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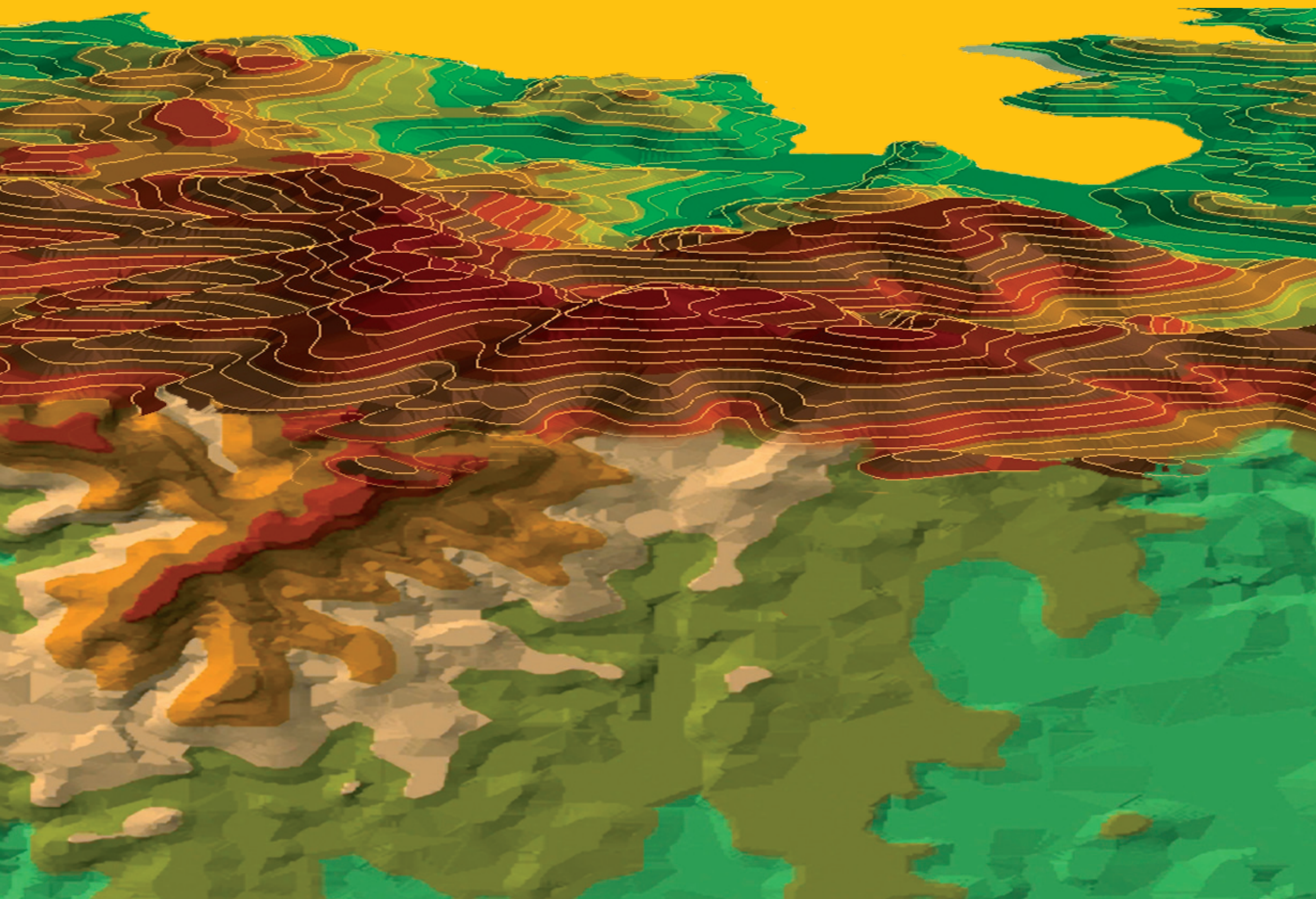

Fig. 2: One of the watercourses in the floodplain forest in the proposed Soutok PLA (Photo J. Miklín)

Fig. 7: Old solitary oaks are typical for meadows of the proposed Soutok PLA (Photo J. Miklín)

