 2011; 4 – existing in 1950 as other continuous vegetation, changed into NFWV till 2011.

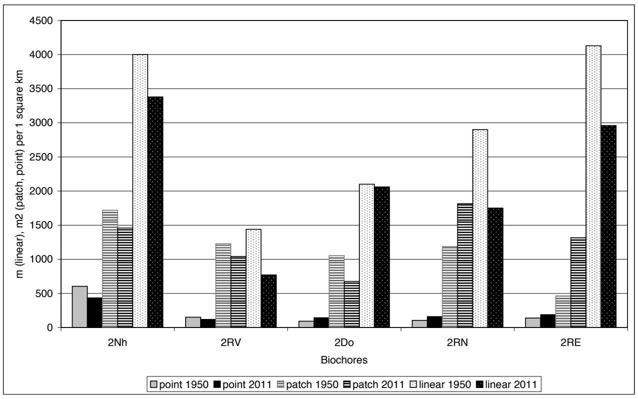

Fig. 3 Changes in density of non-forest woody vegetation in biochores
Explanatory notes to the figure: linear elements are expressed in m per 1 km^2, point and patch elements in m^2 per 1 km^2; 2Nh – loam alluvia of the 2nd altitudinal vegetation zone; 2RV – plains on blown sands of the 2nd altitudinal vegetation zone; 2Do – waterlogged depression on neutral volcanic rocks of the 2nd altitudinal vegetation zone; 2RN – plains on gravels of the 2nd altitudinal vegetation zone; 2RE – plains on loess of the 2nd altitudinal vegetation zone.

of solitary trees on meadows. In 1950, the highest share of patches was in the alluvial biochore 2Nh as well, but it decreased by 18% by 2011. On the contrary, a considerable increase of patches was observed in biochores 2RN (plains on gravels) and 2RE (plains on loess) due to enlargement of abandoned agricultural lands. By contrast, the density of linear elements decreased substantially in all biochores, which is a result of the intensification of agricultural production.

The K-W test confirmed significant differences in the proportion of NFWV between two observed time horizons in the biochore 2Nh (alluvia) and 2RV (plains on blown sands) in all three categories, in the biochore 2Do (waterlogged depression) only as to the linear vegetation. Other changes are not statistically significant.

The comparison of the share of elements of NFWV in the Landscape Memorial Zone (LMZ) Žehušicko, which comprises 35.5% of the study area, and in the rest of the study area is demonstrated in the Table 3.

As it was expected, there is a difference in the proportion of elements of NFWV between the LMZ and the rest of the territory in all categories. Substantially higher share of point elements and patches is observed in LMZ (it is approx. doubled) and they have larger average size there as well. On the other hand, linear vegetation elements have a surprisingly lower proportion in LMZ in both time periods. It is caused by higher density of water courses and roads (which are mostly accompanied by woody vegetation) outside the LMZ.

Lastly, changes in the share of elements of NFWV in 11 landscape character areas delimited in the study area (after Lipský et al. 2013) were observed (Figure 4).

Landscape character area A1 was delimited as predominantly forested landscape so it is logical that all patches and point elements existing in 1950 disappeared and were replaced by forest. Landscape character area B1 represents the alluvial floodplain of the Labe river with rather high density of all categories of NFWV. Although the decrease in the distribution of elements of NFWV in the landscape character area D2 Kačina, which represents forested landscape (a former game park) around the Kačina castle, was markedly, the K-W test does not confirm it as statistically significant (Table 4). On the other hand, there has been observed an increase in density of patches as well as of point elements in landscape character areas E1 and E2. Current patches of NFWV are related to terrain roughness, especially elevations, or to abandoned lands. Changes in both landscape character areas are significant as well.

Table 4 demonstrates significant decrease in density of linear elements in landscape character areas C2, D2 and E2, which represent the core area of the LMZ Žehušicko. In 1950 there were observed much more linear woody structures along roads, field paths and on the plot boundaries. Some other linear elements disappeared because of merging with forest as it was observed in the former game park around the Kačina castle and in the game-preserve Žehušice. In contrast, a considerable increase in the share

Tab. 3 Share of non-forest woody vegetation in Landscape Memorial Zone Žehušicko and in the rest of the study area in 1950 and 2011

	Point elements (in % of the study territory)		Patches (in % of the study territory)		Linear elements (in km per 1 km^2 of the study territory)	
	1950	2011	1950	2011	1950	2011
LMZ Žehušicko	0.07	0.04	0.24	0.24	2.47	1.65
The rest of the territory	0.02	0.02	0.13	0.11	2.74	2.38

Tab. 4 Statistical significance of the Kruskal-Wallis test for non-forest woody vegetation and landscape character areas

Landscape character areas	Point elements	Patch elements	Linear elements
A1 Zábořské bory	**0.0053**	0.1172	**0.0143**
A2 Bernardov	0.1228	0.0617	0.9486
B1 Záboří – Starý Kolín	0.4978	**0.0163**	**0.0002**
C1 Dolní Doubrava	0.1549	**0.0257**	**0.0001**
C2 Žehušice	0.2291	0.0544	**0.005**
C3 Svatý Mikuláš a Kateřina	0.8753	0.0563	**0.0001**
D1 Severní část ke Starému Kolínu	0.2482	x	0.7589
D2 Kačina	0.6687	0.8389	0.0834
D3 Kamajka	**0.0393**	0.1266	**0.0251**
E1 Hlízov	**0.0105**	0.1495	**0.0001**
E2 Nové Dvory	0.0352	0.0126	0.0016

Marked (bold) relations are significant at the confidence level p = 0.05, x – no data.

of NFWV is registered in landscape character areas A1 and D3. Both landscape units are predominantly covered by forest or arable land and the share of linear elements was the lowest in 1950. Nowadays there is a road or field road accompanied by these vegetation structures. Except of landscape character areas A2 and D1, all changes of linear NFWV are statistically significant.

Some vegetation landscape structures linked up with historical artefacts in the landscape like old dams of former fish ponds, old roads, wayside cross, memorials and other landmarks were preserved until the present in the study area. They form an integral part of these historical landscape structures. But most vegetation historical landscape structures were destroyed during the observed period and land use as well as the total landscape structure of the study area has become homogenized (Lipský et al. 2011).

4. Discussion

Identification of non-forest woody vegetation was carried out on the basis of visual interpretation of aerial photographs. Air photos from 1950 are black and white with worse resolution, which makes interpretation more difficult. In case of color orthophotomaps, the interpretation of vegetation structures is more accurate.

Decrease of the extent of non-forest woody vegetation during the last 60 years in all categories was observed in the study area. In case of linear and patch elements it was confirmed as statistically significant. Many elements of NFWV were destroyed during the period of socialist agriculture as it is outlined in literature of many authors (see Lipský 1995). The decrease is caused by land use changes connected with the intensification of agriculture in the second half of the 20th century. The method of cultivation, structure of field crops, harvesting methods, methods of livestock farming as well as other agricultural processes have been radically altered during the last 50 years with concomitant effects on landscape structure. Socialist collectivization of agriculture has caused the extinction

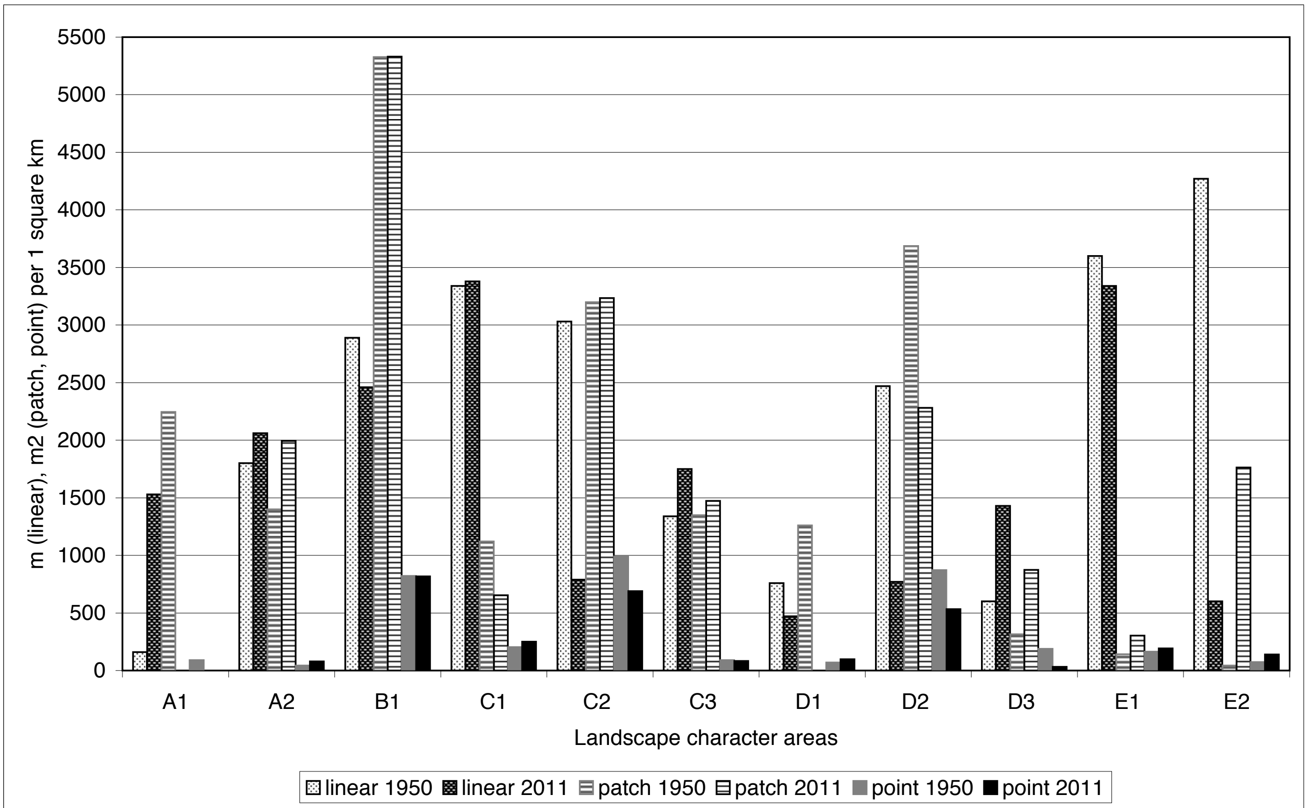

Fig. 4 Density of elements of non-forest woody vegetation in landscape character areas in 1950 and 2011
Explanatory notes to the figure: linear elements are expressed in m per 1 km^2, point and patch elements in m^2 per 1 km^2; related names of landscape character areas are in table 4.

of microstructure of arable land by the merging of small fields with big blocks of arable land, which is closely linked with the removal of everything including vegetation (trees or other biotopes). Parcels of arable land were unified so they would not to be interrupted by meadows, shrubs or other elements hampering efficient cultivation. During the transition to socialist large-scale production, landscape structure changed rapidly towards its significant simplification. The size of agricultural holdings was increased 50 times, plenty of meadows in floodplains were ploughed and most of the permanent vegetation structures in the open agricultural landscape were removed. The traditional character of the Czech rural landscape with its small-scale mosaic of patches has changed into large-scale landscape of collective openfields (Lipský 1995; Meeus 1995).

Density of linear elements decreased by 20%, which is similar to the results of Molnárová (2008). But the total area of NFWV sank only by 4.5%, while patch elements recorded the highest decrease (17.5%). These changes were caused not only by intensification of agriculture but also by afforestation. The forest area increased from approx. 9.9 km^2 to 11.5 km^2 (by 16%) in the last 60 years, mostly due to afforestation of adjacent fields. Some elements of NFWV joined the forest. From ecological point of view it should be consider as positive, but in the context of NFWV it could be perceived as a loss of small biotopes in agricultural landscape as well as change (loss) of visual (aesthetic) landscape qualities.

Research in western European countries recorded length reduction of hedgerows by 23% between 1984 and 1990 in Great Britain (Barr, Gillespie 2000), while in Brittany (France) it was 35% between 1952 and 1985 (Burel, Baudry 1990). It seems to be more dramatic in comparison with our results, but differences may be caused by different methodology: our study does not concern only hedgerows.

Relation of NFWV to natural conditions presented by biochores was recognized. The highest share of all categories of NFWV is in alluvial plains along water courses with linear vegetation structures. But at the same time, significant decrease of NFWV in all categories was confirmed in alluvia and plains of blown sands. Destruction of vegetation due to intensification of agriculture or afforestation was mostly presented in these two biochores.

High proportion of NFWV in alluvia is also caused by the presence of the game park Žehušice, which is nature protected area. This fact confirms the starting hypothesis that NFWV is more supported and better preserved in areas under some kind of nature or landscape protection, as it was documented on the example of the Landscape Memorial Zone Žehušicko as well.

Although statistical evaluation of changes of NFWV does not show significant changes in all cases, it does not mean that there were no noticeable landscape structure changes. The number of patch and point elements sank as well as length of linear vegetation. From landscape with remnants of meanders accompanied by riparian vegetation and solitaires of trees on meadows has become open unified landscape with monofunctional use. The K-W test is only auxiliary tool for accurate quantification of changes in this study.

The paper presents results about development of NFWV in a small study area but none of the research in the Czech Republic has assessed such relations so far. There is only one study about development of structural attributes of hedgerows (Molnárová 2008). Therefore the results cannot be placed into a broader context. This is the first time that such data have been available at the local or regional scale in the Czech Republic and Slovakia as well. For more accurate differentiation of trends in landscape development under differing political doctrines, it would be possible to use aerial photographs from approx. 1990. These data are generally available for the whole country territory. But according to our experience from the area under investigation, the trends in landscape development did not change essentially here.

There is always a lack of data about these biotopes and without their evidence it is not possible to protect them adequately. Further research is required at the national scale. Great Britain where the Countryside Surveys provide a rich source of data about hedgerows (e.g. Barr et al. 1993) could serve as good example.

5. Conclusion

This work has documented the following findings:

- decrease in proportion of non-forest woody vegetation in the study area since 1950 until the present (areal extent, quantity), although not every change is statistically significant;
- only 42% of original NFWV (existing in 1950) were preserved until today (mostly out of arable land);
- loss or destruction of NFWV was caused by socialist intensification of agriculture accompanied by re-allotment of land as well as land-consolidation and other land use changes;
- loss of original function and importance of NFWV (nowadays no longer essential as a source of wood and fruit or for demarcation of field boundaries);
- new occurrence of NFWV in relation to environmental conditions (on abandoned and unused lands);
- proportion and distribution of elements of NFWV is influenced both by natural conditions (primary landscape structure), land use changes (secondary landscape structure) as well as legislative nature and landscape protection measures (tertiary landscape structure).

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RÉSUMÉ

Vývoj nelesní dřevinné vegetace v krajině Novodvorska a Žehušicka (Střední Čechy)

Rozptýlená zeleň (nelesní dřevinná vegetace stromů a keřů) je významným prvkem krajinné struktury, podílí se na její funkčnosti a pestrosti, zvyšuje biodiverzitu krajiny a je určujícím znakem krajinného rázu. Během posledních 60 let došlo k velkým změnám ve struktuře a rozšíření rozptýlené zeleně v krajině. Zatímco v minulosti byly dřeviny do volné krajiny cílevědomě vysazované v podobě alejí, remízků i solitérů, v období socialistického zemědělství byla tato vegetace v důsledku zcelování pozemků a intenzifikace zemědělství naopak likvidovaná, protože byla vnímaná jako překážka souvislého obdělávání zejména orné půdy. Potvrzují to i výsledky této studie, realizované na příkladu intenzivně využívané zemědělské krajiny ve středních Čechách. Zájmové území leží v povodí dolních toků Doubravy a Klejnárky a zaujímá přes 60 km^2.

Porovnáním současného stavu se stavem v roce 1950 bylo zjištěno, že v tomto území se snížilo zastoupení rozptýlené zeleně ve všech kategoriích (bodové, liniové a plošné prvky). Plocha bodových prvků se snížila o 17,5 %, plošných o 6,5 % a liniových o 4 %. Jako statisticky významné byly vyhodnoceny změny v případe liniové a plošné vegetace. Po napřímení vodních toků zmizely z krajiny zbytky břehových porostů bývalých říčních meandrů, vlivem kolektivizace zmizely liniové vegetační prvky na hranicích pozemků. Tato ztráta byla částečně nahrazená nově vysazovanými stromořadími podél cest nebo nesouvislými porosty na březích upravených vodních toků a umělých melioračních kanálů. V krajině se zachovaly některé vegetační struktury vázané na význačné artefakty, které můžeme označit jako historické krajinné struktury. Příkladem jsou liniové porosty dřevin na hrázích bývalých rybníků, podél starých cest nebo skupiny či solitéry dřevin vázané na místní krajinné dominanty jako jsou kříže, boží muka apod.

Rozšíření, struktura a hustota prvků rozptýlené zeleně v krajině závisí jednak na přírodních podmínkách (primární krajinná struktura), dále na způsobu využívání krajiny (sekundární krajinná struktura) a konečně také na legislativních limitech a stupni ochrany daného území (terciérní krajinná struktura). Studie potvrdila, že nejvyšší zastoupení prvků rozptýlené vegetace je v biochorách údolních niv a v charakteristických prostorech krajinného rázu vymezených v údolních nivách Labe a dolní Doubravy. Potvrdilo se, že v krajinné památkové zóně Žehušicko, vyhlášené na ochranu kulturní krajiny s významnými stopami starých krajinářských úprav je vyšší zastoupení prvků rozptýlené zeleně než v okolní nechráněné krajině mimo krajinnou památkovou zónu.

Za posledních 60 let došlo nejen ke snížení rozsahu (hustoty) rozptýlené zeleně v krajině, ale také ke změně jejího významu a funkce. V minulosti byla využívaná k účelům, které jsou dnes převážně nevýznamné a druhořadé (zdroj dřeva, případně květů nebo jiných částí rostlinné biomasy, sběr ovoce, vyznačení hranic pozemků apod.). V současnosti převládá její funkce estetická, krajinotvorná. Úbytek rozptýlené zeleně ve volné krajině je částečně kompenzován současným šířením nelesní dřevinné vegetace v krajině procesem sukcese na opuštěných a nevyužívaných plochách.

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ACCURACY ASSESSMENT AND CLASSIFICATION EFFICIENCY OF OBJECT-BASED IMAGE ANALYSIS OF AERIAL IMAGERY

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ABSTRACT

Following text is focused on finding a proper balance between classification accuracy and classification efficiency of object based image analysis of aerial imagery. For image classification were used tools of Feature Analyst, an ArcGIS extension, which are based on image filtering and searching for homogeneous segments corresponding to the threshold values defined by the training areas and corrected with tools of object recognition.

The classification accuracy was assessed using the error matrices and calculating user's and producer's accuracy. To evaluate the time and work consumption, index of classification efficiency was introduced, which is a weighted value of accuracy and number of objects. To evaluate the tools of object recognition, the principle of fuzzy logic was used, which calculates accuracy with inclusion of alternative category.

For the study was used a cut of aerial imagery of protected area of Křivoklátsko as a typical example of the character of available image data in the territory of Czech Republic – large area of fields, forests and meadows with a very heterogeneous character, water body with sun reflection, net of narrow roads and small villages.

From the final values of accuracy is obvious, that Feature analyst provides comparable results with other authors. From the point of view of classification efficiency, application of tools of object recognition and its effect on the time and work consumption, it is a question of the extent of study area and the heterogeneity of the features of the physical world on the image data.

Key words: OBIA, accuracy assessment, feature analyst, classification efficiency, object recognition

1. Introduction

In the territory of the Czech Republic is aerial imagery currently the most accessible image data that can be used for mapping the land cover structure and its time-changes. The imagery covers the whole state territory in several time horizons (the oldest ones date back to the mid-20th century) in a detailed spatial resolution. Until recently, the evaluation process was based above all on a visual interpretation and manual vectorization. The development of image analysis methods has enabled particular automation and application of procedures.

The basic unit for an object based image analysis (OBIA) is a group of spatially related pixels with similar characteristics, which are joined by the process of segmentation until the classification criteria (shape, size, homogeneity) are met (Dobrovolný 1998). Through these methods, the image is divided into segments (objects) that relate to features in the physical world and correspond with features in the input image (Železný 2005).

The basic principle of object-based image analysis is the search for homogeneous areas within the image data. In this study were used the tools of Feature Analyst, an ArcGIS extension, to classify the aerial imagery. The tools are based on image filtering, during which the filter window searches through the image for homogeneous segments corresponding to the threshold values defined by the training areas. Classification runs together with the segmentation, and during one set of iterations all image areas which correspond to the given conditions (one class of land cover) are found.

Since the spatial delimitation of naturally homogeneous areas in the landscape, and therefore also in the image data, often do not match the individual areas of land cover, the classified vector features also do not correspond with features in the physical world.

Accuracy assessment is currently perceived as a fundamental component of the thematic classification of the image data, although a standard evaluation method has not yet been accepted (Foody 2002). The general potential of the accuracy evaluation was discussed, for instance, by Foody (2002 and 2006), and an evaluation of the result accuracy by means of segmentation and object-based image analyses by Bruzzone (2008) and Chmiel (2010).

Accuracy assessment is also often specified by the principle of fuzzy logic. Benz (2004) defined fuzzy logic as multi-valued logic quantifying uncertain statements. The basic idea consists in replacement of the two Boolean logical statements "true" and "false" with a continuous range of values in the interval <0,1>, where "0" means "false" and "1" means "true". All values between "0" and "1" represent a transition between the statements "false" and "true" (Benz et al. 2004).

This principle is used when interpreting analysis results, where a numerical value of affiliation degree to various categories of the analysis is assigned to the individual

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features. However, the principle is only used by analysis methods which first segment the image into homogeneous features, and in the second step classify all categories on the basis of training areas represented by segmented homogeneous features. The affiliation values are calculated by means of affiliation equations.

The classification accuracy depends mostly on the character of the imagery, on the definition of the training areas and on the number of the classification iterations. The specific value of accuracy (both producers and users) is calculated using the error matrices, where the area of correctly- and wrongly-classified objects is compared. In general – the better specified training areas and the higher number of iterations, the higher is the final accuracy but also the higher number of objects that correspond to one feature in the physical world and bigger time consumption. Because of that a proper balance between classification accuracy and classification efficiency must be found.

2. Study area

For the needs of this project, emphasis was put during the selection of the study area on the data representativeness with respect to the character of commonly available data sources. The selection of classification categories was aimed to the needs of a hydromorphological evaluation of the watercourses, which needs to evaluate, in addition to the basic categories of land cover, the presence of single trees and green belts on the banks and along the rivers.

As the study area was used a mosaic of two orthorectified aerial photographs taken above a protected landscape area in the Křivoklát region (near the village of Kalinova Ves) in the Berounka river basin. It represents a settled, rural landscape with a road network, a significant proportion of forest and green belts, and a watercourse with an alluvial plain.

The photographs were scanned in the spring 2003, with a spatial resolution of 1 m; the size of the processed area was 10 km^2 (2.5 × 4 km). There are only few overshadowed features and the image data is representative in term of the homogeneity of individual features. The aim was to determine the classification accuracy and efficiency of commonly available data, which is usually complicated by cast shadows, reflecting water bodies and heterogeneity within vegetation objects of the physical world and its change during the year seasons. The features are heterogeneous within one category of land cover as well as within the individual objects. Furthermore, the various categories are represented by a similar interval of the DN pixel values. Therefore, these categories coincided during the analysis.

On figure 1 is shows a cut-out of an aerial photograph, where the internal heterogeneity of the individual objects (fields are partly bare and partly covered with crops) and their mutual diversity (some fields have differently-grown crops, others are ploughed) is obvious. The similarity between various land cover categories is also obvious (e.g. roads x parts of ploughed field, or meadow x fields with crops, etc.).

Fig. 1 A cut-out of the aerial photograph of the study area

3. Methods

3.1 Image Analysis

The Feature Analyst extension works on the basis of defining the training sets delimited in the image. The image is classified and segmented in the same time while the filter window searches through the image for homogeneous segments corresponding to the threshold values defined by the training areas. During one set of iterations all image areas which correspond to the given conditions (one class of land cover) are found. It is possible to use a predefined settings for single land cover classes which takes into account the size, shape and homogeneity of searched features (e.g. long and narrow objects for the class "roads"). A user settings is also possible.

The objects classified according the training sets (spectral class) are however not identical with a class of the land cover (information classes). For example the spectral class "permanent herbage" can be further divided, e.g. into the information classes "meadows", "gardens", "parks", etc. Or, on the contrary, the classes "red roofs" and "brown roofs" can be merged into the "built-up area" category.

In the second step objects can be automatically removed on the basis of the DN pixel values or by means of the characteristics of the object's shape and size. According to (Opitz 2008), the combination of methods that works with both spectral (radiometric) pixel values and spatial parameters is called "object recognition".

The individual categories were classified in several steps. In the first step, all image features which met the given conditions were selected on the basis of the definition of the training areas. In the following steps, the wrongly-detected features were removed, and the missing ones were added.

Except the "*water*" category, the analysis began with large and very heterogeneous objects and continued to tiny homogeneous objects. First was detected the Berounka watercourse and two small water bodies. The training areas for this class were defined so widely, that there were as few as possible final vector objects for the watercourse (the individual features displaying free water body, overshadowed water surfaces, rapids sections under the weir and reflecting surfaces were merged into one whole). It was also essential that the definition of water body features remained in contrast to the bank zone. The classification resulted in a layer of 936 objects, in which field and forest features were also delimited, in addition to the successful classification of the water bodies. Since only six features corresponded to the water bodies, the water bodies were exported into a single layer and the layer was removed from the vector mask for the next analysis. So it does not represent a real result of the classification, and therefore the user's accuracy was expected to be 100%.

Next, the forest features were analysed. In the addition to the forests were also delimited the features of green belts along the watercourses and the fields covered with crops. These wrongly-classified areas were removed by means of the shape and size characteristics of the object recognition (large homogenous forest features *vs.* small non-compact wrong features). The minimum area of the features was set as large as the built-up area could not be includeded into the layer (the DN pixel value of some roofs corresponds to the DN pixel value of forests).

As third was analysed the built-up area and the roads. The clutter was removed using characteristics of the size of the object recognition. By removing the roads layer from the vector mask were definitively separated the areas, which could otherwise be joined over a narrow road in one object (e.g. field – road – field, field – road – meadow, etc).

Then, the "field" land cover class was analysed. The fields in the study area had a very heterogeneous character at the moment of aerial scanning (Figure 1) and six different training sets had to be defined to detect all objects in the study area. Collision with the "meadow" land cover class occurred very often. Clutter was removed using characteristics of compactness and size by means of object recognition.

The "meadow" class was then analysed. Since other "green" areas had already been removed from the vector mask, the user's accuracy should have been 100%. The minimum classification area was set as large as the gardens were not included in this class.