Illustrations related to the paper by J. Miklín and V. Smolková

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Articles:

THE URBAN HEAT ISLAND IN KRAKÓW, POLAND: INTERACTION BETWEEN LAND USE AND RELIEF

Anita BOKWA

Abstract

Automatic measurements of air temperatures at five points in Kraków in the period from March 2009 to January 2010, were used to study the urban heat island (UHI). Mean seasonal UHI intensity is highest in the street canyon in summer (3.3K) and lowest in urban green areas in winter (0.5K). UHI intensity >3.0K occurs 58.4% of the time at night in summer and 7.9% in winter in the street canyon. In spring and summer, UHI intensity is much higher than in other Polish cities of comparable size, due to the location of Kraków in the Vistula River valley and the resulting occurrence of a cold air reservoir.

Shrnutí

Městský tepelný ostrov Krakov, Polsko: Interakce mezi využitím půdy a tvary terénu

Pro studium tepelného ostrova města (UHI) byla použita automatická měření teploty vzduchu za období březen 2009 až leden 2010. Hlavní sezónní intenzita UHI je největší v uličním koridoru (3,3 K) a nejnižší v plochách městské zeleně v zimě (0,5 K). Intenzita UHI >3,0 K se vyskytuje v uličních koridorech v 58.4 % nočních hodin v létě a 7,9 % v zimě. Na jaře a v létě intenzita je UHI mnohem větší než v jiných polských městech srovnatelné velikostí, což je důsledek lokalizace Krakova v údolí řeky Visly a výskytu jezer chladného vzduchu.

Key words: *urban heat island, katabatic air flow, cold air reservoir, Kraków, Vistula River valley, Poland*

1. Introduction

Studies on urban heat islands (UHI) are most often conducted in cities located in flatlands where mesoclimatic differences in air temperature are mainly effects of the land use impact (e.g. Arya, 1988; Oke, 2004). However, as stated by Y. Goldreich (1984, 2009), most cities are located in areas which are not entirely flat and only in few studies the relief impact was treated as an important factor controlling the urban climate. A. J. Arnfield (2003) and C. S. B. Grimmond (2006) pointed out that the role of relief in urban climate modification is not sufficiently known and should be the subject of further studies. Most works concerning the role of the relief in UHI control were realised for mountainous towns (e.g. Nkemdirim, 1980; Kuttler et al., 1996). The presented study aims to show the relief impact on UHI in a large city located in a wide valley, in a non-mountainous area.

Kraków is a city located in Southern Poland, on the Vistula River, with the area of 326.8 km^2 and 754,624 inhabitants (data of 2009). The city and its environs are located at the junction of three large regional units. According to German (2000–2001), the northern part belongs to the southern margins of the old uplands belt of Central Poland and is divided into the following mesoregions: Kraków Upland, Miechów Upland and Proszowice Plateau. Most of Kraków's area is situated in the Vistula River valley, which belongs to the Carpathian Foredeep. It can be divided further into the eastern part where the valley is as wide as 10 km and has many terrace levels and the western part where the valley is closed by isolated hills, tectonic horsts. The southern part comprises the Wieliczka Foothills, a part of the Carpathian Foothills. The height differences between the Vistula River valley bottom, going from east to west, and the nearby hill tops, surrounding the city from the north, south and west, reach about 100 m. Urbanized areas are located in both concave and convex landforms. The location of Kraków makes it a convenient place to study the interaction between the land use and landforms in controlling UHI. The aim of the presented paper is to show the issue on an example of city part situated at the bottom of the valley, where the city centre is located and where land use is most diversified. Apart from densely built-up areas typical of the old city centre, there are districts with blocks of flats or with residential estates. There are also numerous green areas, in some places forming green zones between the built-up districts.

2. Material and methods

Within the framework of a project described by Bokwa (2010), an automatic air temperature measurement network was established in Kraków and its vicinities in the period 2007–2009. It consists of 21 points, located in various landform types and in each landform – in various land use types. The HOBO and Minikin sensors are used to record the temperature every 5 minutes. They are located 2–4 m above the ground, in the radiation shelters (Fig. 1). Additionally, in order to study the vertical air temperature structure, a sensor was located at the top of a broadcasting mast, in the western part of the city, at a height of 115 m above the ground. Measurements from the mast were compared with parallel measurements performed at the mast base, 2 m above the ground. The stationary measurements were completed with seven mobile measurements taken in 2006–2009 in co-operation with the Wrocław University, using the methodology described in the work by Szymanowski (2004). The routes of the mobile measurements were organised in N-S and W-E profiles, so as to cover various land use and relief types. They were performed during cloudless and windless nights. The analysis of various measurements from 2009–2010 showed that the area of Kraków and its surroundings has a complicated spatial structure of air temperature, due to the interaction of land forms and land use. Therefore, the UHI magnitude should be defined separately for particular vertical zones of the whole area. In the present analysis, data from 5 points located only in the valley bottom are used, from the period between March 2009 and January 2010. The points are described in Tab. 1 and are all placed in the western part of the river valley (Fig. 2), at similar altitudes.

Fig. 1: Measurement point in Bema St.

Table 1 shows that the points differ in land use and also in the Sky View Factor, an index used to characterise the geometric features of the areas used in urban climate studies which influence the heat budget of a place due to the modifications in the radiation budget. It is defined as a part of radiation emitted by a certain element of the radiation surface which was not absorbed by the surrounding surfaces (e.g. Oke, 1981; Johnson, Watson, 1984; Bärring et al., 1985; Brown, Grimmond, 2001).

The data available were divided into sub-periods so as to represent particular seasons. Synchronous measurements from all the points were available for the following sub-periods:

1. Spring: 24 March–16 May 2009;
2. Summer: 16 July–29 August 2009;
3. Autumn: 1 September–30 November 2009;
4. Winter: 1 December 2009–28 January 2010.

The period from March 2009 to January 2010 was compared to the period 1901–2000 in terms of its representativeness concerning the average monthly air temperature and mean monthly sums of precipitation. No major anomalies were found, only April 2009 was exceptionally dry, with the sum of precipitation as low as 0.5 mm. The number of so-called clear nights, with cloudiness $\leq 2/8$ and wind speed $\leq 2\ \mathrm{m \cdot s^{-1}}$, when the mesoclimatic differences are best visible, could be compared only within a shorter period and the years 1971–2005 were chosen for that purpose; no major anomalies were found either (Bokwa, 2010).

Measurement point	Abbr.	Land use	Height (m a.s.l.)	Sky View Factor
Jeziorzany	J	non-urban area	211	0.956
Krasinskiego St.	K	city centre, street canyon	204	0.457
Bema St.	B	residential estate	208	0.822
Podwawelskie district	P	blocks of flats	203	0.605
Botanical Garden	BG	park area in the city centre	206	0.690

Tab. 1: Measurement points in the Vistula River valley bottom in Kraków and its vicinities
Explanatory notes: Abbr. – abbreviations of the stations' names used in the text, figures and tables