The "green belts" class was analysed in order to detect the vegetation zones in the alluvium along the watercourses. This class was distinguished from the "single trees" on the basis of the size criterion.

Finally, the "garden" class was analysed. In this layer were included all remaining unclassified image areas. A total of 2,338 features were classified in this category, but the clutter could not be simply removed from the layer. Therefore alow value of user's accuracy can be expected in this category.

3.2 Accuracy assessment

The accuracy was assessed by comparing the areas of correctly- and wrongly-classified features from both points of view – the producer's and the user's. The producer's accuracy gives the probability with which the physical world feature (captured in the image data) is correctly classified. The user's accuracy gives the probability with which the vector feature corresponds to the physical world feature.

The classification accuracy was determined on the basis of two different approaches – one using the error matrix, and another error matrix based on a fuzzy evaluation according to Sarmento (Sarmento 2008). The fuzzy evaluation was based on the creation of a reference file of features, where to each feature was assigned two possible categories of land cover – the primary reference class and the alternative reference class.

The feature reference file was selected from the features set created by means of an unsupervised segmentation. The unsupervised segmentation works with the image data without setting the training areas, i.e. only according to the definition of the number of final classes, number of the iterations, and size of the minimum area. The unsupervised segmentation thus results in homogeneous image objects, whose degree of homogeneity is not defined by the user but results from the natural process of segmentation. On figure 2 are shown two examples of classification results and unsupervised segmentation of aerial imagery.

3.3 Classification efficiency

Internally heterogeneous features of physical world are mostly divided into several large correctly-classified objects and a high number of wrongly-classified, small-area objects. The final number of vector objects within one heterogeneous physical world feature depends on the precision of definition of the training sets. The more precise definition, the higher is the accuracy, but also higher number of the vector objects and bigger time consumption. To evaluate the time and work consumption, a classification efficiency index was defined (formula 1).

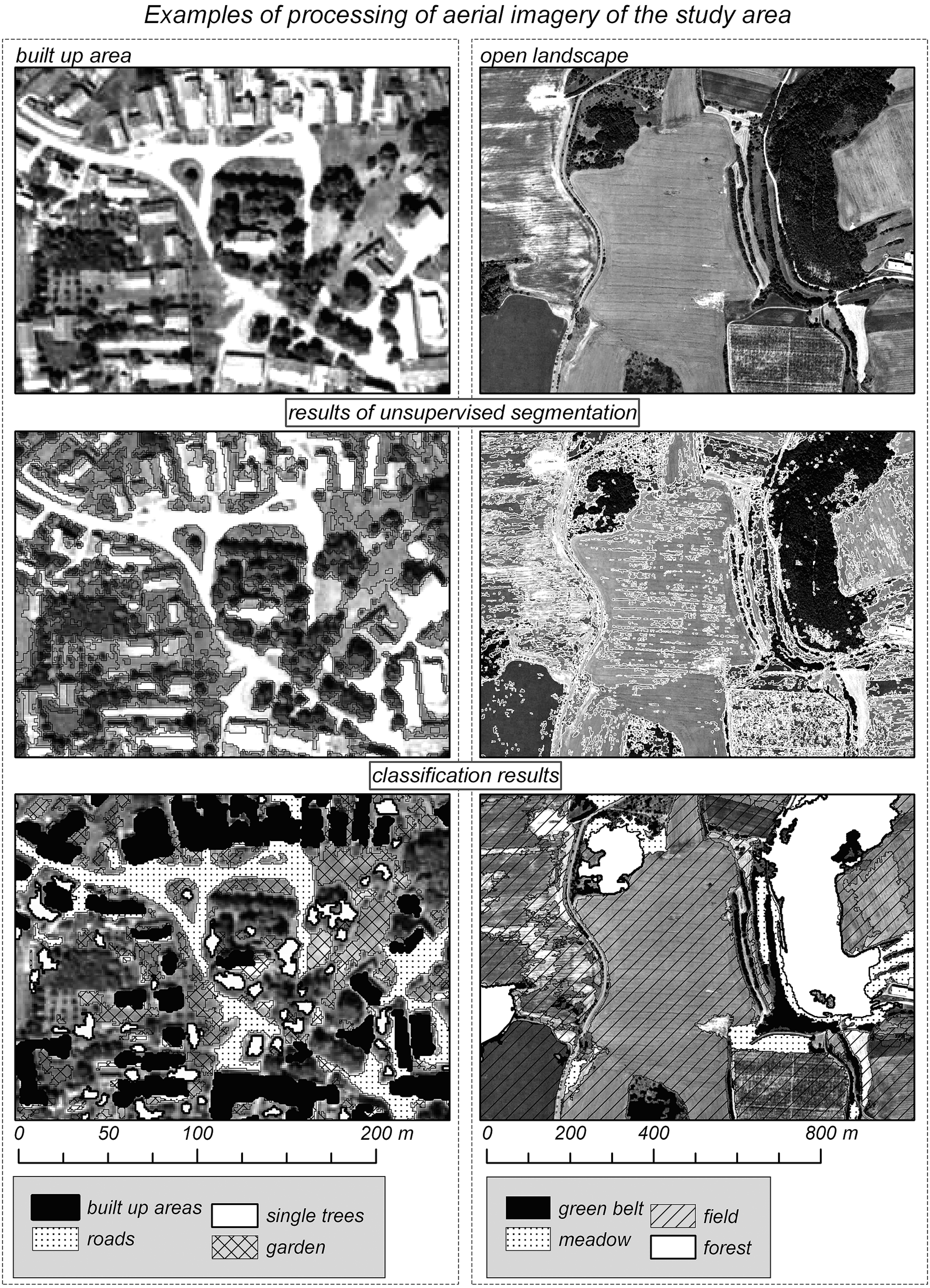

Fig. 2 Examples of processing of the aerial imagery

The index normalizes the frequency of the features by their area and is based on the principle of weighted values, which assigns different importance to the individual elements of the file. The assignment of importance can be viewed from two different points. The application of the index according to theof object frequency suppresses the importance of a large number of small-area objects and emphasises the importance of a small number of large objects. According to the object area, the small suma of areas of small objects is balanced by their high frequency, and the importance of large objects is decreased by their low frequency.

The formula (1) for the index calculation is as follows:

$$Obj(a) = \frac{n(a)\,\Sigma\, p(a)}{N\,\Sigma\, p} \cdot 100 \qquad (1),$$

where $Obj(a)$ is weight index of features in interval a,
$n(a)$ is number of features in interval a,
$p(a)$ are areas of features in interval a,
N is number of features in analysed file,
p are areas of features in analysed file.

The indices were calculated for single intervals (Table 1), inserted into error matrices (the frequency in the "*a*" interval was multiplied by the index of the "*a*" interval), and the producer's efficiency and user's efficiency were determined. For the calculation was used a data file created by removing the reference file features from the final file to provide the independence of the reference file The final file contains 6,135 features.

Tab. 1 Values of the index *Obj*(*a*) for individual intervals

Area interval	***Obj*(*a*)**
≤30 m²	0.1878
(30–50> m²	0.0839
(50–100> m²	0.177
(100–1,000> m²	0.7267
≥1,000 m²	5.8465

It must be stressed that this is not the classification accuracy. The final value includes the internal heterogeneity of features in individual categories (represented by the feature frequency) in addition to the accuracy, and therefore it also includes the efficiency and time consumption. The "efficiency and time consumption" term means multiple definitions of the training areas and the whole classification procedure, until the physical world features are represented in the given category by the vector features as much as possible. The index is not exactly numerically expressed, but if the training areas and the analysis are correctly set, it can generally be said that the lower the user's accuracy, the higher the heterogeneity of the physical world features and the lower the classification efficiency, as well as the need for a higher number of training sets.

3.4 Accuracy assessment using the principle of fuzzy logic

In the case of processing with the Feature Analyst, where classification runs together with segmentation, the fuzzy logic principle has not been used for classification but rather for determination of the classification accuracy. The reason for using fuzzy logic consisted in the fact that the areas (which actually represent various categories of land cover) are represented in the image data by pixels in the same DN value interval, and in terms of processing and the search for image homogeneous areas, they are assigned to the same category. A typical example is the grown green parts of fields versus herbage areas in meadows and gardens. These areas can be distinguished by feature recognition on the basis of shape and size characteristics, but only to a limited extent.

These objects were thus detected correctly according to the definition of the training set; however, they did not belong to the classified category and it was not possible to remove them from this category using the tools of object recognition. For that reason was defined the alternative category, as the second possible classification category into which the object could be assigned, according to the training set. The use of the alternative category should help to evaluate the potential of the Feature Analyst for detecting the image homogeneous areas more precisely.

When determining the classification accuracy, the following values was assigned to the reference object:

- 1 if the feature was classified correctly,
- 0.5 if the alternative category corresponded to the character of the physical feature,
- 0 if the feature was classified wrongly.

By means of the contingency tables, error matrices were formed, and the producer's and user's accuracy were determined for all classification categories. The accuracy was calculated according to the frequency and the area of individual features. If the classification results did not correspond to the reference category but complied with the alternative category, only the half-value (both of frequency and area) was taken into account.

4. Results

4.1 Accuracy assessed by error matrices

Classification of aerial images of the study area resulted in a file of 6,459 vector objects, classified into 9 categories of land cover (hereinafter the "*final file*").

In the first part of classification, the image was searched for large features (forest, field, meadow, water bodies, green belts) and uniquely detectable features (roads, built-up area). The final layers for these catego-

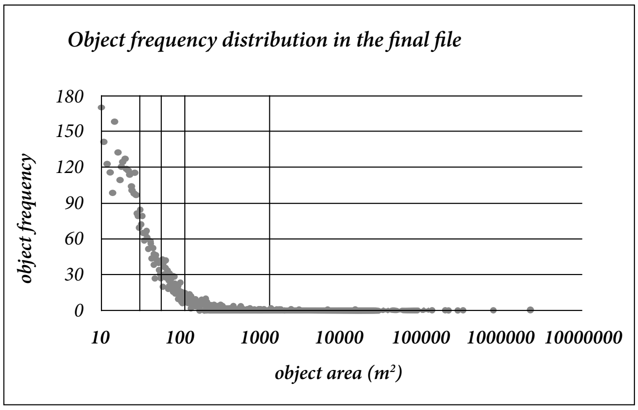

Fig. 3 Object frequency distribution in the final file, semi-logarithmic diagram with delimitation of limits of the size categories, the logarithmic scale was used for the category axis x

ries contain (in comparison with other categories) a small number of objects whose area is relatively large or close to the physical world features. For these categories, we can expect both the producer's and user's accuracy to be high.

In the second part of classification, the image was searched for small-area features (gardens, single trees), which are not typical in terms of their spectral reflectance, but are different due to their size and shape. Besides the searched features, so-called remaining areas (smaller areas in the middle of large heterogeneous features) were also assigned to these categories during the classification. The vector layers of these categories contain a large number of small-area features. The high number of "remaining areas" caused a low value of the producer's accuracy, while the user's accuracy was relatively high. This means that a high percentage of, e.g. gardens in the study area were identified correctly in the image, but a low percentage of vector objects classified as gardens, really are gardens.

The reference file intended for a comparison of results has traditionally been created by manual vectorization. In the case of this study area, the individual physical-world objects are internally heterogeneous, and therefore one physical object is represented by several vector objects. For the reasons of a better accuracy determination as well as time savings, the reference file was selected from the final file.

The selection of the reference file features was first limited by the object area (according to frequency distribution in both the final file and categories of land cover), and then were objects chosen randomly. The frequency distribution in the final file is displayed in the following semi-logarithmic diagram (Figure 3).

The frequency distribution was studied in five intervals with the limits of 30 m^2, 50 m^2, 100 m^2, 1,000 m^2, and over 1,000 m^2, which covered the whole interval of obtained values. The interval limits are marked (vertical lines) in figure 3, and were selected so that the number of features in eachinterval was equal, and corresponds to the specificity of the final categories. A percentage representation of the number of category features for the individual size intervals is provided in the following table 2.

A limit of minimum 5% was set for the selection of features from the final file for the reference file. A total of 324 features were selected for the reference file and the percentage representation varied within the individual categories (5–50%). For example, 50% of the features from the water body category were selected; however, this represented only three features. On the contrary, 108 features from the garden category were selected, representing, however, only 5% of all features classified as a garden.

The selection of the reference objects itself was run in the database table outside the ArcGIS workspace to avoid a preferential selection of wrongly- or correctly-classified features and the reference file was independent. Then was each object assigned to a correct classification category (according to aerial imagery), and by means of contingency tables were created error matrices (using the area

Tab. 2 A percentage representation (%) of the analysis categories, by size intervals, for the final file (*Ff*) and the reference file (*Rf*), with the number of features (*No.*) given for a random selection in the individual intervals

Size interval (m^2)	≤30			(30–50>			(50–100>			(100–1,000>			≥1,000			Total		
Final file (*F*) / Reference file (*Rf*)	*Ff*	*Rf*		*Ff*	*Rf*		*Ff*	*Rf*		*Ff*	*Rf*		*Ff*	*Rf*		*Ff*	*Rf*	
Percentage share (%) / number of features (*No.*)	%	%	*No.*	%	%	*No.*	%	%	*No.*	%	%	*No.*	%	%	*No.*	*No.*	*No.*	%
Roads	2	3	3	5	4	2	5	5	3	11	9	6	10	5	2	344	16	5
Forest	0	0	0	0	0	0	0	0	0	1	3	2	16	27	11	73	13	18
Meadow	0	0	0	0	0	0	0	0	0	0.2	2	1	17	29	12	73	13	18
Field	0	0	0	0	0	0	0	0	0	2	6	4	38	24	10	192	14	7
Single trees	24	24	27	29	30	15	25	25	14	14	12	8	0	0	0	1,392	64	5
Green belts	14	13	15	29	30	15	26	25	14	30	26	17	13	7	3	1,416	64	5
Water body	0	0	0	0	0	0	0	0	0	0.2	3	2	1	2	1	6	3	50
Garden	59	59	66	30	30	15	22	23	13	22	20	13	4	2	1	2,337	108	5
Built up area	1	1	1	7	6	3	21	21	12	20	18	12	2	2	1	626	29	5

Tab. 3 User's and producer's accuracy and classification efficiency (all values in %)

	Roads	Forest	Meadow	Field	Single trees	Green belts	Water body	Garden	Built-up area
producer's accuracy	95	99	96	97	78	95	99	76	96
user's accuracy	93	96	100	99	44	92	100	52	98
efficiency – producer's view	87	93	72	84	70	79	95	73	93
efficiency – user's view	86	72	100	89	47	81	100	40	98

Tab. 4 Accuracy assessment using the alternative categories, values in %

	Roads	Forest	Meadow	Field	Single trees	Green belts	Water body	Garden	Built-up area
producer's accuracy	100	93	98	95	97	95	100	78	100
user's accuracy	94	66	95	100	87	100	100	79	84

of objects) and calculated producer's (hereinafter PA) and user's accuracy (hereinafter UA).

In the categories classified in the first part (forest, field, meadow, water bodies, green belts, roads and built-up area) were reached values of more than 90%, while the categories that included a high number of remaining areas reached relatively lower values. All values are written in table 3.

Classification efficiency was calculated also using contingency tables and error matrices, but the area of the objects was weighted by the quantity of objects according to formula 1. Values of efficiency from the producer's and user's point of view are written in table 3.

4.2 Accuracy assessment using the principle of fuzzy logic

For accuracy assessment was used the result of unsupervised segmentation. This divides the image into homogeneous features on the basis of definition of the minimum area size, number of classification categories, size and shape of the input representation, and number of iterations. The result of the unsupervised analysis is represented by objects that should be internally homogeneous and should represent (or should be a part of) only one physical world feature.

A total of 60,156 objects were created, from which was selected a reference file consisting of 263 objects with identical frequency distribution in the size intervals (analogously to the selection of the reference file described above). To all objects in the reference file were then assigned the results of classification by Feature Analyst, the reference category according to image data, and the alternative category. Accuracy values are given in the following table 4.

5. Discussion

The number of reference features is always limited within the study, and is mostly a compromise between the most accurate evaluation possible and time efficiency (Grenier 2008). The particular numbers are from within tens and hundreds of reference samples. For example, Huang (2008) used 257 reference features, and Xiaoxia (2005) determined the accuracy on the basis of 65 checkpoints. The potential for the exact determination and calculation of the minimum number of reference points was discussed in detail by Grenier (2008).

The accuracy of object-based analyses of aerial imagery by the Feature Analyst extension mainly depends on the character of the analysed data. The homogeneity of individual areas is affected by vegetation season, overshadowed of the objects, and the sun reflection in the water bodies. The second important factor is the selection of the classification categories and correct definition of the training areas.

The above mentioned conditions influenced especially the number of final objects within one feature of physical world and within a category, and time and work consumption. Therefore the number of objects was included in the calculation of classification efficiency as a weighted index.

As for the accuracy assessment, in the main analysis categories were achieved values of 90% for both producer's and user's accuracy. As to the "single trees" and "gardens" categories, the producer's accuracies were 78% and 76%, and the user's accuracies 44% and 52%, respectively. Both categories were classified at the end of the analysis. Since they represent small-area features of various shapes and radiometric characteristics, it was not possible to easily remove the wrongly-classified objects from these categories using tools of object recognition. The values and number of reference objects are comparable with other authors (Table 5).

The highest differences of accuracy and efficiency values were noticed in the land cover categories with very heterogeneous character in the image data – forests, fields and meadows (Figure 2). These categories are in the image represented with a few large objects. From the point of view of time and work consumption it would be easier in a small-extent study area, to vectorise these land cover categories manually and run the classification for the categories with small heterogeneous objects in a masked-out extent.

In the comparison of accuracy assessment with and without alternative category were noticed the highest differences in the categories "forest", "garden" and "single trees", whereas trees in the forests were often classified as

Tab. 5 Comparison of the analysis results with other authors, *the author analysed the data by means of Feature Analyst extension

	Study area		Honková (2006)		Huang (2008)		Xiaoxia (2005)		Rahman (2007)		Walker (2005)		Arroyo (2010)	Weih (2009)*	
	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	PA	PA	UA
Roads	95	93	76	56	80	58	75	60						87	94
Forest	99	96	89	97							88	99	98	67–91	56–87
Meadow	96	100	75	53									49	91	84
Field	97	99	87	79									87		
Green belts	95	92	84	73											
Water body	99	100			90	100	100	91	100	100			83	90	100
Built-up area	96	98	54	79	76–100	82–100	80–100	67–80	97	80			99	86	86
Data source	Aerial RGB		Aerial BW		QuickBird		QuickBird		IRS P6 LISS III		Aerial RGB		Ultra Cam-D	various data	
Spatial resolution	1 m				MS, 2.44 m		0.7 m, pansharp		23.5 m		0.61 m		0.25 m		
Reference file	minimum 5% of class				257 ref. features		65 points (pixels)				500 points		50 points in class		

single trees, or garden. So the errors were caused rather by wrong object recognition than a wrong classification This also shows, that manual vectorisation of large heterogeneous objects would put more precise in the classification accuracy.

Acknowledgements

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RÉSUMÉ

Přesnost a efektivita objektové klasifikace leteckých snímků

Článek se zabývá objektovou klasifikací výřezu leteckých snímků z území CHKO Křivoklátsko v okolí obce Kalinova Ves. Sledována je především přesnost objektové klasifikace v porovnání s její efektivitou, pracností a časovou náročností zpracování. Pro zpracování leteckých snímků byly použity nástroje extenze Feature Analyst pro ArcGIS, pracující na základě vyhledávání homogenních ploch v rámci obrazu, které odpovídají kriteriím nastaveným pomocí trénovacích ploch a pomocí tzv. rozpoznávání objektů.

Přesnost klasifikace byla stanovena pro jednotlivé sledované kategorie krajinného krytu pomocí kontingenčních tabulek a chybových matic na základě referenčního souboru objektů, který z hlediska počtu a velikosti objektů odpovídal rozložení objektů v jednotlivých kategoriích. Byla sledována přesnost jak z hlediska uživatele (zda všechny vektorové objekty, které reprezentují objekty reálného světa v rámci jedné kategorie, byly klasifikovány správně), tak z hlediska zpracovatele (zda objekty v rámci jedné kategorie byly klasifikovány správně). Zároveň byl definován index efektivity, který přesnost klasifikace váží počtem objektů v rámci kategorie, čímž je do výpočtu zahrnuta i pracnost a časová náročnost zpracování.

Přesnost klasifikace byla rozšířena i o tzv. alternativní kategorii využívanou v rámci fuzzy principu, tedy druhou možnou kategorii, do které mohl být objekt zařazen s ohledem na radiometrické hodnoty definované pomocí trénovacích ploch. Porovnáním výsledků přesnosti klasifikace se započtením alternativní kategorie a bez jejího započtení je možné posoudit úspěšnost rozpoznávání objektů v jednotlivých kategoriích.

Z hlediska zpracování je možné rozdělit výsledné kategorie krajinného krytu na kategorie, které jsou tvořeny několika velkými plochami s heterogenním charakterem na obrazových datech (pole, les, louky), kategorie, které jsou tvořeny velkým počtem plošně malých objektů s radiometricky homogenním obrazem (komunikace, zastavěná plocha), a kategorie, které mají podobnou radiometrickou definici jako jiné kategorie a je možné je identifikovat pouze pomocí funkce rozpoznávání objektů (zahrada vs. louka, telené pásy podél toků vs. les).

Obrazově heterogenní kategorie byly klasifikovány v první fázi a pro následné zpracování byly z klasifikační masky odstraněny. Z porovnání přesnosti se započítáním alternativní kategorie, přesnosti bez jejího započítání a s efektivitou klasifikace vychází, že z hlediska pracnosti a časové náročnosti (s ohledem na rozsah zpracovávaných dat) je vhodnější vytvořit vektorový obraz těchto kategorií pomocí manuální vektorizace. Oproti tomu plošně malé a radiometricky homogenní objekty jsou poté v obrazových datech identifikovány bez pracného několikanásobného definování trénovacích ploch, časově náročné vícenásobné iterace a rozpoznávání objektů. Z hlediska přesnosti zpracování jsou výsledky dosažené pomocí extenze Feature Analyst porovnatelné s výsledky, které byly dosaženy v pracích jiných autorů.

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DISPLAYS OF HARD COAL DEEP MINING IN AERIAL PHOTOS

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ABSTRACT

Deep hard coal mining manifests itself in the landscape in a specific way: primarily through anthropogenic landforms and secondarily through land cover changes not directly related to mining activity. A majority of these displays can be interpreted using aerial photos. Multitemporal data then make it possible to analyse the development of identified displays. However, correct interpretation is based on a profound acquaintance with the displays of deep coal mining in aerial photos. This article focuses on the identification of primary and secondary displays of deep hard coal mining in aerial photos as well as the interpretation of elementary landscape processes that are conditioned by mining.

Key words: visual photointerpretation, aerial photo, anthropogenic landforms, landscape changes, Ostrava-Karviná Mining District

1. Introduction

Aerial photos represent a significant data source of ongoing landscape transformation with regard to relatively high dynamics of anthropogenically conditioned landscape changes in hard coal deep mining areas. The study of quality photos of mining displays in the landscape is based on the principles of visual photointerpretation the aim of which is to identify individual objects and assess their importance (Jensen 2006). Aerial photointerpretation starts from visual perception of the objects of the outer world (Ciolkosz, Miszalski, Oledzki 1999).

The principles of photointerpretation have been developing on the basis of empirical experience for more than 150 years (Jensen 2006).

Visual aspect and character of objects in images are identified and described using interpretation criteria (Čapek 1978; Ciolkosz, Miszalski, Oledzki 1999; Pavelka 1999; Jensen 2006). Elementary interpretation criteria include location, tone and colour, size, shape, texture, structure, shade, height and depth, gradient, appearance, position and connection. Relationship between the appearance of an object in an image and its appearance in a moment of ground observation is expressed by means of a photointerpretation key (Čapek 1978). Correct interpretation is thus always dependent on the interpreter's experience.

The photointerpretation key is necessary for the correct evaluation of the content of an aerial photo. Its importance increases when interpreting photos of areas with specific displays of the landscape configuration and with the high dynamics of ongoing landscape changes. The aim of this article is to characterize so far unpublished displays of hard coal deep mining in aerial photos using the example landscape of Ostrava-Karviná Mining District (OKMD). This study will therefore help interpret aerial photos of the areas of deep mining for the purpose of the evaluation of landscape changes and landscape processes, identification of anthropogenic landforms and its multitemporal changes, etc.

Displays of deep hard coal mining on the ground surface comprise specific anthropogenic landforms directly connected with mining. The very mining-related landforms include: deep coal mines, waste banks and tailings ponds (Kirchner, Smolová 2010). Other related accompanying landforms occurring in the landscape are e.g. ground subsidences, manipulation areas, reclamation areas or road and rail embankments. Landforms related to the mining of fossil fuels including excavation, levelling and accumulation activities are, in all the cases, results of secondary processes as they are not intended to be the goal of mining but only its by-products (Szabó, David, Loczy 2010). Under given climatic conditions, the processes of natural denudation produce secondary (semi-anthropogenic or natural-anthropogenic) landforms on these newly developed surfaces.

Subsequent subsurface coal mining accelerates landscape processes that can be identified in aerial photos on the basis of land cover changes as, for instance, in the case of abandonment (urban fabric changing into semi-natural areas) or water body emergence that manifests itself mainly in the formation of submerged ground subsidences.

2. Study area and methods

In this study, displays of deep hard coal mining in aerial photos are presented on the area of the Ostrava-Karvi-

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ná Mining District (Figure 1). The Ostrava-Karviná Mining District (OKMD) is a major hard coal district in the Czech Republic representing the southern part of the Upper Silesian Coal Basin, a larger part of which occupies neighbouring Poland. From the point of view of geology, it is formed by the Ostravian part comprising Ostrava and Orlová Basins and the Karviná part. Outside of our interest area lies the Beskydian part of the OKMD where coal mining practices have so far been taking place to a limited extent (Machač, Langrová a kol. 2003). In the 1850s the Ostrava and Karviná regions turned into areas to industrialize rapidly thanks to high-quality black coal deposits. One-time agrarian regions gradually changed into industrial areas dominated by mining, metallurgic and chemical industries. All these activities, particularly coal mining, had a considerable effect on the Ostrava and Karviná landscape character.

The displays of deep coal mining in the landscape were detected using contact copies of archive black-and-white aerial photos from the period of 1947 to 1995 (provided by the Military Geography and Hydrometeorology Office in Dobruška) and a coloured orthophoto from 2003 and 2009 (map service of the Portal of the Public Administration of the Czech Republic). Scanned aerial photos were transformed into the S-JTSK coordinate system using polynomial transformation in the PCI Geomatica V10.3 software. Landforms was identified by means of visual photointerpretation of aerial photos in the ArcGIS 10 software. Landscape analysis was further used to determine processes (pressures) within the study area and theirs displays in aerial photos (Mulková, Popelková, Popelka 2010).

3. The displays of deep hard coal mining

Displays of deep hard coal mining interpreted on the basis of aerial photos have been divided into two basic groups:

- primary displays of deep hard coal mining: waste banks, ground subsidences, tailings ponds, manipulation areas and mine buildings and structures,
- secondary displays of deep hard coal mining: reclamation areas, dry tailings ponds, road and rail networks and vegetation-free areas.

Other deep mining related processes presented in this study include abandonment, forestation and water body formation.

3.1 Primary displays of hard coal deep mining

Primary displays of hard coal deep mining are represented in aerial photos by anthropogenic landforms directly related to mining practices. These include post-mining landforms (waste banks, ground subsidences) and industrial landforms (tailings ponds, manipulation areas).

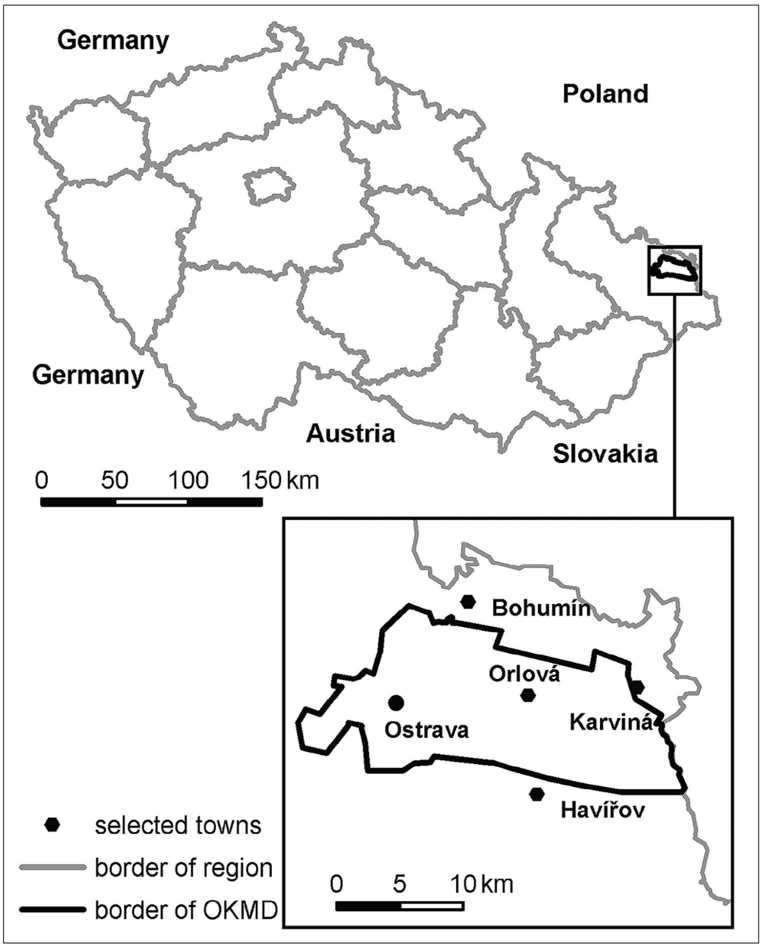


Fig. 1 Localization of the Ostrava-Karviná Mining District (OKMD) within the Czech Republic

Areas of subsurface mining can as well be identified, namely based on the presence of mine buildings and structures.

3.1.1 Waste banks

Waste banks are convex landforms whose area can reach from a few areas to tens of hectares (Havrlant 1980). They originate as a result of the deposition of extracted coal waste during deep coal mining. The OKMD area includes the following basic types of waste banks (Havrlant 1980): cone-shaped waste banks, waste piles, plate-shaped waste banks, terrace-like waste banks, flat waste piles or their combinations. Processes of natural geomorphological evolution on waste banks are faster than geological erosion in the area (Szabó, David, Loczy 2010). Geomorphological evolution is closely correlated with waste bank material, weather changes, slope gradient and vegetation cover. In some cases spontaneous ignition of deposited waste bank material is observed along with self-sustaining combustion. Losses in the volume of the burnt-out material result in further subsidence and mass movements (Szabó, David, Loczy 2010).

Active waste banks in the photos represent vegetation-free surfaces with clearly visible contours (Figure 2). They are generally found in the proximity of mine buildings.

Waste banks can be reclaimed after waste piling is terminated (Figure 3).

Waste banks characterised by self-sustaining combustion can best be identified in colour aerial photos in which the original black colour of waste bank surface is red (colour appendix Figure 18). This colouring is due to the conversion of clayey sediments due to high temperatures during combustion.

Fig. 2 (a, b) Waste banks in (a) an aerial photo from 1947 in Karviná-Doly mining area (© MO ČR/GeoSI AČR) and (b) an aerial photo from 2009 in Lazy mining area (© GEODIS BRNO, spol. s r. o.)

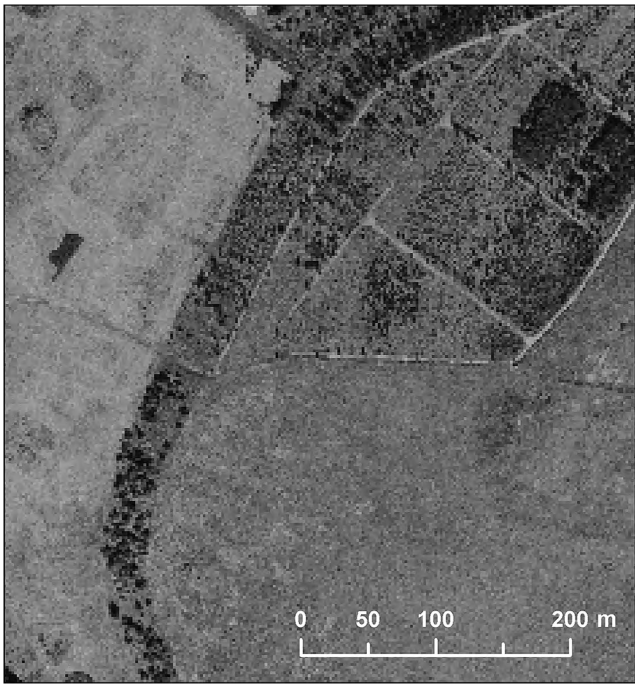


Fig. 3 The part of reclaimed Hohenegger waste bank in Lazy mining area and Karviná-Doly mining area in an aerial photo from 2003 (© GEODIS BRNO, spol. s r. o.)

3.1.2 Ground subsidences

Ground subsidences originate as a result of surface subsidence above mined-out space (Demek 1988). It concerns flat subsidences whose size depends on geological conditions, tectonics and the area and thickness of coal seams (Havrlant 1980). The subsidences can be filled with water. Submerged ground subsidences are displays of unfavourable disturbance of the regime of surface and subsurface waters the level of which has infiltrated above the bottom of subsided terrain (Zapletal 1969).

The extent of ground subsidence can best be determined on the basis of the photogrammetric evaluation of stereoscopic pairs of photos, radar interferometry and laserscanning. Clear-cut visual interpretation is particularly that of submerged ground subsidences that represent secondary mining displays and largely participate in the formation of water bodies. Unlike other water surfaces, they usually have an irregular broken shape (Figure 4, colour appendix Figure 24). It is changes in the shape and extent of water surfaces that can generally be observed when interpreting multitemporal aerial photos. Submerged ground subsidences positively affect ecological value of landscape as they increase species diversity of the territory. The banks of submerged ground subsidences provide favourable environment for wetland plant species as well as important animal species such as rare

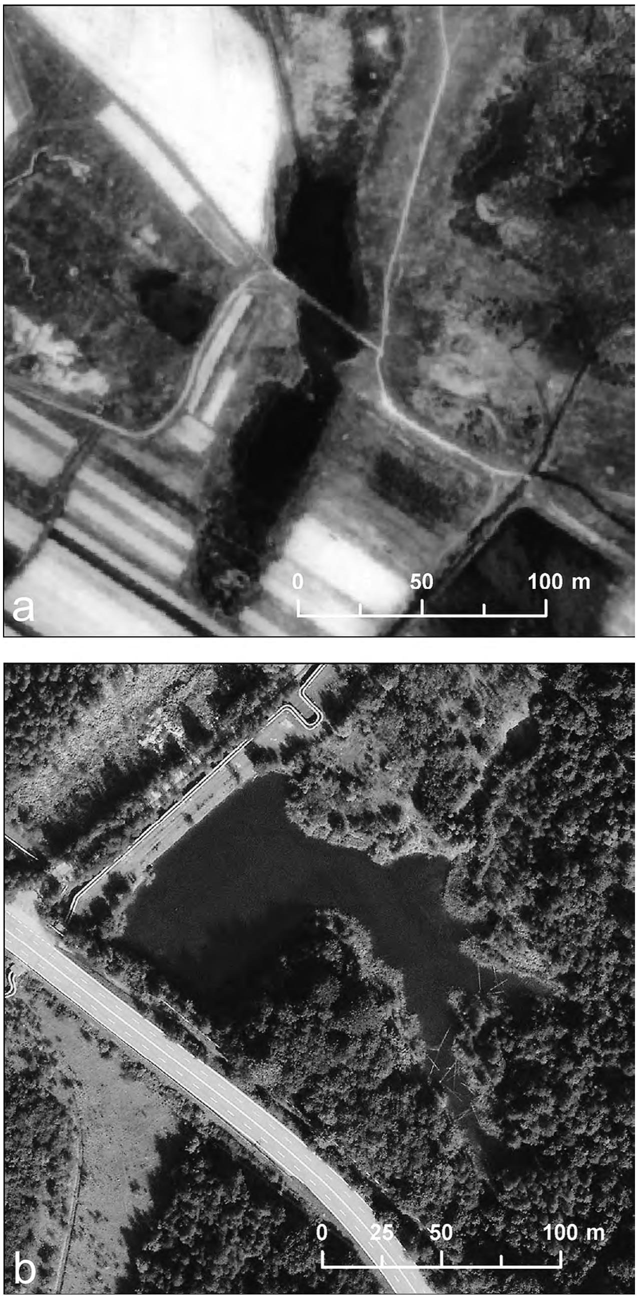


Fig. 4 (a, b) Submerged ground subsidences (a) in an aerial photo from 1947 (© MO ČR/GeoSI AČR) and (b) in an aerial photo from 2009 (© GEODIS BRNO, spol. s r. o.) in Karviná-Doly mining area

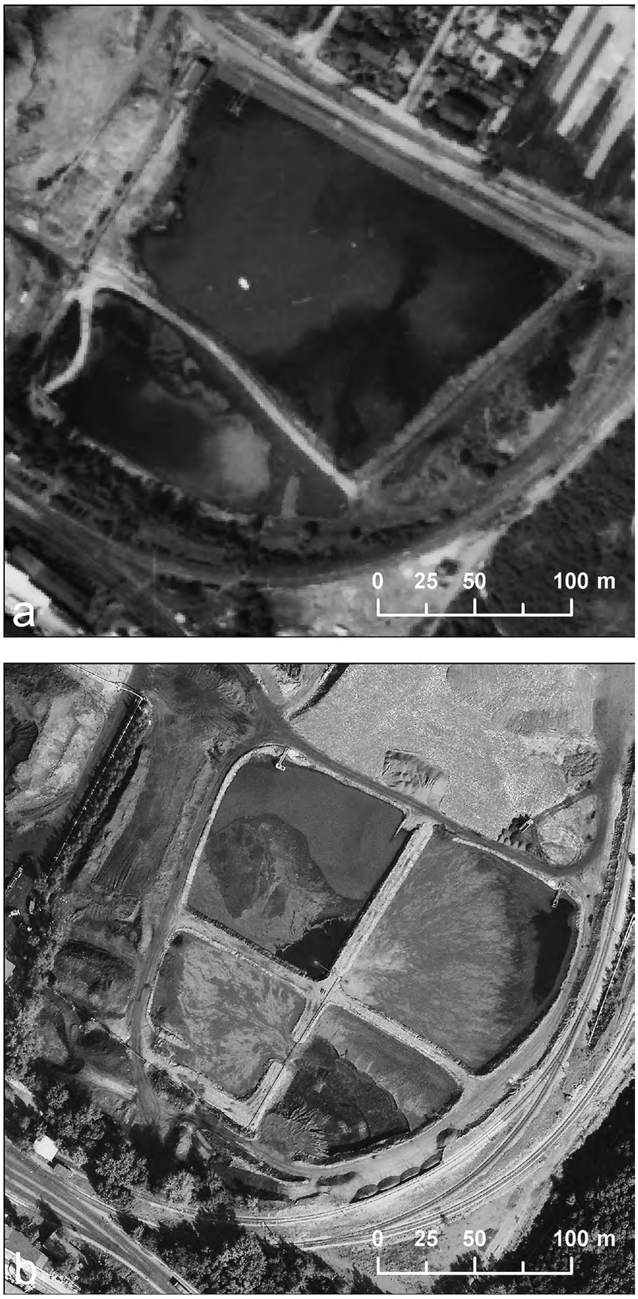


Fig. 5 (a, b) Tailings ponds in Lazy mining area in (a) an aerial photo from 1971(© MO ČR/GeoSI AČR) and (b) an aerial photo from 2009 (© GEODIS BRNO, spol. s r. o.)

invertebrates (e.g. specially protected dragonflies, crayfishes and shells) (Dolný, Ďuriš 2001).

3.1.3 Tailings ponds

The tailings pond, a natural or excavated basin, serves for permanent or temporary storing of hydraulically transported tailings (Kirchner, Smolová 2010). Hard coal deep mining area includes a few types of such ponds: flotation tailing ponds, coal ash ponds, coal sludge ponds and final sedimentation ponds. It particularly concerns water surfaces of a regular, often geometric, shape in the proximity of mine buildings (Figure 5, colour appendix Figure 22).

Final sedimentation ponds can have a character of natural water surfaces, which makes their interpretation in aerial photos difficult (Figure 6). As for problematic cases, clear-cut interpretation is possible making use of supporting data (the information about the sludge management of the mine).

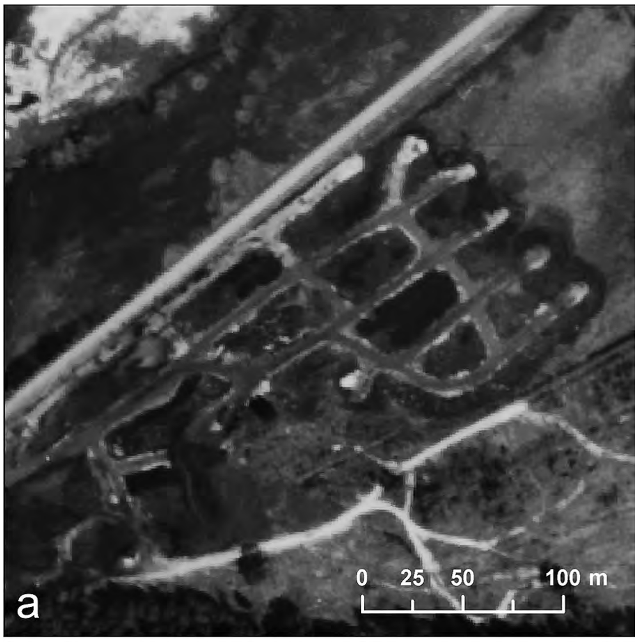
3.1.4 Manipulation areas

Manipulation areas that are generally found in the proximity of mine buildings, tailings ponds or waste banks are anthropogenic levels and terraces of various shapes and sizes including access roads. They are detected in aerial photos as bare surfaces, either convex or concave, serving as manipulation areas for e.g. transport (Figure 7).

3.1.5 Mine buildings

Individual mine buildings including winding towers and other mining-related buildings can be identified in aerial photos (Figure 8, colour appendix Figure 23).

Fig. 6 Final sedimentation pond in Lazy mining area in an aerial photo from 2009 (© GEODIS BRNO, spol. s r. o.)



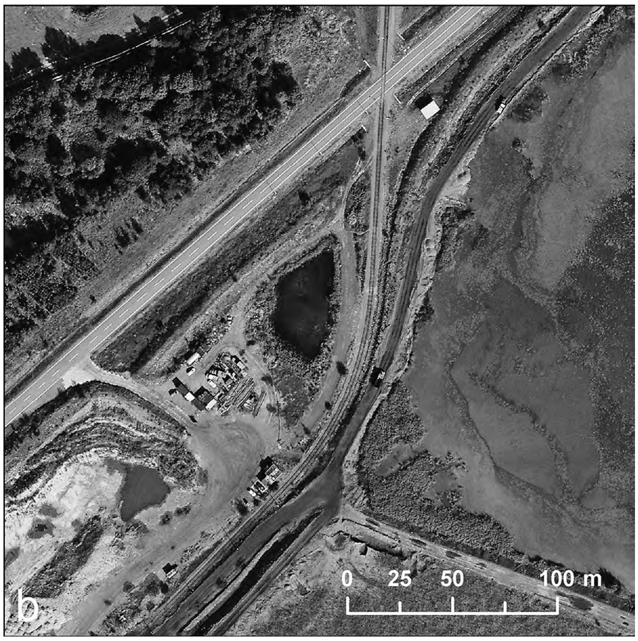


Fig. 7 (a, b) Manipulation areas (a) in an aerial photo from 1971 (© MO ČR/GeoSI AČR) and (b) in an aerial photo from 2009 (© GEODIS BRNO, spol. s r. o.)

They include temporary buildings that are renovated after the termination of mining practices. For example, the area of the ČSA 3 Mine (Jindřich Pit), which is visible in aerial photos from 1971 in the western part of the Karviná-Doly I Allotment, was covered with soil and grassed after the demolition of buildings. The contemporary orthophoto shows trees, scrub and herbaceous vegetation associations in this area. What points to one-time mining activities in this area are the foundations of old mine buildings that are visible in the orthophoto (Figure 9).

3.2 Secondary displays of deep hard coal mining

Secondary displays of deep hard coal mining identified in aerial photos include anthropogenic landforms that are not directly related to mining practices, particularly reclamation areas, dry tailings ponds and communication landforms.

3.2.1 Reclamation areas

Reclamation areas, which make up a component of reclamation construction sites, are characterised by temporary convex landforms in a shape of low flat waste banks (Figure 10). These should be levelled with the surrounding landscape after the termination of reclamation works. Reclamation areas are created in order to deal with negative effects of hard coal deep mining. The photos facilitate easy interpretation of new reclamation areas in the form of bare surfaces. Unlike waste banks, reclama-

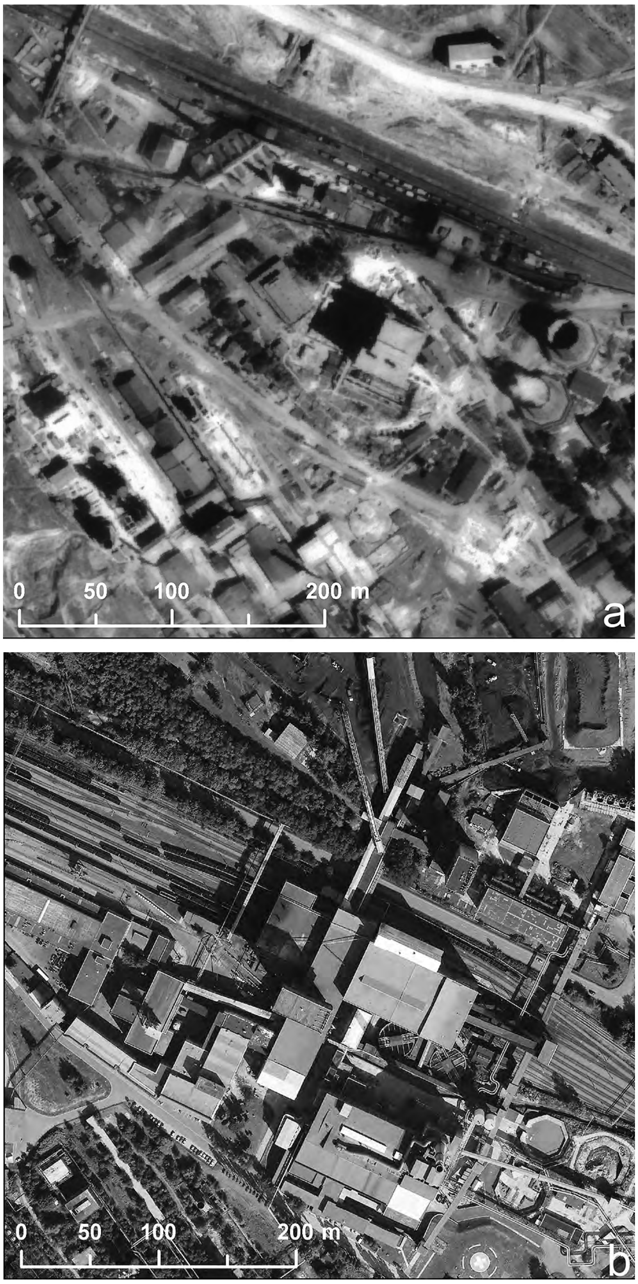


Fig. 8 (a, b) Mine buildings (a) in an aerial photo from 1947 (© MO ČR/GeoSI AČR) and (b) in an aerial photo from 2009 (© GEODIS BRNO, spol. s r. o.)

Fig. 9 (a, b) Area of the ČSA (a) in an aerial photo from 1971 (© MO ČR/GeoSI AČR) and (b) in an aerial photo from 2003 (© GEODIS BRNO, spol. s r. o.)

tion areas can be found relatively far from mine buildings. In many cases, visual photointerpretation needs to be carried out with the use of supporting data (the maps of the reclamation construction sites, documentation of reclamation etc.) in order to avoid confusion with waste banks.

3.2.2 Dry tailings ponds

These are shallow concave vegetation-free landforms that appear in the landscape after the termination of sludge management activities. Filled tailings ponds dry out and if no reclamation is carried out, they gradually overgrow with self-seeded vegetation.

Dry tailings ponds can be identified in aerial photos on the basis of their shape that usually remains preserved after the life of the ponds has come to the end (Figure 11). Clear-cut interpretation is facilitated by the comparison of time series of aerial photos.

3.2.3 Communication landforms

If some areas have been undermined, embankments are created to level surface deformations that damage communications. High embankments of up to a few meters are built due to the modification of the roads. The types of embankments that manifest themselves as lines and are easily identifiable in aerial photos involve railway and road embankments as well as embankments of engineering networks (Figure 12, colour appendix Figure 25).

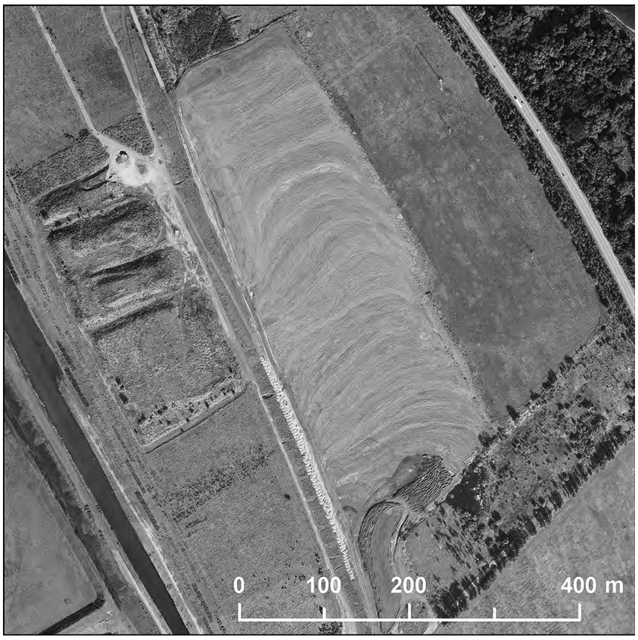


Fig. 10 Reclamation areas in Louky mining area in an aerial photo from 2009 (© GEODIS BRNO, spol. s r. o.)

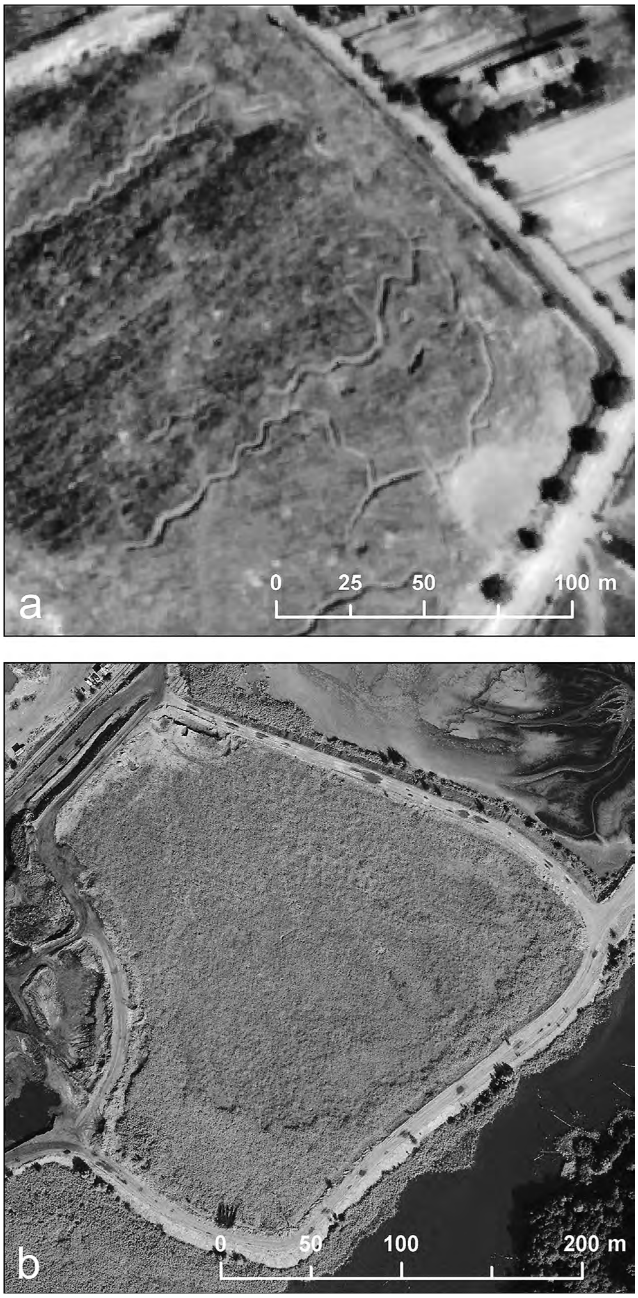


Fig. 11 (a, b) Dry tailings ponds (a) in an aerial photo from 1947 (© MO ČR/GeoSI AČR) and (b) in an aerial photo from 2009 (© GEODIS BRNO, spol. s r. o.)

3.2.4 Vegetation-free surfaces

Vegetation-free surfaces are most often related to bare surfaces appearing particularly after the demolition of buildings (Figure 13). Their duration is relatively short as they gradually overgrow with self-seeded vegetation.

4. Processes related to deep mining

Time series of aerial photos make it possible to observe landscape changes on the basis of ongoing processes that can be visually interpreted indirectly from land cover changes. The most frequent mining-related processes involve submergence and abandonment that can consequently lead to the process of forestation.

4.1 Abandonment

As based on multitemporal aerial photos, the process of abandonment can be identified at places where artificial surfaces, agricultural areas, forests or water bodies turn into semi-natural areas of trees, scrub and/or herbaceous vegetation associations (Figure 14, colour appendix Figure 21).

Undermining, which is accompanied by land surface deformations, generally leads to the disturbance of the structural mechanics of buildings and consequently to their demolition. The photos clearly show a visible decrease in the build-up area and its gradual overgrowth by self-seeded vegetation. A typical example is the Church of St. Peter of Alcantara in the northern part of the Karviná-Doly II Allotment (Figure 15). Due to mining practices in the area, the church subsided by 36 m (Popelková 2009).

Fig. 12 Railway embankment in Lazy mining area in an aerial photo from 2009 (© GEODIS BRNO, spol. s r. o.)

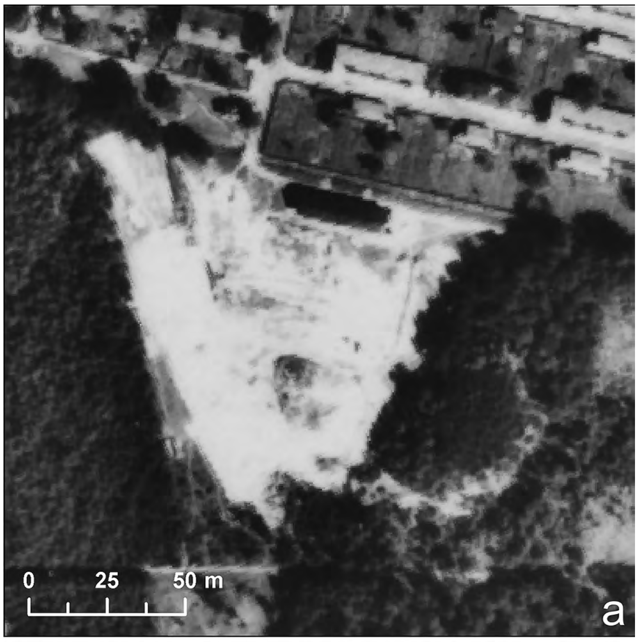


Fig. 13 (a, b) Vegetation-free surfaces (a) in an aerial photo from 1947 in Karviná-Doly mining area (© MO ČR/GeoSI AČR) and (b) in an aerial photo from 1995 in Lazy mining area (© ARGUS GEO SYSTEM 1995)

All buildings in the proximity of the church have been demolished. A submerged ground subsidence is found to the east of the church (Figure 16).

Aerial photos also help to identify the process of abandonment in originally agricultural areas which gradually turn into semi-natural areas as a result of being disused.

4.2 Forestation

In most cases, the process of abandonment is succeeded by the process of forestation in which abandoned areas overgrow with self-seeded vegetation in the first phase followed by a subsequent gradual transition to forest stands.

4.3 Submersion

Submersion represents a process of the change of artificial surfaces, agricultural areas, forests and semi-natural areas into water bodies. New water surfaces originate primarily in a close relation to mining (tailings ponds) or secondarily as a consequence of undermining (submerged ground subsidences). Aerial photo time series facilitate the identification of the process from both spatial and temporal points of view (Figure 17, colour appendix Figure 20).

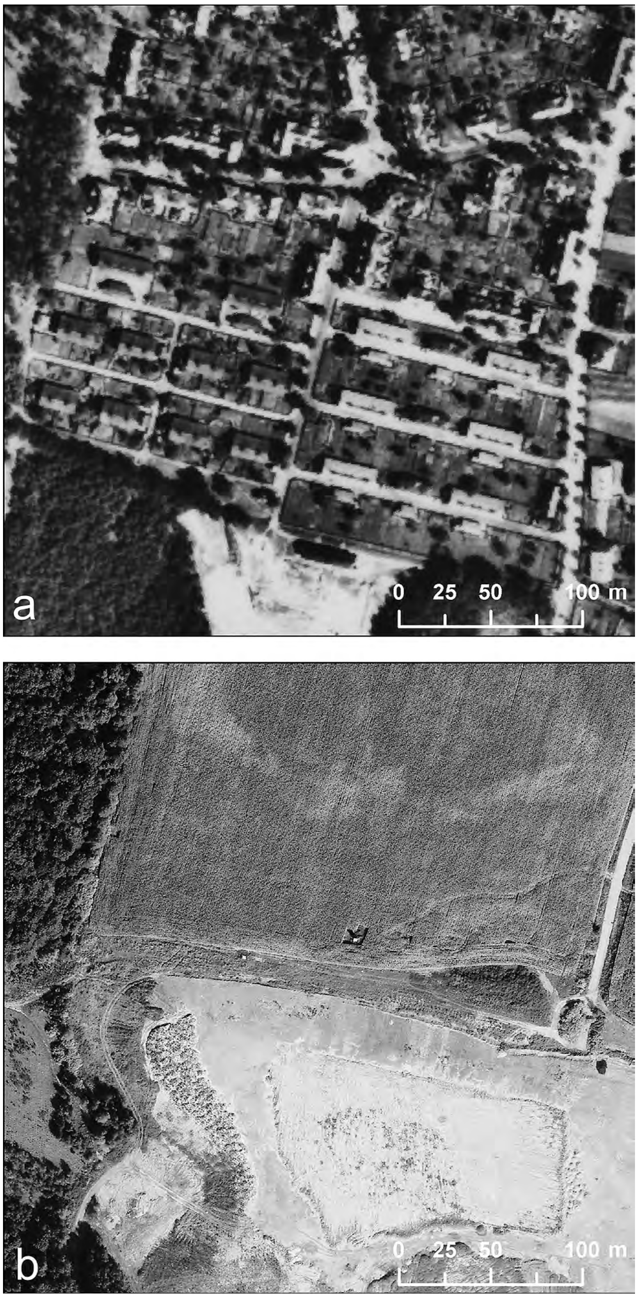


Fig. 14 (a, b) The process of abandonment in the artificial surfaces in Karviná-Doly mining area (a) an aerial photo from 1947 (© MO ČR/GeoSI AČR) and (b) an aerial photo from 2003 (© GEODIS BRNO, spol. s r. o.)

Fig. 15 Contemporary view of the Church of St. Peter of Alcantara in Karviná-Doly mining area. Photo: R. Popelková, 2007

Fig. 16 Church of St. Peter of Alcantara in Karviná-Doly mining area and its vicinity in an orthophoto from 2003 (© GEODIS BRNO, spol. s r. o.)

Fig. 17 (a, b) The area before (year 1947) (© MO ČR/GeoSI AČR) and after (year 2003) the occurrence of a submerged ground subsidence in Lazy mining area (© GEODIS BRNO, spol. s r. o.)

5. Conclusion

Aerial photo-based analysis of the effects of mining on landscape showed that both direct and indirect signs must be taken into consideration in visual photointerpretation (Figure 19). In order to identify the primary and secondary displays of mining activities, stress is put on direct signs contained in a respective photo: shape, size, tone, colour, texture and structure of an object. However, these signs must be complemented with the interpretation of indirect signs, i.e. logical signs that require deep knowledge on the research phenomena (Ciolkosz, Miszalski, Oledzki 1999). Indirect signs used in the interpretation of anthropogenic landforms include particularly the location of an object and its relations to other objects in a photo.

Unlike the primary and secondary mining displays, the processes are absent in the photos, however, they can be derived from multitemporal analysis of aerial photos. Such processes are presumed on the basis of indirect signs in combination with supporting information used in order to differentiate between mining-related processes and other processes that take place in the landscape.

The photointerpretation key of the anthropogenic landforms in the mining landscape was created by the authors for the purpose of detecting landscape changes based on visual photointerpretation of aerial photos. Although it has not been published yet, it has been applied in previously published studies (Mulková, Popelka, Popelková 2010; Mulková, Popelková 2011; Popelková, Mulková 2011; Mulková, Popelková, Popelka 2012; Popelka, Popelková, Mulková 2013).

Correct interpretation of deep mining displays depends on the interpreter's direct experience with activities taking place in the mining landscape. Subsequently, accurate visual interpretation of deep mining displays enables us to quantify the extent of changes, determine their direction and analyse processes in landscape heavily affected by man. Aerial photos represent an important source of information in the study of territorial differentiation of changes, their intensity, character and causes. Complex understanding of these processes makes it possible to analyse historical development of the landscape, predict the landscape evolution and assess ecological and social effects of deep hard coal mining.

Acknowledgements

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RÉSUMÉ

Projevy hlubinné těžby černého uhlí na leteckých snímcích

Letecké snímky jsou významným zdrojem dat pro sledování změn v krajině. Hlubinná těžba černého uhlí se v krajině projevuje specifickým způsobem. Pro detekci projevů hlubinné těžby v krajině autorky použily kontaktní kopie archivních černobílých leteckých snímků z období 1947 až 1995 a barevné ortofoto z roku 2003 a 2009.

Projevy hlubinné těžby černého uhlí, které je možné interpretovat z leteckých snímků, autorky rozdělily podle jejich typu do dvou základních skupin: primární projevy hlubinné těžby a sekundární projevy hlubinné těžby. Primárně se hlubinná těžba černého uhlí na leteckých snímcích projevuje výskytem antropogenních tvarů reliéfu přímo spojených s hornickou činností. Patří sem montánní tvary reliéfu (odvaly, poklesové kotliny) a industriální tvary reliéfu (kalové nádrže, manipulační plochy). Oblasti s podpovrchovou těžbou lze identifikovat rovněž na základě přítomnosti povrchových staveb hlubinného dolu. Sekundárními projevy hlubinné těžby na leteckých snímcích jsou antropogenní tvary reliéfu, které nepřímo souvisí s těžební činností. Jedná se o rekultivační plochy, suché kalové nádrže, komunikační tvary reliéfu, povrchy bez vegetace.

Pro správnou interpretaci projevů hlubinné těžby v krajině je nezbytná znalost jejich zobrazení na leteckých snímcích. Pro každou kategorii autorky uvádí podrobný popis a ukázku konkrétního projevu hlubinné těžby na leteckém snímku. Při zjišťování primárních a sekundárních projevů hornické činnosti na leteckých snímcích převažuje práce s přímými znaky, které jsou přímo ve snímku obsaženy: tvar, velikost, tón nebo barva, textura a struktura objektu. Tyto znaky je však potřeba doplnit o interpretaci znaků nepřímých, tj. znaků logických vyžadujících vysokou znalost zkoumaných jevů. Z nepřímých znaků se pro interpretaci antropogenních forem reliéfu využívá zejména poloha a vazby s ostatními objekty na snímku.

Procesy nejsou na rozdíl od primárních a sekundárních projevů hornické činnosti přímo ve snímku obsaženy, ale lze je odvodit z multitemporální analýzy leteckých snímků. Na základě změn krajinného pokryvu je možné interpretovat procesy související s hlubinnou těžbou. Autorky ve studii popsaly a demonstrovaly na příkladech tyto základní procesy: zavodňování a opuštění, které může následně vést k procesu zalesnění. Procesy můžeme detekovat na základě znaků nepřímých s využitím podpůrných informací pro odlišení procesů souvisejících s těžbou od ostatních procesů v krajině.

Fig. 18 Waste bank characterised by self-sustaining combustion in Heřmanice mining area (© GEODIS BRNO, spol. s r. o., 2009)

Fig. 20 Submersion in the Lazy mining area (© MO ČR/GeoSI AČR, © GEODIS BRNO, spol. s r. o., 2003)

Fig. 19 Anthropogenic landforms on aerial photo of Lazy mining area (© GEODIS BRNO, spol. s r. o., 2003)

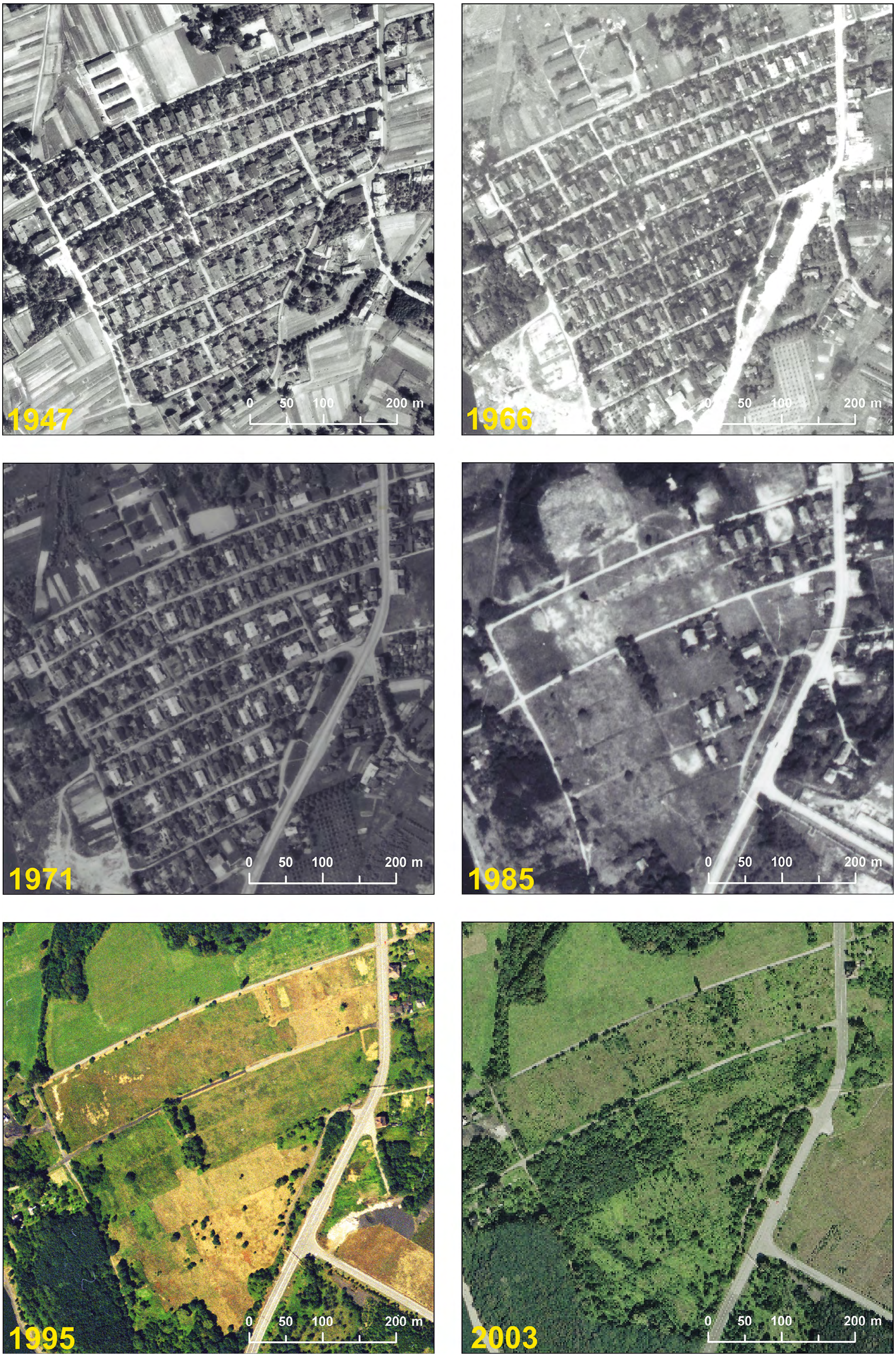

Fig. 21 Abandonment in the area of Chobotova colony in Lazy mining area (© MO ČR/GeoSI AČR, © ARGUS GEO SYSTEM 1995, © GEODIS BRNO, spol. s r. o., 2003)

Fig. 22 Tailings pond (Lazy mining area). Photo: M. Mulková, 2007

Fig. 23 Mine buildings of Lazy mine. Photo: M. Mulková, 2003

Fig. 24 Ground subsidence (Lazy mining area). Photo: M. Mulková, 1998

Fig. 25 Communication landforms (Lazy mining area). Photo: M. Mulková, 1998

ANTONÍN STRNAD (1746–1799) – THE FIRST PROFESSOR OF PHYSICAL GEOGRAPHY AT CHARLES UNIVERSITY IN PRAGUE

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ABSTRACT

The paper is concerned with the life of Antonín Strnad (1746–1799), who became the outstanding representative of mathematics, astronomy and physical geography at the Artistic Faculty of Charles University in Prague. Main professional activities, methodological approaches and research results of professor Antonín Strnad are emphasized, namely in relation to physical geography.

Key words: Antonín Strnad, physical geography, mathematics, astronomy, Charles University in Prague

1. Introduction

The 2nd half of the 18th century was one of the significant periods of progress in natural sciences at Charles University in Prague. Antonín Strnad (1746–1799) became the outstanding representative of mathematics, astronomy and physical geography at the Artistic Faculty. The presented study is concerned with the life of Antonín Strnad, his main professional activities, methodological approaches and research results, namely in relation to physical geography.

At the Faculty of Science of Charles University in Prague was realized in the year 2006 the conference at honour of 150 years of the significant event in history of the university. In 1856, Jan Kašpar Palacký (1830–1908), lecturing and going in for regional and physical geography, habilitated as docent (reader) of geography at the Faculty of Arts of this university. His habilitation thesis dealt with the morphographic patterns of central Africa. The extraordinary professor of geography at Prague University was Dionys Wilhelm Grün (1819–1896) who was promoted in 1872 and became a full professor in 1876. Jan Kašpar Palacký was later appointed extraordinary professor in 1885 and full professor of geography in 1891 (Horák 1954; Häufler 1967). The geographical sections of J. K. Palacký and D. W. Grün at the Department of Philosophy of Charles University were foundation stones for the progressively developing Geographical Institute (compare Jeleček et al. 2006).

However, geography oriented lectures and publications existed at Charles University long before the habilitation of the geographer J. K. Palacký in 1856. After the foundation of this university by Charles IV in 1348, the fundamentals of mathematical geography were included into the philosophically and theologically conceived lectures of Stanislav of Znojmo and Křišťan of Prachatice in the second half of the 14th and in the 15th centuries. For example, English-Czech contacts grew sensibly stronger after the foundation of Charles University in Prague (Goudie, Kalvoda 2007). It was at the time when the Czech princess, Anne of Luxemburg (1366–1394), became the Queen of England.

A fervent Czech explorer, who already in the first century of existence of Charles University used his extensive geographical experience from the whole of Europe (and Palestine) in his theological sermons and works, was the eminent philosopher and Church reformer Jerome of Prague (Hieronymus Pragensis, 1378–1416). It was exactly the master and later professor of the Faculty of Liberal Arts (or Artistic Faculty) of Prague University, Jerome of Prague, who brought to Prague from his studies at Oxford University copies of the reformatory works of the English theologian and Oxford professor John Wycliffe (1320–1384). Jerome of Prague was a follower of the theological teaching of the master Jan Hus and likewise was burnt at the stake after the Council of Constance.

Geographical findings of the 15th and the 16th century were taught at Charles University within astronomical, philosophical and historical lectures for instance by Jan Ondřej Šindel (1375–1456), Vavřinec of Březová (1370–1437), Jan Zahrádka of Prague (1501–1557), Daniel Adam of Veleslavín (1545–1599) and Tadeáš Hájek of Hájek (1525–1600). Doctor, astronomer, botanist and also geographer Tadeáš Hájek of Hájek was undoubtedly the most eminent Czech natural scientist of the 16th century (Horák 1954). He also promoted works by Nicolaus Copernicus, especially his important heliocentric work *De revolucionibus orbium coelestium* (1543). It is said that Tadeáš Hájek of Hájek arranged, as personal doctor of the Emperor Rudolf II, the invitation to Prague for the Danish astronomer Tycho de Brahe and for the German astronomer Johannes Kepler.

At the beginning of the 17th century, geography was included in the lectures of Martin Bacháček of

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Nauměřice (1539–1612). In 1724, the professor of philosophy and theology of Prague University Honorius Martin Czechura (1688–1726) published an extensive work including also parts dedicated to physical geography. An astronomical observatory was established in 1752 at the Jesuit Faculty of Philosophy at Charles University, where uninterrupted meteorological measurements have been done since 1771. These observations were initiated by Professor Josef Stepling (1716–1778) and continued by Professor Antonín Strnad (1746–1799). The latter was, after the general reforms by Emperor Maria Theresia, appointed professor of mathematics and physical geography in 1778.

After another reform by the Emperor Josef II (1784), natural science and physical geography became regular auxiliary subjects taught at the Faculty of Philosophy (Häufler 1967; Munzar 1996). At that time, mathematical geography and cartography were lectured at Prague University as parts of mathematics and astronomy. These reforms and Czech endeavours towards national revival in the first half of the 19th century set the basis for historical changes in geography studies at Charles University in particular and in the Czech countries in general, which were carried through by the generation of natural scientists at the time of Jan Kašpar Palacký.

2. A brief curriculum vitae of Antonín Strnad

Antonín Strnad was born on 10th August 1746 in Náchod (eastern Bohemia) and acquired an extensive education as a student of the Jesuit Order in Brno, Uherské Hradiště and Olomouc (Schuster 1931; Šolcová 1999; Vlčková 1999). He worked in Prague from 1771, firstly as an assistant of Joseph Stepling (1716–1778), who was the founder of the astronomical and meteorological observatory in the Clementinum College (1751, Figure 1). Antonín Strnad (written also as Anton Strnadt or Sternat in manuscripts published in German or Latine language) was nominated director of the Clementinum observatory in 1781, worked as administrator of the Mathematical museum (1774–1785) and director of the Royal Czech Society of Science (1787–1788). In the year 1784, Antonín Strnad was also nominated as a member of the Meteorological Scientific Society in Mannheim. He was appointed as professor of mathematics and physical geography (1778), dean of the Artistic Faculty (1792) and the chancellor of Charles-Ferdinand University (1795). Antonín Strnad initiated a rescue and general repair of the Prague Astronomical Clock (1781), and was very famous for his scientific library, research and practical papers as well as excellent professional lectures and popular talks. Profes-

Fig. 1 Clementinum astronomic tower in the 1930's. Source: Archives of the National Library of the Czech Republic

sor Antonín Strnad died, after a severe disease, on the autumn equinox day, the 23th September 1799, at Sazená castle. He was buried in the cemetery of parish church of St. Climent in Chržín near Velvary in central Bohemia.

3. Orientation, style and scope of Antonín Strnad's professional activities

Professor Antonín Strnad tirelessly developed all major aspects of professional work that are essential also for contemporary science and university teaching. First, he systematically collected and studied written materials as valuable sources of data on natural environment as well as on efforts to preserve cultural values. He also tried to gather primary data on natural environment in view to analyse them correctly and to interpret them in line of laws of nature. He systematically published partial results of his work and transmitted them to his university students. A characteristic feature of Antonín Strnad's extensive professional work was his sharp sense for using research results for the profit of the society (Novotná, Kalvoda 2012).

The exact approach of Antonín Strnad to research and pedagogical work resulted both from his extraordinary talent and assiduity as well as from his systematic and universal education during his long studies. Antonín Strnad studied at grammar school in Hradec Králové thanks to financial backing from his uncle Jan Strnad, dean in Náchod and canon of Hradec Králové Chapter. On 21st of October 1763, Antonín Strnad jointed the Jesuit novitiate in Brno, where he studied up to 1765. He learned rhetoric, spoke both Czech and German, played musical instruments and was in a good physical condition. Then he left for scholastic studies to Uherské Hradiště (1766), where he followed courses in literature, languages and antique scientific disciplines. In 1767–1768, he studied philosophy and mathematics at the Jesuit College in Olomouc. In 1769, he was selected to the Klementinum College in Prague to be able to perfect his knowledge in mathematics and theology. Antonín Strnad spent his last two years in the Jesuit order (1771–1773) at the Klementinum College working as assistant of the prefect of astronomy, Father Josef Stepling (1716–1778). He ought to take holy orders and definitively join the Jesuit order. In 1773, however, the order was suppressed by a bull of Pope Clement XIV and its possessions passed to the hands of the Habsburg monarchy (Richterová, Čornejová 2006).

Since 1774, Antonín Strnad worked as assistant at Klementinum Observatory (at that time known as Prague Royal Observatory) and in 1781 became its director with the title of Astronomer Royal (Pejml 1975). The geographic position of this observatory was specified by Antonín Strnad in his studies *Astronomische Beobachtung des oberen Sonnenrandes und daraus gezogene Polhöhe der hiesigen Sternwarte* (1777) and *Berichtigung der geographische Länge der Stadt Prag* (1786). During his regular meteorological observations, Antonín Strnad measured several times a day temperature, air pressure and humidity as well as magnetic declination. Thanks to Antonín Strnad, meteorological stations were established also outside Prague, the most important of them being Žitenice near Litoměřice, Telč and Teplá Monastery near Mariánské Lázně.

The professional library of Josef Stepling was, after the death of this leading astronomer in 1778, bequeathed to the University Library. Antonín Strnad progressively constituted a new collection, the major part of which is now deposited in the Premonstratensian Library at Strahov (Seydl 1939), some prints are in the library of the Astronomical Institute of the Academy of Sciences of the Czech Republic and other ones in different castle libraries. Antonín Strnad was also in charge of collections in the so-called Klementinum Mathematics Hall. In 1774–1785, he was custodian of the Mathematical Museum founded as the first public museum in the Czech lands as soon as in 1722.

After the death of his teacher Josef Stepling, Antonín Strnad, as his successor, was appointed as extraordinary professor of mathematics and physical geography at Prague University. Up to 1797, he gave lectures on practical astronomy and physical geography at the Faculty of Arts. Besides regular lectures, Antonín Strnad organized on Thursdays "colleges" on mathematical geography, meteorology and knowledge of heavens. In 1792, Antonín Strnad was appointed as dean of the Faculty of Arts and in 1795 as rector of the Charles-Ferdinand University (Čornejová 1995; Šolcová 1999).

Since 1781, Antonín Strnad collaborated with several European meteorological societies, for example with those of Mannheim, Berlin, Vienna and Leipzig. In Mannheim, he contributed to *Ephemerides Societatis meteorological Palatina* (1781–1792). His astronomical observations were published from 1786 until his death in Vienna and Berlin Astronomical Calendar and in the treatises of the Royal Society of Science (Munzar 1996, 2001). He observed for instance eclipses of the Sun, the Moon and the Jupiter's Moons. Projection of parhelia was dealt with in 1790 in his work *Kurze Beschreibung, Erklärung und Abbildung der am 17. May 1790 erschienen Nebensonnen*. Antonín Strnad published also in Dresden edition Sammlung physikalischer Aufsätze his reflections on degrees of temperature (*Betrachtung über die verschiedenen Grade der Wärme ihren Nutzen, aus Versuchen und Beobachtungen*) and dealt also with mean barometric altitude of Prague. In 1788, he published a physical and meteorological calendar. Antonín Strnad wrote in total 23 meteorological studies, 31 works, reports and treatises on astronomy, four casual speeches and four popularization works. He also published 13 translations of Josef Stepling's Latin studies.

In 1784, Antonín Strnad married Kateřina Marsanová, an Italian living in Prague. They had four children: Kateřina, Leopold, Antonín and Aloisie. Although the family lived in a very modest way, they were in contact with many Prague intellectuals and revivalists. For instance, Josef Jungmann gratefully used to think back to Strnad's lessons and support, which helped him to get a teaching post at a grammar school in Litoměřice. In his biography, he wrote about his great involvement in physical and astronomical geography.

In 1781, Antonín Strnad contributed to rescue and reparation of Prague astronomical clock (Figure 2). Already in 1760, Jan Klein tried to draw attention to this unique piece of work and to the necessity of its reconstruction. However, Prague city fathers were convinced that it was nothing else than scrap iron and intended to put it away (Horský 1988). Antonín Strnad initiated a commission charged to establish the extent of damage and the sum needed for reparation and to propose a solution. The Prague astronomical clock was then repaired under Strnad's supervision in the years 1787–1791. In 1788, he wrote a study on the astronomical clock *Von der Prager Uhr auf dem Altstädter Rathause aus Balbins Miscellaneen, mit Zusätzen und Anmerkungen*. Another work describing famous clockmaker's and artistic works in Prague Old Town City Hall and in Prague Observatory was published in Prague (1791) and in Dresden (1794). The Prague City Council acknowledged Antonín Strnad's merits and in 1793 took him and his sons among freemen of Prague.

In 1784, Antonín Strnad became regular member of the Meteorological Scientific Society in Mannheim. He was also one of the founder members of the first Bohemian Learned Society, where he published in 1775 his first article on meteorology. This learned society was in 1784 called Societatis scientiarum Bohemica and since 1790 used the honorary title the Royal Bohemian Society of Science. Antonín Strnad published in *Abhandlungen* of the Royal Bohemian Society of Science in total 18 studies dealing mostly with meteorological subjects. He worked also as archivist, librarian and custodian of collections of this Society. In 1790, Antonín Strnad published in Prague his work *Chronologische Verzeichnis der Naturbegebenheiten in Königreiche Böhmen von Jahr 663–1700 mit einigen ökonomischen Aufsätzen auf das Jahr 1790* (Figure 3). Inspired by chronicles and old manuscripts, he described historically interesting natural phenomena, lists of comets, solar and lunar eclipses, hard winters and hot summers, crop failures, meteorite falls, floods and other catastrophes. In 1791, he gave lecture on solar eclipse at a solemn session of the Royal Bohemian Society of Science in which also the Emperor Leopold II took part.

Antonín Strnad was busy with popularization of science and since 1789 cooperated with the Patriotic Economic Society (Seydl 1947). His handbook *Physikalisches Taschenbuch auf das Jahr 1789 für Freunde der Ökonomie und Witterungskunde* was intended for farmers. Since

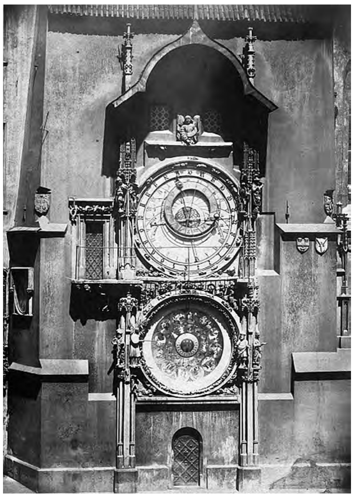
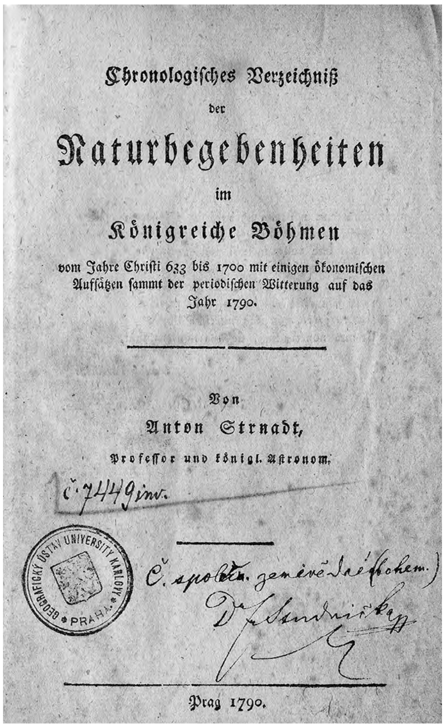


Fig. 2 Old Town astronomic clocks in 1890. Sources: Prague City Museum



Chronologisches Verzeichniß
der
Naturbegebenheiten
im
Königreiche Böhmen
vom Jahre Christi 633 bis 1700 mit einigen ökonomischen Aufsätzen sammt der periodischen Witterung auf das Jahr 1790.

Von
Anton Strnadt,
Professor und königl. Astronom.

č. 7449 inv.

GEOGRAFICKÝ ÚSTAV UNIVERSITY KARLOVY PRAHA

Prag 1790.

Fig. 3 Front-page of the book by Antonín Strnad (Anton Strnadt) from 1790: *Chronologisches Verzeichniss der Naturbegebenheiten im Königreiche Böhmen vom Jahre Christi 633 bis 1700 mit einigen ökonomischen Aufsätzen sammt der periodischen Witterung auf das Jahr 1790.* Source: Royal Bohemian Society of Science, Prague

Fig. 4 Commemorative plaque of Professor Antonín Strnad by sculptor J. Plíšek in Náchod. Source: Náchod City Museum (Photography: Zdeněk Halíř)

1749 to his death, he reviewed Housekeeping Calendars published in Czech, although his scientific works were published in German and Latin. The first of them, published by the famous Czech patriot V. M. Kramerius, *Stoletý Kalendář na způsob Krysstofa z Helwiku* (1793), is at the same time a pioneering work on agrometeorology. In his Housekeeping Calendars he wrote also about the position of the Sun, planets, about animals' behaviour before rain and storm, he gave advice what to do each month in the field, vineyard, forest and garden. He occupied himself also with healthy diet and instructed lecturers on suspicious and poisonous plants and mushrooms. He wrote about beekeeping and about their treatment. He explained spontaneous ignition of hay, described smut fungus and how to remove it, he wrote about conservation of eggs. He paid attention to heating with hard coal, which was then only little known.

Exhausting work and distress due to bad economic situation of his family ruined Antonín Strnad's health. At the invitation of the Prince Ferdinand Kinský (1781–1812), he left Prague for Sazená Castle near Velvary to recuperate. Unfortunately, his serious illness was going worse and on September 23, 1799, he died in Sazená, aged only 53 years (Figure 4). His death inspired many of his contemporaries, patriots and near friends to speeches and literary works reminding of his scientific, human and patriotic qualities.

4. Conclusions

The progress in physical geography is a consequence of an expansion of theoretic conceptions and technologic means used in Earth and Space sciences. Since the 2nd half of the 18th century, the extent of space and time, in which it is possible to observe and investigate natural processes and objects, has sensibly increased. However, variability and style of professional activities of Antonín Strnad, especially his methodological approaches and scientific results, reflected pioneer stages of research efforts to apply mathematical and physical methods with specialized techniques and devices for determination, description and measurement of the components of the natural environment. He emphasized systematic and precise observations of natural processes and phenomena, cultivated and taught mathematics and physical geography as a part of natural sciences and published many papers concerning meteorology and mathematical geography. Professor Antonín Strnad is now recognized as one of the most significant personalities of Charles University in Prague during the Age of Enlightenment.

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RÉSUMÉ

Antonín Strnad (1746–1799) – první profesor fyzické geografie na Univerzitě Karlově v Praze

Druhá polovina 18. století byla jedním z významných období rozvoje přírodních věd na Univerzitě Karlově v Praze. Významnou osobností matematiky, astronomie a fyzické geografie Artistické (Filosofické) fakulty se v té době stal Antonín Strnad. Narodil se 10. srpna 1746 v Náchodě ve východních Čechách a získal rozsáhlé

vzdělání jako student Jezuitského řádu v Brně, Uherském Hradišti a Olomouci. Antonín Strnad pracoval v Praze od roku 1771, a to nejprve jako asistent Josefa Steplinga (1716–1778), který byl zakladatelem astronomické a meteorologické observatoře v Klementinu (1751). Ředitelem této observatoře se Antonín Strnad stal v roce 1781, dále byl administrátorem Matematického muzea (1774–1785) a ředitelem Královské české společnosti věd (1787–1788). V roce 1784 se Antonín Strnad stal členem Meteorologické vědecké společnosti v Mannheimu a spolupracoval s podobně zaměřenými společnostmi v Berlíně, Vídni a Lipsku. Profesorem matematiky a fyzické geografie byl jmenován v roce 1778, děkanem Artistické fakulty v roce 1792 a rektorem Karlovy-Ferdinandovy Univerzity v roce 1795.

Antonín Strnad inicioval záchranu a generální opravu Staroměstského orloje, proslulá byla jeho vědecká knihovna a vynikající odborné i populární přednášky. Zdůrazňoval nezbytnost systematických a přesných pozorování přírodních procesů a jevů, rozvíjel matematiku a fyzickou geografii jako součásti přírodních věd a publikoval řadu odborných i populárně-naučných prací, zabývajících se zejména meteorologií a matematickou geografií. Podstatným rysem Strnadovy rozsáhlé činnosti byl vyhraněný smysl pro využívání výsledků odborné práce ve prospěch společnosti. Upřesnil geografickou polohu observatoře v Klementinu, prováděl zde pravidelná meteorologická měření, včetně sledování změn magnetické deklinace, pozoroval zatmění Slunce a Měsíce, popsal historicky známé katastrofické jevy, např. velmi chladné zimy, horká léta, krupobití, povodně a pády meteoritů a byl zaníceným průkopníkem agrometeorologie.

Vyčerpávající práce a neutěšená ekonomická situace rodiny podlomily jeho zdraví. Antonín Strnad zemřel po těžké nemoci 23. září 1799 na zámku Sazená a je pohřben na hřbitově u kostela Sv. Klimenta v Chržíně u Velvar ve středních Čechách. V současné době je uznáván jako jedna z nejvýznamnějších osobností Univerzity Karlovy v Praze v osvícenecké době.

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THE REGIONAL DIMENSION OF THE SOCIO-POLITICAL URBAN-RURAL CONFLICT IN SLOVAKIA

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ABSTRACT

Political behaviour of citizens is traditionally formed by a wide range of factors that influence their voting decision in the election. Dichotomy of both the space and society into the town and the countryside generates different election results constantly. A key aim of this paper is to assess the extent of rurality concerning the electoral support of relevant political parties operating on the Slovak political scene after the groundbreaking elections held in 1998 until ballots of 2010 not only at national, but also at the regional level. Evaluation of level and dynamics in socio-political cleavage between rural and urban space is one of the most important research ambitions of this study. We shall note the position of particular regions in Slovakia in terms of size and acceleration of the conflict and try to categorize them according to the similarity in values of indicators characterizing this social discrepancy. On the basis of found facts, we shall appraise the electoral success of political parties in urban and rural environment and compose the regional typization of Slovakia concerning the party representatives of urban and rural environment. Finally, we shall evaluate the potential of the regions to be future outbreak sites of latent cleavage influencing their differential political inclination.

Key words: socio-political conflict, political party, urban, rural, functional urban region

1. Introduction

Social cleavage characterized by a conflict between the town and countryside was firstly identified by Lipset and Rokkan in the late 1960s. These authors have defined the conflict lines emerging from structure of social-economic relations formed between groups of political community. They stated four long-term social cleavages regarded as a consequence of both the industrial and national revolution: employers vs. workers, urban vs. rural, state vs. church and centre vs. periphery. Half a century later, these social conflicts still affect political behaviour of electorate.

Urban-rural cleavage played a significant role in politics already at the end of the nineteenth century. Both the culminating industrialization and growth of international trade generate increasing tension between farmers in the countryside on one hand and traders together with industrialists in the urban space on the other. Most researchers draw attention to the decrease in importance of this conflict in Western Europe at the beginning of last century, i.e. in the countries already highly industrialized at that time. Northern European countries declared a remarkable influence of this factor on domestic political affairs even in the middle of the twentieth century. Today it is possible to watch the socio-political conflict between the town and countryside in post-socialist countries of Central and Eastern Europe and less developed countries, where the process of industrialization has not been clearly completed yet. In the case of former Eastern Bloc countries, agrarian parties enjoyed considerable popularity even at the end of the nineties of the last century (Stoll 2004). Lipset and Rokkan (1967) stated that the social conflict of this nature is typical of social tension emerging just in transforming societies. Ideological dimension of the conflict between the rural and urban way of life is associated with the issue of state subsidies for farmers, rural development and land use management as well.

Therefore, agrarian parties were developed as guardians of the rural economy against urban industry dealing with the tariff level for agricultural products. However, this does not mean that the peasant parties necessarily arise wherever the farmers live. Other parties may also defend the interests of the countryside, because the division of territory (or society) in urban and rural space overlaps with other social cleavage, such as “state vs. church” conflict or “centre vs. periphery” conflict. Therefore, Christian democratic parties or parties of ethnic minorities may also address the rural part of the electorate, although these parties often represent rather the cultural identity then the economic interests of the agriculture sector. At the turn of the century, Zarycki (2000) applied classic Lipset-Rokkan model to conditions of transforming post-communist societies of Central and Eastern European countries considering the historical context of socio-political division in Poland. In 2003, Johannsen conducted an extensive research concerning the development and nature of urban-rural conflict after 1989 in 21 post-communist countries of Central and Eastern Europe. According to results of this study, urban population claims a higher support to the market and prefers limitation of the state’s role in the process of resources distribution in most countries of the region. This result

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was expected, since the loss of the rural economy in the transition period was significantly higher compared to the town (Lemel 1998; Lerman 1999; Swinnen 1999).

Issue of socio-political cleavage between town and the countryside has been properly covered by Czech and Slovak political scientists, as well. Kostelecký and Čermák (2004) dealt with the socio-spatial changes occurred in metropolitan areas of the largest cities in Czech Republic and assessed their impact on political behaviour of particular region. Similar research was also conducted by Kyloušek (2007), who tried to find linkage between spatial distribution of socio-demographic and electoral characteristics on the example of Brno and its hinterland. In 2009, Kyloušek and Pink compared territorial pattern of electoral support for main socio-democratic party in Czech Republic on one hand (ČSSD) and Slovakia on the other (Smer-SD) regarding its urban-rural context, too.

Slovak sociological, political and geographical research has also focused on the issue of identifying the factors influencing the electoral decisions of voters in the countries of the former Soviet bloc with special attention to the political behaviour of electorate in the Slovak Republic, of course. The contribution of these very often cooperating disciplines using mutual piece of knowledge is greatly appreciated mainly due to their efforts to affect the partial socio-political conflict lines dividing the Slovak society during the transition period after 1989 on the one hand and also reflecting the heritage of the historical development of society in Slovakia on the other. Study of sociologist Krivý (2000) is considered as one of the most valuable work within domestic political science dealing with the voting preferences of different groups existing in Slovak society. In this analysis, he sufficiently emphasizes the geographical context of given issue through the differential electoral pattern of people living in both the urban environment and rural communities as well. This voting preferential peculiarity is associated with the size structure of territory where they live in, thus quite substantial differences in the votes of urban and rural voters can be observed. Such as the polish political scientists in the case of our northern neighbour did (Shabad, Slomczynski 1999; Zarycki, Nowak 2000), Krivý (in relation to the Slovak reality) comes to the same finding that the urban environment is negatively set towards the values of egalitarianism, paternalism or authoritarianism, which are typical mainly for rural voters. According to his findings, value and ideological discrepancy between urban and rural electorate is more perceptible than the social status of the population or its level of education evaluated in the context of these two different social worlds.

More than decade later, Madleňák (2012) notes that the direct institutionalized link between latent socio-political cleavage of electorate living in urban and rural communities and crucial political formations in the state is constantly missing. Therefore, the party system in Slovakia still lacks urban-rural cleavage and overlaps with other conflict lines that shape relationship between voters and political elites (e.g. mečiarizmus–antimečiarizmus, conservative–liberal, socio-economic or nationalistic), in fact.

2. Methodological issues

In addition to assessing the differences in support of major political parties in the urban and rural areas at statewide and regional level as well, the essential part of our research is to determine the regional disparities in urban-rural profile of political parties in Slovakia during the first decade of the new millennium. For this purpose it is necessary to choose such a concept of territorial units, which would accept the preferential uniqueness of individual regions given by long-term historical development of our society and its parts as far as possible. Since there are not spatial units defined in Slovakia, which would reflect an intra-territorial cohesion of electoral support, therefore in order to evaluate the urban-rural divergence the concept of functional urban regions ("FUR" in short) seems to be the most acceptable because the urban and rural space is delimited on the basis of real socio-spatial (rather than administrative or statistical) criteria, there. Although this territorial concept was constructed based on apolitical criteria non-reflecting the electoral behaviour of those living in the territory, for analysis with similar ambitions the consistency in definition of urban and rural space might be important indicator of urban-rural voting preferential disproportion between urban and rural environment. They represent the most real territorial units of the regional level reflecting the long-term link formed between the centre and its hinterland. In Slovakia, this spatial concept was applied by Bezák (2000), who identified two alternative ways of daily urban system (or functional urban regions) delimitation in his study. For the empirical part of this paper, we will deal with the level "A" consisting of 51 regions. In order to thorough depiction of studied relationships existing at regional level, we will also use the traditional historical names of Slovak regions in some sections of the text.

The data structure that was utilized in mathematical calculations and statistical procedures carried out in the empirical part of this paper also deserves our attention, i.e. results of four elections to the parliament in total at the municipal level conducted in Slovakia during the period of 1998–2010. Diapason of political parties under study consisted of those, which after 1998 became at least once the part of the National Council of Slovak Republic and thus represented a significant number of Slovak voters in the political field during this period. The group of analyzed political parties was represented by (12): People's Party – Movement for a Democratic Slovakia (ĽS HZDS), Hungarian Coalition Party – Magyar Koalíció Pártja (SMK-MKP), the Slovak Democratic and Christian Union – Democratic Party (SDKÚ-DS), Slovak National Party (SNS), Direction – Social Democracy (Smer-SD), Christian Democratic Movement (KDH), the Party of Civic Understanding (SOP), Party of Democratic Left (SDĽ), the Communist Party of Slovakia (KSS), Alliance of New Citizen (ANO) , Freedom and Solidarity (SaS) and Most-Híd (Most-Híd). Election results of given party were taken into consideration just in the case if the party gained at least 5% of the votes cast in the ballots that guaranteed the representation of this party in the National Council. SNS in election of 2002 was only exception, when its electoral gain was added together with votes for PSNS (partisan SNS voter elected either SNS or PSNS due to the split of Slovak nationalists in that ballots) and also in the case of ĽS-HZDS and SMK-MKP (political parties traditionally active in domestic political scene) that only slightly did not exceed the 5-percent quorum required to enter the parliament at elections in 2010.

In this paper, rurality index of party's electoral outcomes (R_i in short) was the main indicator evaluating the urban-rural profile of the political party at national and regional level. This rate represents the ratio between the share of the votes gained by party in rural environment and the share of its electoral result in urban areas at given election during the period of 1998–2010. The higher the number than 1 is, the higher the rurality of party's electoral gain is and thus in terms of its electorate support it might be seen more rural. On the contrary, value lower than 1 indicates the urban character of the party's electorate. Thus, the lower these values below the number 1 are, the more urban this party is considered to be. In addition to this indicator of urban-rural cleavage, Krivý (1999) in his work applied slightly different coefficient, which expresses the same relationship, but seen from a position of urban voters. Method of delimitation of rural and urban space within particular regions of Slovakia was based on statutory criterion of the town and countryside definition. Of all more than 2900 municipalities in Slovakia, exactly 138 with the status of town was considered to be urban electoral basis, remaining ones represented the rural part of electorate.

The difference between rurality index of parties with the highest and the lowest value of this variable in the particular election is understood as the size (level) of urban-rural conflict in given region. The greater this difference is, the more significant socio-political conflict between urban and rural space can be expected, and vice versa. Average value for the whole period under study is used.

Acceleration of regional urban-rural conflict is defined as a growth in size of this cleavage in the region during the period of 1998–2010 (the growth rate regarding the level of values observed at the beginning and end of the period). If this rate reaches values higher than 1, then there is a strengthening of socio-political conflict between the town and countryside in given territory, if less than 1, the urban-rural cleavage is weakening in particular region. In order to catch the short-term inter-electoral change in socio-political urban-rural cleavage, we will also regard the growth rate from one election to the other and calculate its average value for the whole period.

Integral indicator taking into account both the size and growth rate of socio-political conflict between urban and rural electorate can be seen as a potential of urban-rural conflict line, which reflects the history of socio-political cleavage between these two very distinct social environments and allows estimating his future character at the same time. To the greatest objectivity in assessing process of the size and acceleration in urban-rural conflict not only for the region, but also in inter-regional comparison, the values of these two indicators were appraised by three different multi-criterion evaluation methods (ranking method, point method, factor comparison method). The final ranking of regions evaluated based on the potential of socio-political urban-rural conflict is to be determined following the average ranking for all three utilized methods.

In order to assess the regional size and growth rate of urban-rural conflict, the regional typization was composed, which divided territorial units into four different categories based on achieved values of these two variables. The overall level of urban-rural conflict in the region during the reporting period 1998–2010 was calculated as the average size of the regional socio-political conflict between the town and countryside in all elections under consideration. Given party had to obtain at least 5% of all votes cast at ballots in the region. The first group (type A) includes those regions which had above-average size of urban-rural conflict compared to the state-wide mean and recorded growth in the level of this conflict at the same time (growth rate greater than 1). The second regional type (type B) consists of those regions where an above-average socio-political conflict between urban and rural votes was observed, but it was weakening during the period (growth rate less than 1). Territorial units typical of below-average but strengthening urban-rural conflict in the period of 1998–2010 form the third category (type C). The last group of the regions (type D) was characterized by below-average socio-political conflict between urban and rural electorate, which was even weakening during the period under study.

Regional typization of Slovakia according to the long-term party representatives of the urban-rural conflict posed the last phase of the empirical work. In composing of this typization, the party's electoral gain of more than 5% of the valid votes cast at ballots at least in three of four analysed elections was condition to being party representative of this conflict. This measure reduced the number of political parties to 6 (ĽS-HZDS, SMK-MKP, SDKÚ-DS, SNS, Smer-SD and KDH), while remaining 6 political parties did not meet this condition (SDĽ, SOP, KSS, ANO, SaS and Most-Híd). In addition to this term, the party of the first group had to get at least 5% of total votes cast at all four polls in a particular region, too. This took into account the regional peculiarities in the electoral gains of the parties and prevented the situation of being party representative of urban or rural environment despite the marginal electoral support in given region. Then, the political representative of urban electorate was regarded that party, which fulfilled all above-mentioned conditions and also achieved the lowest rurality index among all parties under consideration during the period we studied. On the other hand, the party with the highest rurality index of own election results was seen as a representative of the rural voters within the socio-political urban-rural conflict.

3. Results

3.1 Size of socio-political urban-rural conflict and its regional particularities

In regions with relatively little difference between the electoral behaviour of urban and rural population, it can be assumed a low level of socio-political conflict between urban and rural environment and vice versa. In this section, we will focus on differentiation of Slovakia assessed by this criterion in the period of 1998–2010, when four elections to the National Council of the Slovak Republic were held. We will take a look not only at size of the investigated socio-political cleavage of regions dividing themselves into the urban and rural part, but not forget to comment on the development of this conflict during the period under study (Table) as well.

Between 1998 and 2010, SMK-MKP and SDKÚ-DS have been profiled as political parties characterized by the deepest discrepancy in votes considering its urban-rural context at state-wide level. First mentioned party has been gaining mainly from rural environment of southern part of the country, whereas the latter one has been markedly dependent on support springing from urban space of the most urbanised regions of the state. In spite of that divergence, these two parties have been collaborating not only within the national political disputes, but even in government for a long time, which can be thought as evidence confirming the weakness of urban-rural conflict in the crucial socio-political topics in Slovakia. However, remarkable rurality of SMK-MKP's election outcomes is given by territorial distribution of Hungarians occupying the southern low-urbanised regions of the country. Therefore, its greater electoral gains in countryside are mainly due to spatial composition of ethnic structure in Slovakia rather than defending the real values traditionally peculiar to rural communities and their economic basis (support to agriculture). Smer-SD, KSS and SNS can be regarded as parties having very similar ratio of their election outcomes in both studied environments. It is interesting that contemporary governing party has taken the huge number of voters from ĽS-HZDS characterized by striking rurality and therefore Fico's party changed it profile from moderately urban to slightly rural over decade.

Assessing the global state of this issue, we can conclude that the studied conflict weakened at the national

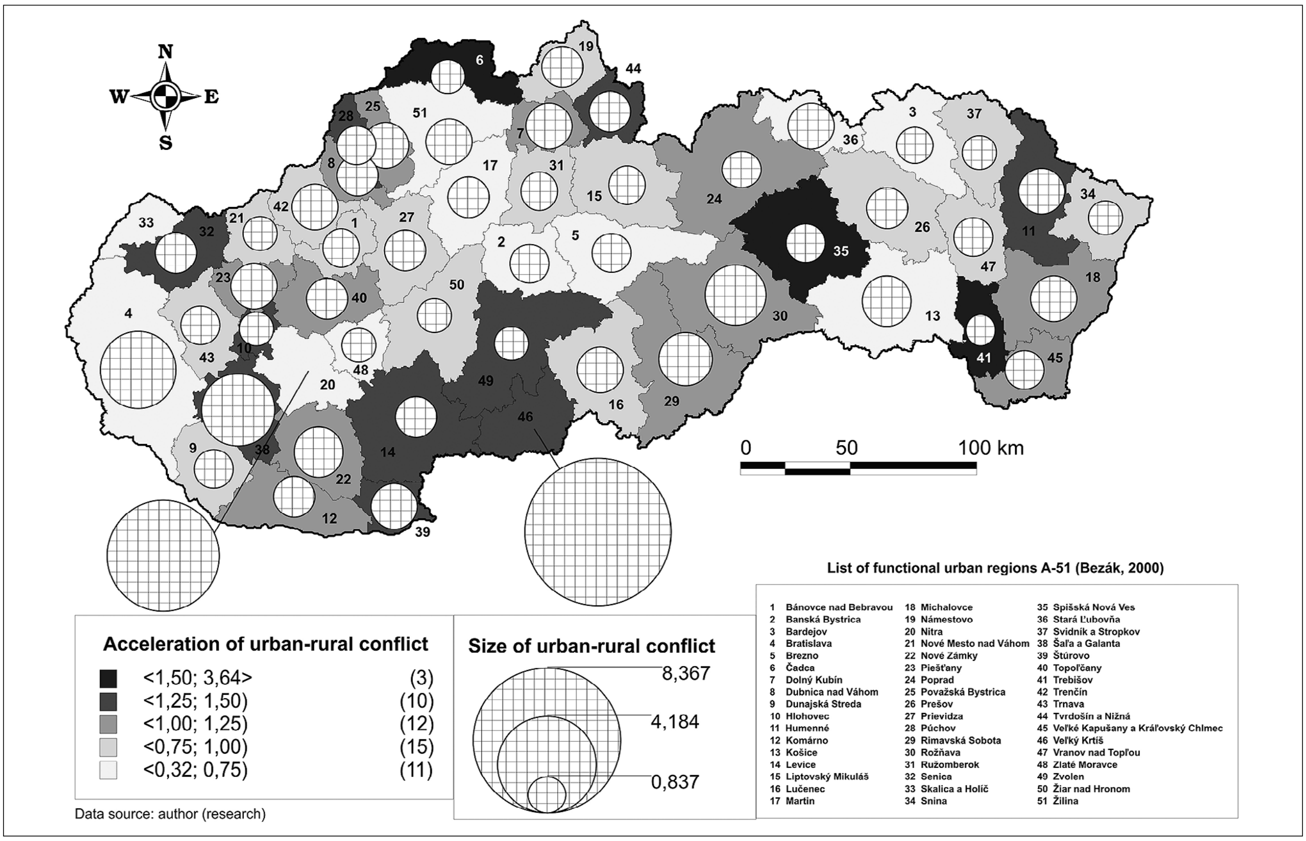

Fig. 1 Size and acceleration of socio-political urban-rural conflict in particular regions of Slovakia based on parliamentary election results in period of 1998–2010

level between 1998 and 2010. The most significant socio-political fragmentation of society based on differences in electoral preferences of urban inhabitants on the one hand and of the countryside on the other was occurred in groundbreaking parliamentary elections held in 1998. Conversely, the highest degree of similarity between the election results of urban and rural space was recorded on the occasion of the Slovak parliamentary elections conducted in 2010. Thus, research results confirm that the elections to the National Council of the Slovak Republic in 1998 are rightfully marked as the battle between the town and countryside reflecting significant disparity in political behaviour of these two specific environments then. However, if we would not consider the socio-political cleavage between urban and rural voters in the southern parts of Slovakia given firstly by ethnic composition of the local population (typical of high territorial concentration of ethnic Hungarians), then we could regard elections taking place in 2002 as the most important fight of real urban and rural values at all.

During the period under study, the most significant socio-political cleavage between rural and urban electorate was found in regions of Veľký Krtíš (SMK-MKP as rural, Smer-SD as urban political representative), Nitra, Bratislava, Šaľa and Galanta, Rožňava and Rimavská Sobota (in all of these five regions, SMK-MKP vs. SDKÚ-DS), where the difference in rurality index of votes gained at ballots by relevant parties with the lowest and the highest value exceeded the level of 1.500 (Figure 1). On the other side, election results followed in urban and rural space were the most similar in the regions of Skalica and Holíč, Trebišov, Zvolen, Nové Mesto nad Váhom (in these four regions, KDH vs. SDKÚ-DS), Svidník and Stropkov, Snina, Hlohovec, Čadca, Zlaté Moravce and Žiar nad Hronom (in all of these six regions, ĽS-HZDS vs. SDKÚ-DS), where the numerical value of the socio-political discrepancies in political preferences of these two specific environments ranged below 0.750. Nature of electoral support manifested by the town and countryside can be regarded as significantly different in several regions located in the south and southwest, while a very similar in some border regions of eastern Slovakia, in the central part of the state in Podpoľanie region, in the north of Tekov region and Hont region, in Kysuce region and populationally and in territorially smaller regions situated in the west of the country.

3.2 Development of socio-political urban-rural conflict and its regional particularities

The acceleration (development) of examined socio-political conflict in urban and rural votes in individual regions of Slovakia is quantified by growth index concerning this electoral phenomenon. Comparing the first and the last year of the period under study, this kind of socio-political cleavage deepened the most in the regions of Trebišov, Spišská Nová Ves and Humenné located in eastern Slovakia, Čadca, Tvrdošín and Nižná in the north-western part of the country, Zvolen and its catchment area situated in the central part of the republic and Senica, Šaľa and Štúrovo and Galanta lying in the west of the state, in which the monitored discrepancy between urban and rural political inclination increased more than a third. In Trebišov region, this cleavage rose even by 3.5 times. On the other hand, the most significant decline occurred in the regions of Bratislava, Nitra and Skalica and Holíč located in the western part of the country, in the regions of Banská Bystrica and Brezno situated in the central Slovakia and Košice, Stará Ľubovňa, Bardejov and their catchment areas lying in the East. Daily urban systems of Trenčín, Považská Bystrica and Dubnica nad Váhom situated in Považie region, Bánovce nad Bebravou, Trnava and their catchment territories located in western Slovakia, eastern regions of Vranov nad Topľou, Prešov and Veľké Kapušany and Kráľovský Chlmec, Námestovo in Orava region and Žiar nad Hronom with its catchment area lying in the central part of the Slovak Republic can be considered as the parts of country showing a relatively stable level of socio-political cleavage between urban and rural population expressed through the electoral votes of people living in these two relatively distinct environments, where the growth index in mentioned conflict stabilized in the range of 0.90–1.10 during the reporting period.

If we considered growth rate from one election to the other and made its average during the whole period under study, the results would change just slightly. The most significant increase in discrepancy between urban and rural election outcomes was identified in the regions of Trebišov, Humenné and Spišská Nová Ves situated in the east, Veľký Krtíš and Rožňava located in the southern part of central Slovakia, Čadca in the very north-western corner of the country, Nové Zámky, Štúrovo and in the region of Šala and Galanta lying in the south-western Slovakia, Zvolen in the middle part, and in the regions of Senica and Hlohovec that could be found in the western side of the Slovak Republic, where the average growth index regarding inter-electoral changes in socio-political urban-rural cleavage was keeping above level of 1.10. On the other hand, the most similar election results regarding their urban-rural context emerged in the regions of Bratislava, Skalica and Holíč, and Nitra situated in the western part of republic, Košice and Bardejov lying on the opposite side of the country, Brezno and Banská Bystrica in the central part of the Slovak Republic, and in the region of Stará Ľubovňa located in the north, where inter-electoral growth index was lower than 0.90. Eventually, FUR of Trnava lying in the western part of Slovakia, Trenčín and Považská Bystrica in Považie region, Ružomberok in Liptov region and Námestovo in Orava region (both situated in the north) posed the territories with the most stable voting preferential conflict between the town and countryside in the Slovak Republic.

In general, the value gap between the town and countryside manifested by a specific political behaviour of their inhabitants was the most pronounced in those regions of the country, which was typical of a high geographical concentration of Hungarians especially in the rural areas, whereas the urban environment is characterized by a significant representation of citizens with Slovak ethnicity, there. Conversely, the lowest socio-political conflict between the electorate of urban and rural communities was found in those parts of Slovakia, which had similar socio-economic characteristics affecting the political dimension of the whole region, too. In terms of spatial context of the Slovak Republic, the regional pattern regarding the level of socio-political cleavage between urban and rural environment can be considered as a long-term valid. Ongoing process of suburbanization typical for the largest towns in Slovakia mitigating the socio-political conflict between the town and countryside might be seen as a valuable piece of knowledge regarding this analysis.

In assessing the global state of investigated issue we can conclude that voting preferential conflict between urban and rural voters weakened at the national level between 1998 and 2010. The most perceptible socio-political fragmentation of society based on discrepancy in electoral decision making of urban inhabitants on the one hand and people living in the rural communities on the other was observed in groundbreaking parliamentary elections of 1998. Conversely, the highest degree of similarity between the election results recorded in the town and countryside was identified at the end of research period (in the case of 2010 elections). Thus, findings of this analysis testified that the parliamentary elections in 1998 often named as both the struggle between the town and countryside and victory of urban electorate over the rural voters confirm the strong cleavage in political behaviour of these distinct environments within the ballots held 14 years ago. The second highest socio-political conflict between urban and rural population was registered for the elections to the National Council of the Slovak Republic in 2006 when after eight years of right-wing government the coalition of Smer-SD, ĽS-HZDS and SNS came to power. However, if we don't consider the socio-political cleavage between urban and rural space in southern parts of Slovakia typical of high territorial concentration of the Hungarians, which is given mainly by the geographic composition of the local ethnic groups, then the elections in 2002 could be marked as the most important battle between the urban and rural values.

3.3 Regional typization of Slovakia according to size and acceleration of socio-political conflict between urban and rural environment

Based on the achieved level and development of socio-political conflict between urban and rural voters, a typization describing the regional pattern of this issue was designed, which can be understood as a synthetic tool comprehensively assessing the degree of (dis)similarity of regional electoral outcomes in the space-time context. According to size and acceleration of electoral cleavage between the town and countryside, given parts of Slovakia were divided into four categories (Figure 2).

The first of regions (15) are those with above-average level of socio-political cleavage between rural and urban electorate, which simultaneously recorded a strengthening of this conflict during the reference period of 1998–2010 (type A). The spatial pattern of this type is characterized by a considerable territorial compactness, since there is a continuous belt of regions located mainly along the southern border of the Slovak Republic. However, representation of this category was also observed in the western (regions of Piešťany, Senica), north-western (regions of Považská Bystrica, Dolný Kubín and Tvrdošín and Nižná) and eastern part of the country (regions of Humenné and Michalovce).

The second category consists of regions that manifest an abnormally high socio-political conflict between urban and rural communities, but losing on its intensity at the same time (type B). This is the least numerous group (9 regions) but having a relatively high population size of spatial units falling into. In this category, two cities of Bratislava and Košice and "big" towns in Slovakia (Nitra, Trenčín, Žilina, Martin) are also included. Spatially

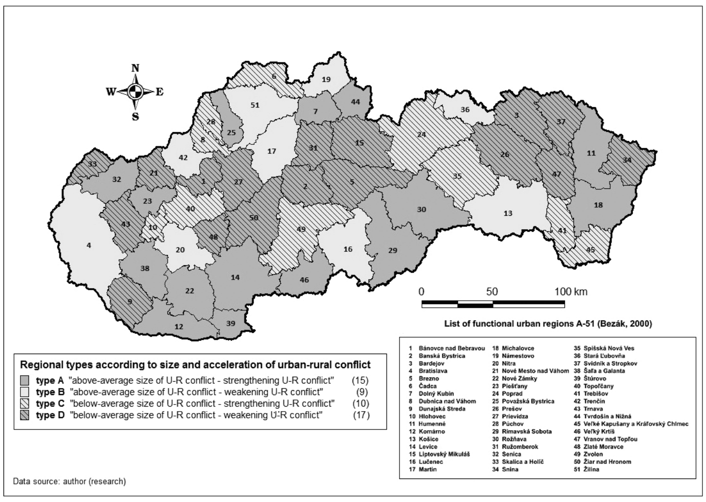

Fig. 2 Typization of Slovak regions according to size and acceleration of socio-political urban-rural conflict based on parliamentary election results in period of 1998–2010

compact concentration of regions with above-average but declining socio-political cleavage of urban and rural voters was identified in the north-western skirt of the Slovak Republic. Behind the mitigating of discrepancy between urban and rural electoral mood in these regions we can find current process of suburbanization concerning the biggest towns and cities in Slovakia, since a significant share of urban population have started to occupy an attractive area of rural municipalities located in their hinterlands.

Almost the same number of spatial units (10) is grouped into the following category, which is common for regions with below-average but strengthening size of socio-political conflict between urban and rural electorate emerged in the analyzed period (type C). This regional type does not pose a spatially compact belt. His territorial representatives can be found mainly in the regions of Považie, Kysuce, Tatras, Spiš, Podpoľanie and in the southern part of Zemplín region as well. In the regions of Hlohovec and Topoľčany situated in western Slovakia, below-average but gradually accelerating socio-political cleavage between urban and rural environment was also detected.

The last, and the most numerous category of spatial units (17) grouped on the basis of a relatively weak socio-political conflict between the town and countryside consists of a third of all Slovak regions (type D). These territories are characterized by a high and increasing similarity in the election results recorded in urban and rural environment during the period. Low voting preferential conflict in urban-rural division of space characterized by its further weakening was found in the regions of Šariš, Liptov, Horehronie, in the northern part of Tekov region, in the Horná Nitra region and in several parts of western Slovakia (in the regions of Dunajská Streda, Trnava, Skalica and Holíč, Nové Mesto nad Váhom, Bánovce nad Bebravou and Zlaté Moravce).

3.4 Regional typization of Slovakia according to party representatives of socio-political conflict between urban and rural environment

In the following part of contribution, we will focus on regional typization based on the existence of political parties representing the socio-economic interests of the people living in both the towns and cities on the one hand and the rural communities on the other in the long term.

In terms of political parties representing the urban or rural voters in the individual parts of the country, we came to typization consisting of four types of regions. During the period of 1998–2010, Mečiar's ĽS-HZDS and Dzurinda's SDKÚ-DS was crystallized as the most abundant type of party representatives covering the socio-political conflict between the town and countryside in functional urban regions of Slovakia, which embodied the greatest issue and value rivals in the field of domestic and foreign policy as well. This kind of urban-rural political conflict was recorded in 27 of 51 regions, which is peculiar to the most of central and north-eastern Slovakia (Figure 3). From the political geography point of view, it is concerning the regions generally regarded as the traditional cores of electoral support declared for ĽS-HZDS, whereas its political opponent is reliant on the urban environment in all regions of Slovakia, in fact. However, this does not mean that party of Vladimír Mečiar did not gain the considerable number of votes in the town of these regions at all. But in this case, electoral support appeared in the urban environment was overlaid the most just by the electoral gains coming from the rural environment of this regional type. The second most numerous type of regions (11) represented by both the SMK-MKP as a party of the Hungarian minority living in Slovakia, which is understood as a rural political representative in this context and the SDKÚ-DS shielding the interests of the urban electorate, is geographically concentrated in the south-western part of the country and southern territories located in the eastern half of Slovakia, too. In these regions of Slovakia, above-mentioned SMK-MKP detected its even highest voting support, which is especially dependent on the geographic composition of the Hungarians living there. This population group is typical of relatively strong rural character of its spatial distribution, which is significantly reflected in election results of SMK-MKP. Among all political parties, right-wing SDKÚ-DS relies the most on the votes cast at ballots by urban voters.

Socio-political conflict having reflection in the electoral inclination of the town and countryside characterized by the most prevailing rural support of KDH and striking share of urban votes for SDKÚ-DS is connected with strong spatial dispersion of regions representing this urban-rural cleavage type. Unlike the previous two types (ĽS-HZDS vs. SDKÚ-DS and SMK-MKP vs. SDKÚ-DS), regions of KDH vs. SDKÚ-DS do not pose a compact spatial belt, which indicates a geographical randomness of their occurrence. However, regions of this type are located in the western half of the Slovak Republic more often (8 of 10 in total), while the coherent strip of them might be identified in Orava region and in the western part of Liptov region as well.

In the case of the last regional type, we can talk about "specific conflict" since its political representatives comprise the unique couples in the country. Veľký Krtíš with its catchment area located in the south of central Slovakia is the first region of this type. In addition to the greatest size of socio-political conflict between urban and rural environment, the region is characterized by an atypical twosome of party representatives. The region's rural area is inherently important to the electoral success of SMK-MKP, while the town supports the Smer-SD differential in political and value manner in a large extent. As was mentioned earlier, this situation is caused by a unique ethnic composition of the region. In terms of ethnic representation, the local countryside is inhabited mostly by Hungarians, whereas the towns of Veľký Krtíš and Modrý Kameň are significantly Slovak. Therefore, the studied conflict is based rather on ethnicity than different urban and rural values. However, it should be mentioned that the typical representative of urban voters in other parts of Slovakia (SDKÚ-DS) had only a slightly higher rurality index of its electoral gain in the reporting period 1998–2010 compared to the party of Robert Fico, there.

Regional type of KDH vs. SNS refers to the category regarding the specific couples of socio-political cleavage between the town and countryside, as well. This kind of socio-political conflict was observed only in the region of Tvrdošín and Nižná situated in Orava, which is traditionally typical of significantly rural votes cast for KDH. Finding on the greatest share of urban ballots registered in regional electoral gain of SNS is quite surprising. This is due to several reasons. The most pragmatic cause is that the right-wing political parties (e.g. SDKÚ-DS or SaS) enjoy a very similar popularity in both urban and rural environment there, which has kept their overall rurality index very close to value 1. In the case of SNS, a much larger difference between the party's electoral outcome in the town on the one hand and countryside on the other (in favour of the urban space) is to be expected.

The town of Púchov with its catchment area poses the last region included in the category of a specific conflict covering the socio-political differences between urban and rural voters. After the parliamentary elections of 1998, Ján Slota's party (nationalistic SNS) was the political formation relying the most on the electoral votes coming from the rural environment of the region, whereas the SDKÚ-DS as a historic leader of the right wing was the party, whose regional election result was primarily built up on the electoral support flowing from the urban space.

3.5 The potential of Slovak regions to be a future hub of socio-political conflict between the town and countryside

To assess the potential of socio-political conflict between urban and rural electorate on the basis of its average level and trend observed at the regional level for more than a decade (1998–2010) is the final ambition of this contribution. Such information defining the conditions of its future course tells about the possibilities of its further development in individual parts of the country. The size and growth index of socio-political regional cleavage manifested through the urban and rural electoral choices can be seen as the factors determining its character at the upcoming parliamentary elections.

Regions of southern and south-western Slovakia are considered as the territorial units with the highest potential to be future centres of social splitting based on different political inclination of urban and rural environment (Table 1). In functional urban regions of the Veľký Krtíš, Rimavská Sobota and Rožňava located in southern Slovakia, of Štúrovo, Nové Zámky, Šaľa a Galanta, Nitra and Senica in the western part of the country, of Čadca, Tvrdošín and Nižná in the northwest and of Spišská Nová Ves, Humenné and Trebišov situated in eastern Slovakia were found predispositions of this kind. These territories are characterized by the significant discrepancy in electoral results between urban and rural area, the rapid increase of this heterogeneity in time or simultaneous effect of both these factors.

On the other hand, the region of Horehronie, eastern part of Liptov region, north-eastern Slovakia and some (especially populationally and geographically smaller) regions located in the western half of the state (Skalica and Holíč, Zlaté Moravce, Nové Mesto nad Váhom and Dunajská Streda) have emerged as the regions with the lowest potential to become a hub of socio- political cleavage between urban and rural voters. A very similar electoral behaviour of urban and rural inhabitants is typical for these areas. A high degree of alikeness in voting pattern of urban and rural space, increase in this similarity or common action of both factors have been erasing the socio-political conflict line between these two environments. At the same time, this creates a frame for maintaining the phenomenon of differences in the electoral choices of urban and rural residents to be at a relatively low level also in the future.

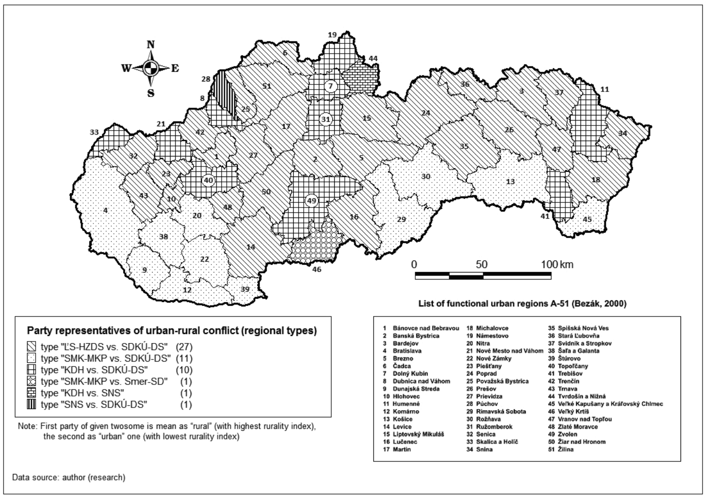

Fig. 3 Typization of Slovak regions according to long-term party representatives of socio-political urban-rural conflict based on parliamentary election results in period of 1998–2010

Tab.1 Size, acceleration and potential of socio-political urban-rural conflict in Slovak regions in period of 1998–2010

	SIZE and ACCELERATION							POTENTIAL						
	1998	2002	2006	2010	1998-2010			RM		PM		FCM		Average ranking
Region	*Size of U-R Conflict*	*Size of U-R Conflict*	*Size of U-R Conflict*	*Size of U-R Conflict*	Size of U-R Conflict	Acceleration of U-R Conflict*	Acceleration of U-R Conflict**	*d1*	*Ranking*	*d2*	*Ranking*	*d3*	*Ranking*	
Veľký Krtíš	10,174	4,698	5,671	12,923	**8,367**	**1,27**	**1,32**	13	1	67,45	1	3,083	1	**1,0**
Šaľa a Galanta	2,618	1,942	2,142	3,472	**2,544**	**1,33**	**1,16**	13	2	33,42	4	0,815	4	**3,3**
Humenné	0,710	1,489	1,200	0,996	**1,099**	**1,40**	**1,24**	18	3	25,84	8	0,317	8	**6,3**
Rožňava	2,279	1,251	1,470	2,526	**1,881**	**1,11**	**1,15**	27	8	26,47	6	0,329	7	**7,0**
Spišská Nová Ves	0,721	0,723	0,841	1,221	**0,876**	**1,69**	**1,21**	31	11	28,50	5	0,524	5	**7,0**
Rimavská Sobota	1,561	1,282	1,333	1,883	**1,515**	**1,21**	**1,09**	22	4	25,63	9	0,283	10	**7,7**
Štúrovo	0,944	0,904	1,031	1,313	**1,048**	**1,39**	**1,12**	23	6	25,38	10	0,285	9	**8,3**
Senica	0,763	1,118	1,044	1,068	**0,998**	**1,40**	**1,14**	26	7	25,19	11	0,273	11	**9,7**
Trebišov	0,265	0,692	0,407	0,964	**0,582**	**3,64**	**1,86**	51	26	53,48	2	2,389	2	**10,0**
Nové Zámky	1,250	1,131	0,893	1,554	**1,207**	**1,24**	**1,14**	22	5	24,29	13	0,197	13	**10,3**
Nitra	7,246	5,081	6,535	2,407	**5,317**	**0,33**	**0,79**	52	27	36,34	3	0,910	3	**11,0**
Tvrdošín a Nižná	0,832	0,948	1,069	1,136	**0,996**	**1,37**	**1,11**	29	10	24,71	12	0,237	12	**11,3**
Čadca	0,504	0,683	0,689	0,807	**0,671**	**1,60**	**1,18**	49	22	26,02	7	0,349	6	**11,7**
Michalovce	0,988	1,198	1,186	1,178	**1,138**	**1,19**	**1,07**	27	9	23,18	16	0,118	16	**13,7**
Levice	0,793	1,020	1,069	1,030	**0,978**	**1,30**	**1,10**	33	14	23,70	14	0,164	14	**14,0**
Dolný Kubín	0,842	1,105	1,165	1,021	**1,033**	**1,21**	**1,08**	33	13	22,85	18	0,098	18	**16,3**
Piešťany	0,994	1,278	1,068	1,147	**1,122**	**1,15**	**1,07**	32	12	22,57	19	0,073	19	**16,7**
Púchov	0,761	0,825	0,798	0,995	**0,845**	**1,31**	**1,10**	42	17	23,00	17	0,117	17	**17,0**
Zvolen	0,534	0,797	0,701	0,749	**0,695**	**1,40**	**1,15**	49	21	23,41	15	0,154	15	**17,0**
Komárno	0,985	0,921	1,044	1,141	**1,023**	**1,16**	**1,05**	38	15	22,03	20	0,037	20	**18,3**
Považská Bystrica	1,050	1,089	1,136	1,064	**1,084**	**1,01**	**1,01**	40	16	20,40	23	-0,086	24	**21,0**
Topoľčany	0,706	0,966	1,052	0,818	**0,886**	**1,16**	**1,08**	46	19	21,22	22	-0,016	22	**21,0**
Dubnica nad Váhom	0,825	0,991	1,076	0,872	**0,941**	**1,06**	**1,03**	49	20	20,14	26	-0,099	25	**23,7**
Hlohovec	0,589	0,804	0,541	0,742	**0,669**	**1,26**	**1,14**	60	34	21,32	21	0,000	21	**25,3**
Trenčín	0,973	1,212	1,058	0,910	**1,038**	**0,93**	**0,99**	45	18	19,04	29	-0,185	29	**25,3**
Bratislava	3,698	2,649	3,026	1,202	**2,644**	**0,33**	**0,75**	54	28	20,27	24	-0,165	27	**26,3**
Námestovo	0,920	1,110	0,930	0,902	**0,965**	**0,98**	**1,01**	50	23	19,25	28	-0,166	28	**26,3**
Poprad	0,746	0,795	0,842	0,838	**0,805**	**1,12**	**1,04**	60	33	20,24	25	-0,085	23	**27,0**
V. Kapušany a Kr. Chlmec	0,872	0,730	0,693	0,943	**0,809**	**1,08**	**1,05**	61	36	19,70	27	-0,126	26	**29,7**
Trnava	0,791	0,981	0,853	0,758	**0,846**	**0,96**	**1,00**	58	31	18,21	30	-0,238	30	**30,3**
Prešov	0,935	0,942	0,871	0,853	**0,900**	**0,91**	**0,97**	56	30	17,92	31	-0,262	31	**30,7**
Lučenec	1,275	1,322	0,950	0,978	**1,131**	**0,77**	**0,93**	51	25	17,29	34	-0,318	35	**31,3**
Žilina	1,133	1,458	1,271	0,839	**1,175**	**0,74**	**0,94**	51	24	17,20	35	-0,328	37	**32,0**
Bánovce nad Bebravou	0,706	1,013	0,958	0,657	**0,833**	**0,93**	**1,02**	64	39	17,77	32	-0,270	32	**34,3**
Ružomberok	0,760	1,078	0,975	0,678	**0,873**	**0,89**	**1,01**	63	37	17,47	33	-0,294	33	**34,3**
Prievidza	0,857	1,098	0,893	0,730	**0,895**	**0,85**	**0,97**	61	35	17,04	37	-0,327	36	**36,0**
Vranov nad Topľou	0,789	0,898	0,744	0,715	**0,786**	**0,91**	**0,98**	72	40	17,14	36	-0,315	34	**36,7**
Žiar nad Hronom	0,663	0,835	0,714	0,603	**0,704**	**0,91**	**0,99**	74	41	16,71	38	-0,343	38	**39,0**
Košice	1,731	1,157	1,241	0,881	**1,253**	**0,51**	**0,82**	55	29	14,48	44	-0,533	45	**39,3**
Martin	1,016	1,179	0,952	0,762	**0,977**	**0,75**	**0,92**	64	38	16,14	40	-0,397	40	**39,3**
Dunajská Streda	0,770	0,810	0,836	0,653	**0,767**	**0,85**	**0,95**	77	43	16,23	39	-0,381	39	**40,3**
Liptovský Mikuláš	0,842	0,902	0,846	0,669	**0,815**	**0,79**	**0,93**	75	42	15,79	42	-0,416	42	**42,0**
Nové Mesto nad Váhom	0,750	0,793	0,661	0,636	**0,710**	**0,85**	**0,95**	77	44	15,89	41	-0,404	41	**42,0**
Stará Ľubovňa	1,195	1,264	1,362	0,629	**1,113**	**0,53**	**0,87**	59	32	13,88	47	-0,571	47	**42,0**
Snina	0,660	0,730	0,565	0,553	**0,627**	**0,84**	**0,95**	85	48	15,26	43	-0,447	43	**44,7**
Svidník a Stropkov	0,748	0,637	0,461	0,589	**0,609**	**0,79**	**0,95**	88	50	14,47	45	-0,505	44	**46,3**
Brezno	0,947	1,044	0,840	0,543	**0,843**	**0,57**	**0,85**	78	45	12,92	48	-0,630	48	**47,0**
Zlaté Moravce	0,596	0,777	0,914	0,432	**0,680**	**0,73**	**0,98**	88	49	14,04	46	-0,540	46	**47,0**
Bardejov	1,152	1,004	0,547	0,610	**0,828**	**0,53**	**0,84**	81	47	12,23	49	-0,681	49	**48,3**
Banská Bystrica	0,903	1,126	0,880	0,469	**0,844**	**0,52**	**0,85**	80	46	12,18	50	-0,685	50	**48,7**
Skalica a Holíč	0,729	0,520	0,301	0,305	**0,464**	**0,42**	**0,77**	100	51	8,53	51	-0,939	51	**51,0**
SLOVAK REPUBLIC	**1,643**	**1,388**	**1,595**	**0,767**	**1,348**	**0,47**	**0,82**	x	x	x	x	x	x	**x**
SLOVAK REPUBLIC***	**0,842**	**1,164**	**0,988**	**0,782**	**0,944**	**0,93**	**1,01**	x	x	x	x	x	x	**x**

Abbreviations:

U-R *urban-rural* — ***RM*** *ranking method*
d1 *integral indicator 1* — ***PM*** *point method*
d2 *integral indicator 2* — ***FCM*** *factor comparison method*
d3 *integral indicator 3*

** calculated as the growth rate of U-R conflict concerning the first and the last elections within the period under study (2010/1998),*
*** calculated as the average of three inter-electoral growth rates of U-R conflict (2002/1998; 2006/2002; 2010/2006),*
**** calculated without 11 regions with more than 20% share of Hungarians in order to eleminate an influence of ethnicity*

Data source: author (research)

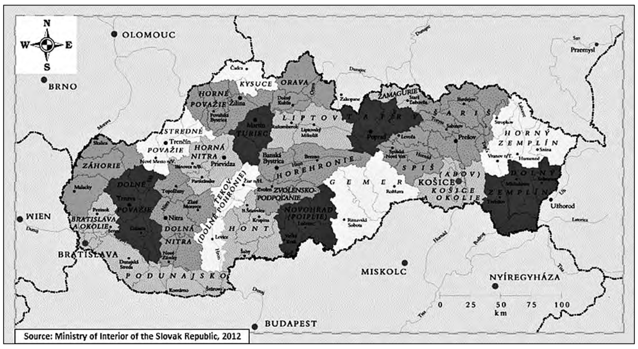

Fig. 4 Historical regions in Slovakia

4. Conclusion

In terms of voting preferential urban-rural dimension, the most notable socio-political cleavage were found in the regions of Veľký Krtíš, Nitra, Bratislava, Šaľa and Galanta, Rožňava and Rimavská Sobota. Conversely, the most similar election results between urban space on one side and rural communities on the other were registered in the regions of Skalica and Holíč, Trebišov, Svidník and Stropkov, Snina, Hlohovec, Čadca, Zlaté Moravce, Zvolen, Žiar nad Hronom and Nové Mesto nad Váhom. Thus, the nature of electoral support manifested by the rural and urban electorate can be regarded as a significantly different in several regions of southern and south-western Slovakia, whereas a very similar in some border regions of eastern Slovakia, in the region of Podpoľanie, in north of Hont region and Tekov region located in the central part of the country, in Kysuce region and in populationally and territorially smaller regions lying in the west of the state.

In the period under study, the socio-political cleavage between the town and countryside deepened the most significantly in the regions of Trebišov, Spišská Nová Ves and Humenné located in eastern Slovakia, of Čadca, Tvrdošín and Nižná situated in the northwest, in Zvolen and its catchment area lying in the central part of the republic and in the western regions of Senica, Štúrovo, Šaľa and Galanta, where discrepancy between urban and rural electoral outcomes increased by more than a third. In the region of Trebišov, this conflict increased even by 3.5 times. On the contrary, the most significant decline in this cleavage occurred in the regions of Bratislava, Nitra, Skalica and Holíč located in the west of the country, of Banská Bystrica and Brezno situated in the central Slovakia and of Košice, Stará Ľubovňa and Bardejov, which can be found in the eastern part of the republic. The regions of Trenčín, Považská Bystrica and Dubnica nad Váhom lying in the middle Považie, the western regions of Bánovce nad Bebravou and Trnava, the regions of Vranov nad Topľou, Prešov, Veľké Kapušany and Kráľovský Chlmec situated in the eastern part of the country, Orava's region of Námestovo, and Žiar nad Hronom with its catchment area located in central Slovakia can be considered as the territories showing a relatively stable level of socio-political cleavage between urban and rural population expressed by the electoral votes coming from the town and countryside.

During the parliamentary elections held in period of 1998–2010, the regional type of Mečiar's ĽS-HZDS (rural) and Dzurinda's SDKÚ-DS (urban) embodying the greatest long-term issue and value rivals within Slovak domestic and foreign policy affairs profiled as the most numerous party representatives' kind of socio-political conflict between rural and urban areas at the regional level. In this period, a massive shift of ĽS-HZDS's voters to electorate of Smer-SD was registered, which transformed a previously weak urban profile of Robert Fico's party into slightly rural with expectation on further strengthening of its rurality.

Particular regions of southern and south-western Slovakia are regarded as the territorial units with the highest potential to be the future centres of social cleavage based on differential political inclination of urban and rural voters. Remarkable discrepancy in election outcomes between the votes cast in the town and countryside, the sharp increase of this dissimilarity during the period under study or common influence of both these factors are peculiar to these areas. The Horehronie region, the eastern part of Liptov region, north-eastern Slovakia and some (mainly populationally and geographically smaller) regions located in the west of the country emerged as regions with the lowest potential to become a socio-political conflict between urban and rural voters. A very similar political behaviour of urban and rural inhabitants is distinctive for these territories. A high level of correspondence in voting pattern between the town and countryside, continual strengthening of this similarity or operating of both factors have weakened the socio-political conflict line existing between the two environments under study. This means predispositions for maintaining the phenomenon of discrepancy in the electoral preferences of urban and rural population at a relatively low level in upcoming years. However, if we consider the socio-political cleavage between the town and countryside in Slovakian space-time context, we should not forget to mind influence of ethic structure (mainly in the case of SMK-MKP and topically Most-Híd) and other conflict lines on final division of votes into urban and rural. Ongoing process of suburbanisation may also cause urban-rural pattern of electoral outcomes.

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RÉSUMÉ

Regionální dimenze socio-politického konfliktu mezi městem a venkovem na Slovensku

Politické chování občanů je tradičně formováno širokou plejádou faktorů, které ovlivňují jejich hlasování v samotných volbách. Dichotomie prostoru i společnosti na město a venkov dlouhodobě generuje rozdílné volební výsledky. Klíčovým úkolem tohoto příspěvku bylo zachycení míry rurality volební podpory relevantních politických subjektů působících na slovenské politické scéně v období po přelomových volbách v roce 1998 až po rok 2010 nejen na národní, ale především na regionální úrovni. Evaluace úrovně a dynamiky sociopolitického štěpení společnosti venkova a města představovala jednu z nejvýznamnějších vědeckovýzkumných ambicí představované studie. Zhodnotili jsme postavení jednotlivých regionů Slovenska z hlediska rozsahu a akcelerace této konfliktní linie a pokusili jsme se o jejich kategorizaci na základě podobnosti hodnot ukazatelů charakterizujících tento společenský nesoulad. Komentovali jsme volební úspěšnost jednotlivých politických stran v městském a venkovském prostředí a na základě zjištěných reálií jsme zkoncipovali typizaci regionů Slovenska podle politických reprezentantů urbánního a rurálního prostoru. V závěru jsme vyhodnotili potenciál jednotlivých regionů ve smyslu budoucích ohnisek latentního štěpení společnosti projevujícího se v politických inklinacích jednotlivých částí země.

Při hodnocení globálního stavu zkoumané problematiky lze konstatovat, že mezi lety 1998 až 2010 došlo na celonárodní úrovni k volebně-preferenční konvergenci urbánního a rurálního prostředí. K nejcitelnějšímu sociopolitickému štěpení společnosti na bázi diference volebních preferencí obyvatel měst na jedné straně a venkovských obcí na straně druhé došlo v přelomových parlamentních volbách v roce 1998. Naopak nejvyšší míru podobnosti volebních výsledků mezi urbánním a rurální prostředím bylo možné evidovat u příležitosti voleb do NR SR uskutečněných v roce 2010. Výsledky provedeného výzkumu tak dokazují, že parlamentní volby v roce 1998 se právem označují jako souboj města a venkova, resp. jako vítězství urbánní části voličů nad rurální, což jen potvrzuje výraznou vyhraněnost politických inklinací těchto specifických prostředí právě v případě voleb před 15 lety. Druhá nejvyšší sociopolitická divergence mezi populací města a venkova byl registrován při volbách do NR SR v roce 2006, kdy se po osmi letech pravicové vlády dostal k moci někdejší vládní trojlístek Smer-SD, ĽS-HZDS a SNS. V tomto období je zajímavý masivní přesun elektorátu ĽS-HZDS k voličské základně Smeru-SD, což v konečném důsledků transformovalo původně nevýrazný urbánní profil strany Roberta Fica na mírně rurální s předpokladem dalšího posilování rurality její volební podpory. Pokud bychom však neuvažovali o společensko-politickém štěpení urbánního a rurální prostoru v jižních oblastech Slovenska typických vysokou územní koncentrací obyvatelstva maďarské národnosti, které je dáno v první řadě geografickou kompozicí etnických skupin zdejší populace, pak bychom mohli za nejvýznamnější souboj skutečných městských a venkovských hodnot považovat ten odehrávající se ve volbách v roce 2002.

Obecně platí, že hodnotový rozpor mezi městem a venkovem projevený prostřednictvím specifického politického chování jejich obyvatel byl nejvýraznější v těch regionech země, v nichž žije vysoký podíl občanů maďarské národnosti, a to především v jejich venkovském prostoru, přičemž urbánní prostředí těchto oblastí je charakteristické významným zastoupením populace slovenské národnosti. Avšak v této souvislosti je třeba zdůraznit, že vysoká ruralita volebních zisků SMK-MKP je vzhledem k prostorové kompozici jejího elektorátu zapříčiněna především etnickou strukturou obyvatel Slovenska charakterizovanou územní koncentrací občanů maďarské národnosti v jižních částech země. Venkovský profil voličské podpory této strany se tedy programově neváže na prosazování hodnot a potřeb venkovské komunity jako takové.

Naopak nejmenší volebně-preferenční nesoulad mezi elektorátem měst a venkovských obcí byl zjištěn v těch částech Slovenska, které vykazují podobné sociální a ekonomické charakteristiky obou prostředí a nacházejí svůj politický rozměr ve volebních

inklinacích samotného regionu bez zásadnějšího vlivu zkoumané konfliktní linie. Regionální obraz úrovně sociopolitického štěpení společnosti urbánního a rurální prostředí lze z prostorového hlediska považovat v rámci území Slovenské republiky za dlouhodobě platný. Rovněž můžeme předpokládat, že ke zmírňování společensko-politického rozporu mezi městem a venkovem přispívá relevantním dílem i probíhající proces suburbanizace největších měst Slovenska.

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LANDSLIDE-INDUCED CHANGES OF VESSEL SHAPE IN *BETULA PENDULA* ROTH. – A PRELIMINARY STUDY

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ABSTRACT

Investigation of relationship between vessel structures and exogenous geomorphic processes like landslides, rockfalls, debris flows as well as snow avalanches are common in present dendrogeomorphology. However, very little is known yet about change of the shape characteristics of vessels of *Betula pendula* as a result of different mass movements.

Analysis of vessel lumen length (LL) and width (LW) change on 49 microsections prepared from 15 landslide-disturbed-birches was the goal of this study. A relationship between LW and LL was reported for the year before (2010) and after (2011) landslide separately using equation of linear regression. To evaluate inter-annual variability of changes in shape parameters of tracheas, the proportions of LW and LL in year 2009 was also described for 8 disturbed trees. Slope of the regression line very well characterizes the relationship between LW and LL and evaluation of inter-annual change between LW and LL was carried out based on annual change index (ACI). ACI was defined as a value of percentage change in the slope of the regression lines before and after the landslide disturbance.

There is statistically significant change in vessel shape parameters between the years 2010 and 2011. Overall, the highest values of ACI were calculated in microsections sampled in the direction of slope distribution – side of reaction wood production, where $ACI_{2010/11}$ average value was higher than 43% which is twice more than values from other samples. Increasing of isodiametricity is also typical, while it was found at 65% of analysed disturbed samples.

Key words: mass movements, dendrogeomorphology, *Betula pendula*, wood anatomy, vessel

1. Introduction

Numerous geomorphic events and processes have significant impacts on trees and leave permanent signs within the wood anatomy (Schweingruber 1996). These signals, manifested as variations in tree-ring widths, as well as structural modifications of the wood mass, allow us backward reconstruction of the beginning, duration, scope and frequency of many geomorphic processes (Sass and Eckstein 1995; Strunk 1997). Since 1960s, tree-ring analysis have been used as a leading method of climate reconstruction, environmental changes analysis, and geomorphic processes – such as debris flows, landslides, rockfalls and snow avalanches – dating (Alestalo 1971; Braam et al. 1987; Schweingruber 1996; Lang et al. 1997, etc.). The recent studies focus on wood anatomical reactions (variations in tension or compression wood, varying vessel sizes and numbers) and application of wood anatomical techniques to study additional information of severity and intensity of past impacts on tree growth (Stoffel et al. 2005b; Perret et al. 2006; Casteller et al. 2007; Heinrich and Gärtner 2008; Schneuwly and Stoffel 2008; Gärtner and Heinrich 2009; Sorg et al. 2010; Bollschweiler et al. 2010; Corona et al. 2010; Bollschweiler et al. 2011; Casteller et al. 2011; Lopez Saez et al. 2011, etc.).

Although dendrogeomorphology is worldwide method used for analysis of many geomorphic processes the vast majority of published studies focus on species of spruce – *Picea* (Casteller et al. 2007; Perret et al. 2006; Bollschweiller et al. 2007 and others), larch – *Larix* (Stoffel et al. 2005a, 2005b; Schneuwly and Stoffel 2008; Corona et al. 2010 and others), pine – *Pinus* (Santilli and Pelfini 2002; Muntán et al. 2009; Bollschweiler et al. 2010; Lopez Saez et al., 2011 and others), firs – *Abies* (Yoshida et al. 1997; Bollschweiler et al. 2010; Köse et al. 2010) and deciduous trees, house beech – *Fagus* (Šilhán and Pánek 2008; Van Den Eeckhaut et al. 2009; Burda 2010; Žížala et al. 2010 and others), oak – *Quercus* (Fantucci and Sorriso-Valvo 1999; Stefanini 2004; Moya et al. 2010 and others), or maple – *Acer* (Daňhelka 2001; Šilhán 2010 and others). Selection of analysed trees or examined species is given by geographical conditions of the habitat, which directly determine the growth of individual species. It is noteworthy that the surveys based on analysis of birch species (*Betula*) are sporadic in published studies, mainly because it has very difficult anatomy of wood, which results in poor visibility of its tree-rings. From number of dendrogeomorphological mass movements' studies this species was used by Casteller et al. (2007); Decaulne and Sæmundsson (2008); Arbellay et al. (2010); Szymczak et al. (2010) and Decaulne et al. (2012).

The recent trend in dendrogeomorphology focuses on describing of the relationship between changes in the environment and the size, spatial distribution and the shape of vessels. For example, the information about the history of inundations (Kozlowski 1997) and flash floods (Ballesteros et al. 2010; Tardif et al. 2010; George 2010) is present in changes of Vessel Lumen Area (VLA) and

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spatial distribution of vessels in the tree-ring. Both processes mentioned above usually tend to the formation of larger number of smaller tracheas (Kozlowski 1997; Ballesteros et al. 2010; George et al. 2010). Changes in size, shape and spatial distribution of vessels were also used to identify the year of root exhumation caused by erosion (Hitz et al. 2008) or for debris-flow activity reconstruction (Arbellay et al. 2010, 2012). The aim of this preliminary study was to test the potential of *Betula pendula* Roth. trees to reconstruct past landslide activity in anthropogenic mining landscapes as well as outline of future research needs. Hence we tested the possibility of using shape parameters of vessels of inclined *B. pendula* trees in order to describe its changes before and after the landslide.

Anthropogenic relief of Most Basin (Czech Republic), intensively formed from the second half of the 20th century, was chosen as an ideal model locality for this research (Figure 1). Extensive areas of dump bodies, heaps and abandoned open-pit mines are the places of evolution of a number of new geomorphologic landforms. These areas remain aside of interests the professional and lay public very often, which also means aside research or monitoring. Numerous slope deformations, many of which have not been mapped or not further investigated, evolved in the past in these areas (e.g., landslides on dumps).

Except for reclaimed areas there were many sites left to natural succession, therefore many of these sites are dominated by self-seeded tree species, especially Silver Birch – *B. pendula* (Lipský 2006). Dendrogeomorphological investigation of *B. pendula* is one of few possibilities of retrospective research of the dynamics and scope of geomorphic processes and exact dating of newly evolved landforms.

2. Material and methods

Twenty Silver Birches were selected for purposes of this dendrogeomorphological experiment in the area of Jezeří landslide (Figure 1). Overall morphology, morphometry as well as triggering factors and landslide evolution were described by Burda et al. (2013). The self-seeded forest stand (8–18yr old) was damaged during the main movement activity in 15 January 2011 (Figure 2), which means before the beginning of growing season.

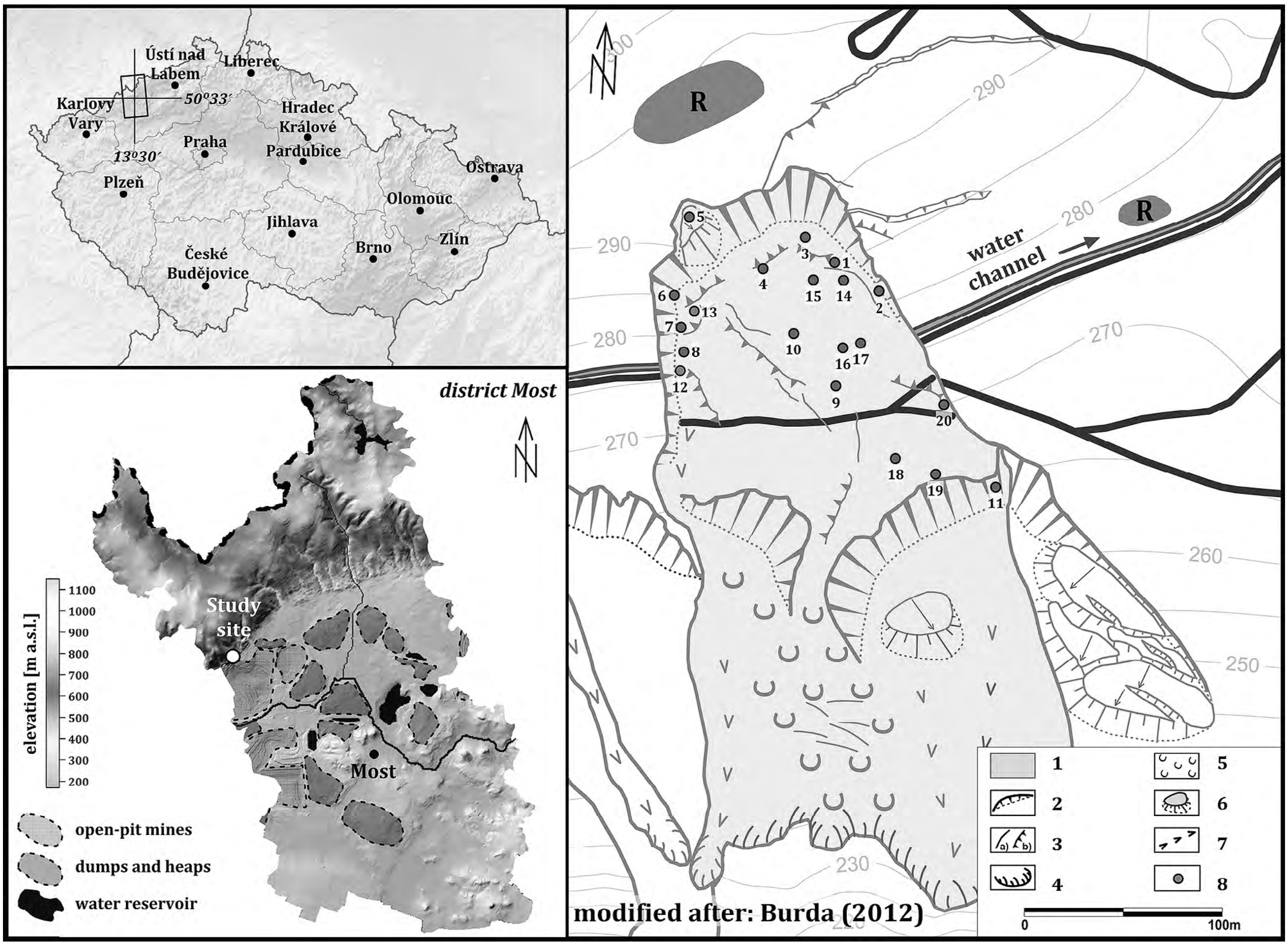


Fig. 1 The experimental research area (right) is located in the edge of Most basin in the Most town district (bottom left) in the northwest of the Czech Republic (top left). The position of sampled trees is shown in the geomorphology sketch map (right): 1 – investigated January 2011 landslide; 2 – headscarps; 3 – (a) tension cracks, (b) tension cracks with vertical offset; 4 – accumulation toes; 5 – accumulation surfaces of landslides; 6 – landslide blocks within the landslide complex; 7 – earthflows; 8 – selected trees; R – reference group

In the study site, we selected trees with different degree and type of macroscopic deformations, four different disturbed groups (T1 to T3) and one undisturbed reference group (R) were set up (Figure 3). Figure 2 shows the positions of all of the 20 sampled disturbed trees. From the sampled trees, 11 stem discs were sawn and polished (nos. 1–11) and 9 increment cores were extracted from rest 9 trees (nos. 12–20). Increment cores were drilled trough the stem in B–D direction that corresponds to the direction of slope disturbance (Figure 4). Other 10 cores were extracted from 10 undisturbed trees near the landslide area (Figure 1). We used these samples as a reference group for comparison to disturbed groups (T1, T1er, T2 and T3) and as these trees are situated in the flat relief, the exact determination of directions A–D lose the sense. Because the reference group should represent the common behaviour of undisturbed trees we artificially set these samples as A–C directions because we expect, that cores coming from disturbed trees in respective direction will record no or very low changes caused by tension (direction B) or compression (direction D) resulting from stem inclination. The field-work was performed during August and September 2011.

Both stem discs and increment cores were extracted at the height of stem curvature whenever possible, otherwise at breast height (~130 cm). The position, macroscopic stem defects (angle of inclination, stem curvature, etc.), local morphology and position of each sample were recorded.

According to Schweingruber et al. (2008), the stem sections and increment cores were cut into 20 μm thick transverse microsections using GSL 1 core-microtome. Four microsections (A–D) were prepared from each stem disc and two (in respective directions) from each increment core; subsequently stained using Safranin and AstraBlue in order to increase the contrast between lumens and walls of vessels. The preparation of microsections from birch proved to be very complicated process due to the high hardness of xylem. Particularly in the case of increment cores it was often impossible to saw a microsection of sufficient quality for subsequent image analysis. Therefore we were able to prepare 49 microsections from 15 disturbed trees and 18 microsections from 9 reference trees.

2.1 Variations in vessels parameters

In this experimental research, we focused on measurement of parameters of shape of vessels and its changes after the slope disturbance. The measurement was performed using the WinCell Pro 2011a software (Regent Instrument Inc.) and vessel parameters were analysed in two years; in the year preceding the slope disturbance (2010) and the year after landslide (2011). We also measured vessels in tree-rings formed in 2009 to compare inter-annual variability of trachea shapes; unfortunately the difficulties with preparing samples of birch wood with appropriate quality limited this only to microsections coming from 8 disturbed cross-sections. The proper measurement was performed from microimages of anatomical structure of the xylem captured in 40× magnification using digital camera and light microscope.

Unlike other studies, which also investigated the relationship between structure of vessel elements and exogenous factors (e.g., Arbellay et al. 2010, 2012; Ballesteros et al. 2010; Kames et al. 2011) and which are most focused on Vessel Lumen Area changes, in our case much more attention was paid to the shape characteristics of vessels (i.e., mainly the length and width of vessels and their mutual relationship). As some studies (e.g., Gonzáles and Eckstein 2003) pointed out the strong influence of spring precipitation on VLA in a specific tree-ring, difficulties with filtering this climatic effect can occur in applications of VLA as pointer of the geomorphological disturbance. Although strong positive correlation between VLA and diameter of the vessel has been documented (Arbellay et al. 2010), climate probably can have only a very limited influence on the ratio between perpendicular diameters of lumens, which are further analysed and discussed.

The WinCell software can understand the concept of width and length in different ways, depending on the user settings – in our case, the length of the vessel lumen (LL) was defined as the longest possible connecting line of lumen borders and width (LW) as the longest possible connecting line perpendicular to the LL (Figure 4). So always LW < LL, only in the case of regular geometric shapes (circles, squares) is LW = LL (Figure 4).

A relationship between LW and LL is reported for each year (2010, 2011 and for some samples also 2009) and each sample separately using developed equation of linear regression based on all vessels that were measured in the annual ring (after manual exclusion of outliers). Slope of the regression line very well characterizes the relationship between LW and LL in the annual ring. It is in addition to our hypothesis, that inter-annual rate of percentage change in slope of the regression lines is a good indicator of the possible effect of external disturbance (Figure 5). Evaluation of inter-annual change between LW and LL was carried out based on annual change index (*ACI*). ACI was defined as a value of percentage change in the slope of the regression lines before and after the landslide disturbance.

$$ACI = 100 \cdot \left| \frac{slope\ (2011)}{slope\ (2010)} - 1 \right|$$

Respective form of equation above was used also for describing changes of the vessel shapes between years 2009 and 2010. Various differences in ACI between reference and disturbed trees and also between different orientations of sample around the stem have been described by means of statistical procedures described e.g., by Hendl (2009). To test the significance of annual changes in

Fig. 2 Aerial view on the study site with marked position of selected trees; R – reference group (foto: J. Burda, 2011)

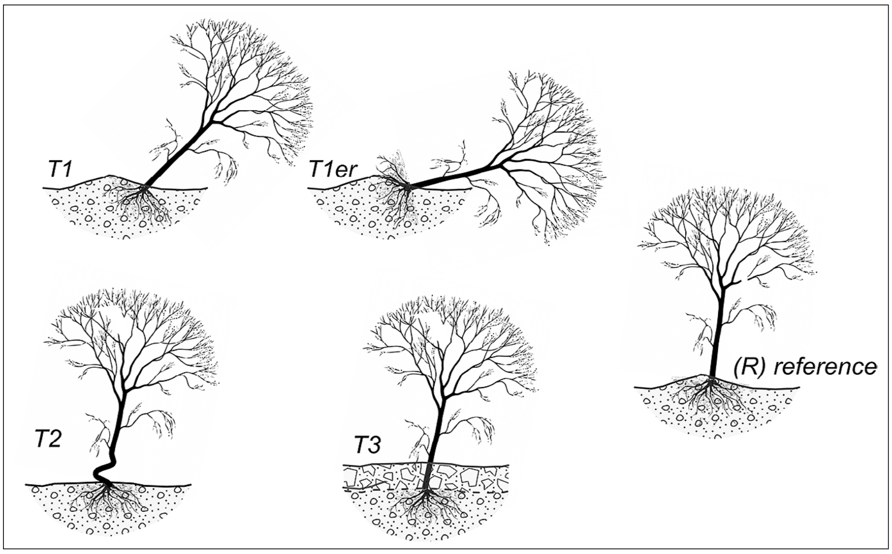


Fig. 3 Basic groups of macroscopic stem defects found in the study site: T1 – stem tilted from vertical direction; T1er – stem tilted from vertical directions and with exposed roots; T2 – significant stem curvature; T3 – buried stem; R – undisturbed tree

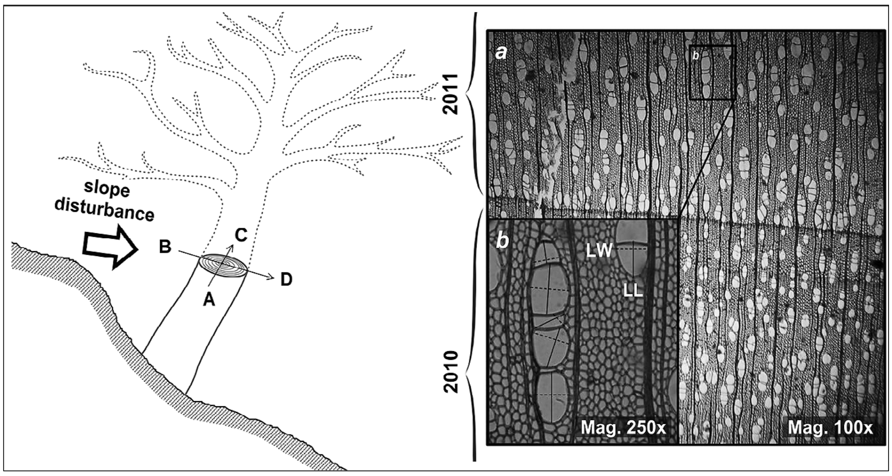


Fig. 4 A method of sampling strategy in respective directions (left). Micro-photo of anatomical structure of xylem of *B. pendula* (right). Solid lines represent orientations of measurement of LL, dashed lines orientations of measurement of LW (a – approximate magnifications 100×, b – Approximate magnifications 250×)

slopes, non-parametric tests of mean (Wilcoxon test, Sign test) were used. Differences in ACI values among 4 directions of sampling were tested with One-way ANOVA (and subsequent post-hoc tests).

3. Results

In total, 67 microsections from 24 trees of *B. pendula* specie were analysed in order to describe parameters of shape of vessels. From these, 8236 vessels were measured (in tree-rings 2010 and 2011), which corresponds to an average of about 340 vessels per tree and 123 vessels per sample. In general, more vessel elements were measured on disturbed samples (134 per sample) and substantially less on reference samples (102 per sample). This is mainly due to larger surface of microsection prepared from the stem section than from the increment core.

3.1 Variations in vessel parameters

Calculated values of $ACI_{2010/11}$ fluctuated between 1 to 85.3% in disturbed trees and in the range from 1 to 70.3% in undisturbed trees. The distribution of $ACI_{2010/11}$ values for disturbed group is very similar in A, C and D directions; the most of calculated $ACI_{2010/11}$ values is lower than 20% (Figure 6), that is also reflected in $ACI_{2010/11}$ average values (Figure 7). The $ACI_{2010/11}$ exceeds 60% only in one case which relationship to the distribution of other observations showed the character of remote observation (outlier), and was therefore excluded from further analysis. $ACI_{2010/11}$ averages for samples A, C and D are 21.1%, 21.7% and 26.2%. Similar values, but with more uniform distribution (Figure 6 and Figure 8), were found in both directions (A and C) of reference group. In these cases the $ACI_{2010/11}$ value did not reach 45%, higher value (70.3%) was found only in one sample and was excluded as an outlier.

The analysis of change of vessels shape parameters in the microsections prepared from samples B, which corresponds to the direction of slope deformation and the side of tension wood production, looks quite different. Most of the values of $ACI_{2010/11}$ is in the range of 30 and 50% with an average value of 43.7% (Figure 6 and Figure 8). In general, the values fluctuated between 1.1% and 85.3% – which is the highest identified value in the data set.

If we compare values of $ACI_{2009/10}$ and $ACI_{2010/11}$ in 8 selected disturbed trees, results indicate that changes in shapes of vessels are more significant after the landslide event comparing the year without slope activity. Average $ACI_{2009/10}$ (group of 8 disturbed trees) for A, B, C and D are 12.6%, 22.1%, 24.2% and 16.7%; $ACI_{2010/11}$ values in respective directions are generally slightly higher: 22.5%, 53.3%, 19.9% and 26.2%. Only in the case of ACI values in direction C, there is small decrease of their level. Although 6 of samples from this orientation record very small values of $ACI_{2009/10}$ (below 15%), the result is strongly influenced by one tree (no. 4) with $ACI_{2009/10}$ almost 95% (Figure 9). If we exclude this observation as an outlier, the average value will decrease from 24.2% to 14.1%.

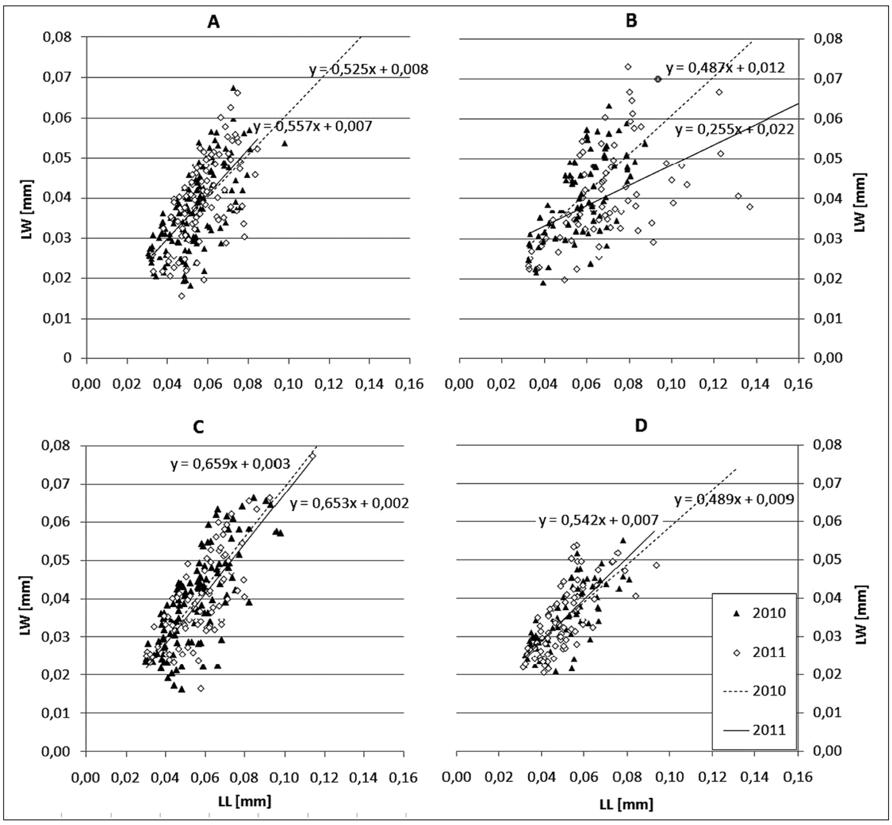


Fig. 5 Charts of LW–LL relations for vessels from disturbed tree no. 11

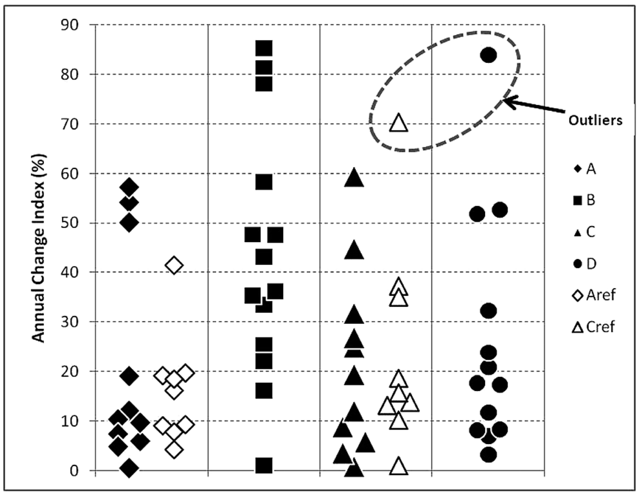


Fig. 6 $ACI_{2010/11}$ values for individual samples with respect to their category (reference or disturbed) and position around the stem circumference

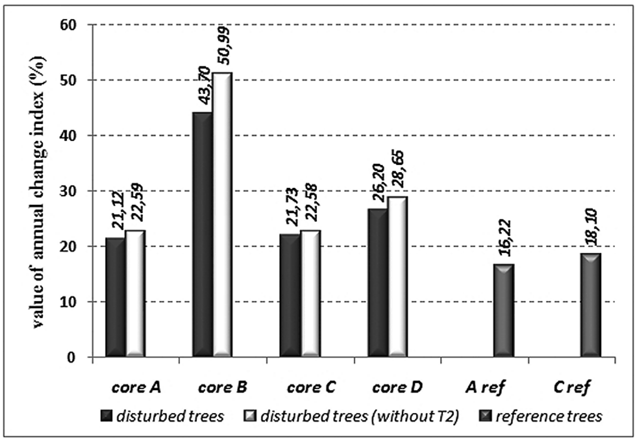
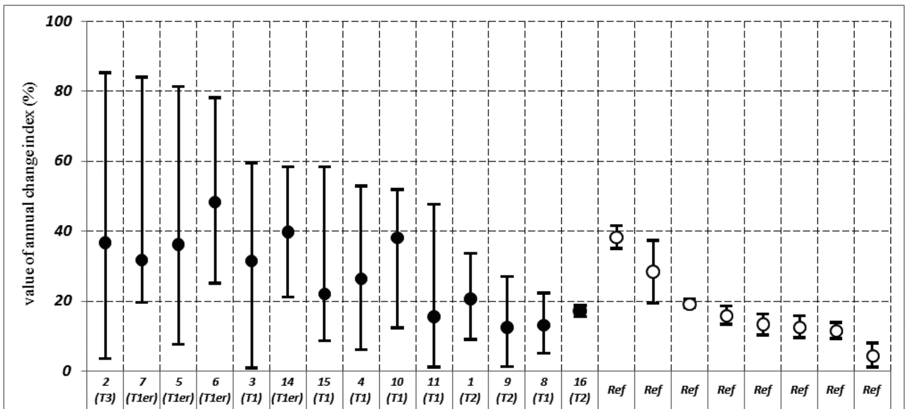


Fig. 7 Average values of annual change index ($ACI_{2010/11}$) for respective directions of disturbed and undisturbed trees as well as with excluded trees from T2



	2 (T3)	7 (T1er)	5 (T1er)	6 (T1er)	3 (T1)	14 (T1er)	15 (T1)	4 (T1)	10 (T1)	11 (T1)	1 (T2)	9 (T2)	8 (T1)	16 (T2)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
ACI - max.	85,3	84,0	81,3	78,0	59,4	58,3	58,3	52,8	51,8	47,6	33,5	26,9	22,1	18,7	41,5	37,2	20,5	18,5	16,2	15,7	13,8	7,88
ACI - min.	3,35	19,4	7,52	25,0	0,65	21,0	8,52	5,92	12,1	0,91	8,90	1,12	4,96	15,4	35,0	19,2	18,0	13,2	10,1	9,38	9,13	0,99
ACI - avg.	36,6	31,6	36,1	48,1	31,3	39,6	21,9	26,3	38,0	15,4	20,5	12,4	13,0	17,0	38,2	28,2	19,2	15,9	13,2	12,5	11,5	4,44

Fig. 8 Fluctuation of $ACI_{2010/11}$ values in individual trees; maximal, minimal and average ACI values have been plot for every single tree separately

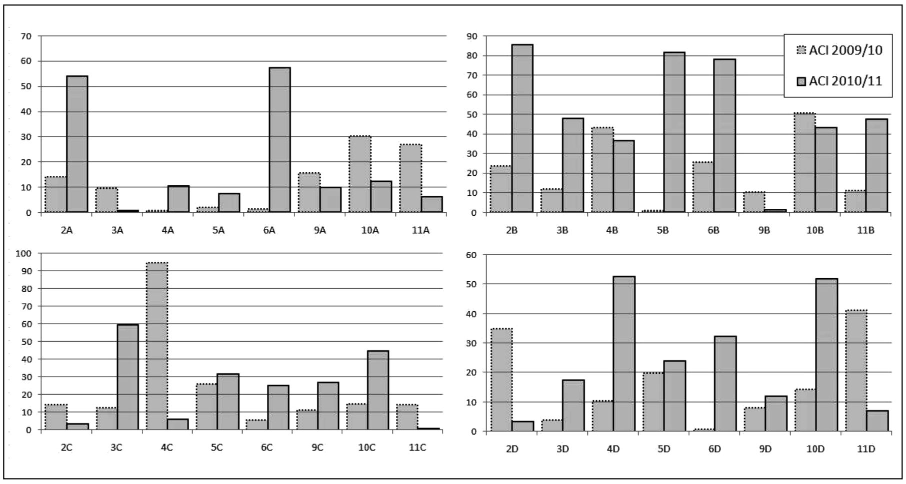


Fig. 9 Comparing of $ACI_{2009/10}$ and $ACI_{2010/11}$ for cross-sections coming from 8 disturbed trees

3.2 The relationship between the values of slope of the regression lines in 2010 and 2011

While in the case of disturbed trees, differences between the slope of regression line in years before and after the event were clearly demonstrable (p-value < 0.001 in both tests), no significant change occurred in reference trees (p-values 0.814 respectively 0.711). ANOVA analysis also pointed (p-value 0.0459), the $ACI_{2010/11}$ is different when it is calculated at disturbed trees in different directions in relation to the effect of slope movement. As it was already mentioned above, the highest is in the direction B, i.e. in the direction similar to the slope disturbance. The second highest values (26.2%) of $ACI_{2010/11}$ were found in the opposite direction (D), while the lowest and almost identical values were found in the directions perpendicular to the slope disturbance (A and C). The post-hoc test (LSD test) documented significant difference of $ACI_{2010/11}$ values calculated in the direction B comparing to other directions, among which there is no demonstrable difference. On the contrary, in the case of reference trees, the differences between the $ACI_{2010/11}$ values measured in different directions are not statistically significant (p-value 0.344).

The direction of change in the slope of the regression line (i.e. whether there was increase or decrease in vessels' isodiametricity after the landslide) was significantly represented by both possibilities in analysed microsections. In microsections from disturbed trees, 32 samples of vessels' isodiametricity increase was observed after the slope disturbance, which is almost twice as much in comparison to isodiametricity decrease – formation of asymmetric vessels (17 samples). The situation is quite balanced in reference group where 10 samples show isodiametricity increase and 8 samples decrease. From these results, there is no clear pattern of these changes with respect to the direction of the slope disturbance.

4. Discussion

Slope of the regression line defining the relationship between LW and LL has a positive value in all analysed samples before as well as after the landslide (minimum value recorded before the landslide was 0.16 and 0.18 after the landslide). This is consistent with the findings of Arbellay et al. (2010), who pointed out the positive correlation of these characteristics of vessels parameters (LL and LW) to each other as well as to the VLA. This means that with increasing vessel' cross-section also both dimensions grow and *vice versa*. In this preliminary study, the decrease of both vessel' shape characteristics (LL and LW) was most common in the year after the landslide (2011) and LL decrease was slightly higher comparing to LW decrease. Due to the fact that LL ≥ LW, such a change leads just to isodiametricity increase, which was documented twice more than isodiametricity decrease. Similar character and trend of changes were documented on smaller statistical sample of seven birches scarred by debris-flow (Arbellay et al. 2010) – average observed LL decrease was 26% while LW decrease was 22%. Although landslides impact the tree with much less energy than fast motions of debris and inclination and scarring probably have partially different response in physiology and anatomy of the wood, these findings suggest that the vessels longer diameter (LL) of *B. pendula* species (which usually corresponds to approximate radial orientation; Figure 4) is more susceptible to disturbance-induced changes than the tangential diameter (LW). The same relationship between exogenous disturbance-induced changes in LL and LW were found also in other deciduous species – such as *Alnus glutinosa* (L.) Gaertn., *Fraxinus angustifolia* Vahl. and *Quercus pyrenaica* L. (Ballesteros et al. 2010).

The relatively low $ACI_{2010/11}$ values observed in the reference trees within our study, as well as similar levels of $ACI_{2009/2010}$ of selected disturbed trees, show, that in the case of trees whose growth was not affected by external disturbances or environmental changes annual change of ratio between LL and LW is less significant. This is consistent with the fact that proportions of reference trees with increasing/decreasing isodiametricity between years 2010 and 2011 are very similar. Because all levels of $ACI_{2009/10}$ of disturbed samples and $ACI_{2010/11}$ of reference trees are below 23%, we can conclude, that the level of ACI below approximately 20% can be in case of *B. pendula* (usually) driven by non-geomorphological causes (e.g., ageing, climate) or possible inaccuracy of measuring and statistical process. Conversely, $ACI_{2010/11}$ values significantly higher in the category of disturbed trees are probably direct consequence of inclination caused by mass-movement event. Some differences in $ACI_{2010/11}$ values were found also between individual disturbed groups (Figure 8). In general, tilted trees with exposed and damaged root system (T1er) show high fluctuation of $ACI_{2010/11}$ values in respective directions and in direction of slope disturbance, the values of $ACI_{2010/11}$ were overall some of the highest detected (58–84%). Similar situation is in the group of trees tilted from the vertical direction (T1) with the difference, that maximal values of found $ACI_{2010/11}$ did not reach 60%. The highest found $ACI_{2010/11}$ value as well as the highest $ACI_{2010/11}$ fluctuation was found in tree no. 2 (T3 – buried stem). $ACI_{2010/11}$ maximum (in direction B) was 85.3%, but we were able to prepare microsections only from one single tree from T3 group and therefore this value has character of unproven observation. Remarkable fact is that among disturbed trees there were found tree examples (nos. 1, 9 and 16 all from T2) with very low $ACI_{2010/11}$ values; rather similar to the reference group (Figure 8). These trees were slightly tilted from vertical direction (to 10°) with significant stem curvature (no. 1 – S-shape, no. 2 – "pistol" butted and no. 16 – "candelabra" form) and so it is obvious trees were only transported within the compact landslide block during the main movement activity. Macroscopic stem deformation, which was the main reason for inclusion of these trees into research, occurred before the landslide initiation more probably as a result of strong heliophilicity of birch or due to other disturbances. If we exclude these three trees from ACI analysis, calculated average values of $ACI_{2010/11}$ increase by 1 to 2.5% in A, C and D directions, but to 51% in direction B (Figure 7). This fully supports above mentioned results, that the landslide was significantly reflected by $ACI_{2010/11}$ in the direction similar to the slope disturbance.

5. Conclusion and future research needs

We tried to analyse suitability of birch in mass movement studies in this preliminary study. In total 67 microsections were prepared from 24 trees of *B. pendula* specie selected in the area of a landslide from January 2011. We focused on vessel parameters variations (LL – lumen length and LW – lumen width) between two years, the year before landslide (2010) and in the year of landslide event (2011). This relationship is expressed by the equation of regression line. Overall 8236 vessels were analysed and an annual change index (ACI) was calculated in order to describe percentage change in the slope of the regression line. ACI was calculated for each sample from each tree.

The results show that there is statistically significant change in vessel size parameters between the years 2010 and 2011. The highest values of $ACI_{2010/11}$ were calculated in samples B (direction similar to the slope distribution and side of reaction wood production), where the average value was higher than 43% which is twice more than values from other samples (directions A, C and D). Increase of isodiametricity (reduce of the asymmetry) was found at 65% of analysed disturbed samples (of total 49). No such trend was found at reference samples. ACI values are substantially lower for reference trees as well for group of disturbed trees between years 2009 and 2010. We suppose, that average annual value of ACI around 20%, which was typical for both reference group and $ACI_{2009/10}$, can't be interpreted as a direct consequence of landslide event but is more probably caused by (i) other natural influences or (ii) inexact measuring process. In both situations, great challenges for future research occur – either identifying non-geomorphological cause(s) of slight ACI change (weather?; tree ageing?) or improvement of the sampling, measurement and statistical evaluation. Highest values of $ACI_{2010/11}$ were found at the tress inclined from vertical and with exposed roots, which means in trees with strongest exogenous disturbance. For a more accurate assessment of the potential (in)dependence of exogenous disturbance (macroscopic defects) and ACI value it would be appropriate to analyse more samples from trees from different landslide affected localities. There is also an assumption that after disturbance of different severity vessel shape parameters will return to pre-landslide level with different lags. If we quantify these lags, we could be able to reconstruct additional information about intensity of old prehistoric landslides.

Acknowledgements

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RÉSUMÉ

Změny tvarových parametrů cév břízy bělokoré (*Betula pendula* Roth.) vyvolané svahovými pohyby – Předběžná studie

Za účelem ověření vhodnosti břízy bělokoré pro dendrogeomorfologickou analýzu svahových pohybů bylo z prostoru lesního porostu poblíž Jezeří, poničeného sesuvem z ledna 2011, připraveno 67 trvalých preparátů z 24 vytipovaných stromů (15 disturbovaných a 9 referenčních). Pomocí softwaru WinCell Pro 2011a byly na detailních mikrosnímcích anatomické struktury naměřeny šířky (LW) a délky (LL) lumenů dohromady 8236 trachejí v letokruzích vytvořených v letech 2010, 2011 a (za účelem zhodnocení meziroční variability tvaru cév) u vybraných jedinců i v roce 2009. Typický tvar buňky v daném letokruhu byl popsán pomocí směrnice regresní přímky udávající závislost mezi LW a LL a následně byla vypočtena meziroční procentuální změna této směrnice v daném vzorku (Annual Change Index – ACI).

Průměrné hodnoty ACI se v případě referenčních a disturbovaných stromů rok před sesuvem (tj. mezi lety 2009 a 2010) pohybují pod hodnotou 23 %, což lze považovat za hranici udávající změny způsobené jinými než vysoce energetickými gravitačními procesy. V případě disturbovaných jedinců mezi lety 2010 a 2011 dosahuje ACI ve směrech A, B, C a D průměrných hodnot 21,1 %, 43,7 %, 21,7 % a 26,2 %. V případě trachejí na straně B (proti svahu, tedy místo působení tahu a tvorby tenzního dřeva) se hodnoty směrnice regresní přímky statisticky významně liší mezi lety 2010 a 2011 (doloženo Wilcoxonovým a Znaménkovým testem – obě p-hodnoty < 0,001) a hodnoty ACI jsou odlišné od hodnot v ostatních orientacích vzorkování u disturbovaných stromů (ANOVA p-hodnota = 0,0459 a následný post-hoc test). Nejvyšší hodnoty $ACI_{2010/11}$ byly obecně zaznamenány u jedinců s nejzávažnějším typem vnější deformace (např. zasypání báze kmene, exponované kořeny).

Závěry této předběžné studie dokládají, že naklonění a další externí deformace kmene břízy bělokoré nacházejí odezvu v tvarových parametrech jejích cév. Nabízí se tak možnost využití trachejí jako indikátoru svahových disturbancí v dalších oblastech antropogenního reliéfu Mostecka i celé ČR; stejně tak však vyvstávají další výzkumné otázky týkající se metody – hlavně pokud se jedná o příčiny nízkého (zhruba do 20 %) ACI zjištěného u referenčních jedinců a v letech bez svahové aktivity.

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