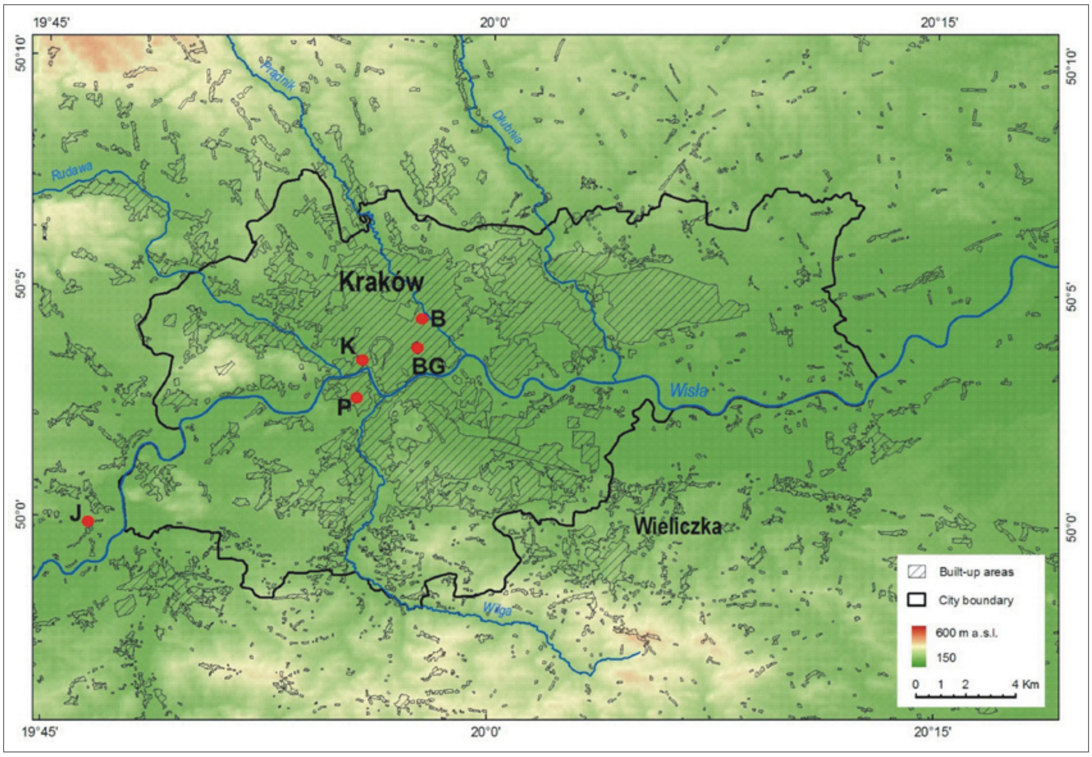

Fig. 2: Location of the measurement points (Figure by P. Chrustek and A. Bokwa)

The intensity of UHI was defined in a classical way, as an air temperature difference between the individual urban stations and the non-urban station (Jeziorzany). As UHI is best developed in the night-time, only the measurements recorded from sunset to sunrise were taken for a further analysis. The mean seasonal values of UHI intensity used further in the text and Table 2 were calculated using air temperature differences between the chosen two points, calculated for every 5 minutes, from the night time (i.e. from sunset to sunrise) for all days in a season.

3. Results and discussion

Mean seasonal UHI intensity in the period from March 2009 to January 2010 is presented in Tab. 2. The highest values in all seasons are observed for the street canyon (Krasińskiego St.), where most surfaces consist of stones, concrete and asphalt and SVF is the lowest, while all other kinds of land use show similar air temperature conditions, in spite of the differences in land use and SVF values. The lowest UHI intensity values are characteristic in all seasons for the Botanical Garden, and the difference between Krasińskiego St. and Botanical Garden varies from 0.8K in summer to 0.6K in autumn. In spring and summer, the UHI intensity is much larger at all points than in autumn and winter. The difference between the highest and lowest seasonal values (i.e. summer and winter) varies from 1.9 to 2.1K in particular points. Previous studies on UHI in Kraków, performed by J. Lewińska

Season	K-J	B-J	P-J	BG-J
Spring	2.9	2.5	2.4	2.3
Summer	3.3	2.8	2.6	2.5
Autumn	2.0	1.4	1.4	1.4
Winter	1.2	0.7	0.7	0.5

Tab. 2: Mean seasonal UHI intensity (K) during the night-time in different types of land use in the period from March 2009 to January 2010

et al. (1982), estimated its intensity to be 1.9K in the cold half-year and 2.0K in the warm half-year in the city centre, while for green urban areas it was 0.9 and 0.8K, respectively. Those values are much lower than those presented in Tab. 2, especially for the warm half-year, i.e. 2.9–3.3K in the city centre and 2.3–2.5K in green areas for spring/summer, and there are a few factors, which may have contributed to that. Lewińska et al. compared the air temperature in the city centre with the mean air temperature for a few non-urban stations while in the present work only one non-urban station is used, representing the coolest non-urban area. The non-urban surroundings of Kraków are characterised by a large variety of landforms, which results in significant differences in local climate. Besides, the measurement techniques were different in the two cases, which can also be one of the reasons for the above-mentioned differences.

The UHI intensity in Kraków may be compared with UHI intensities in other Polish cities of similar size, i.e. cities located in comparable climatic conditions but in flat areas. In Wrocław (Szymanowski, 2004), the mean UHI intensity for the night-time in the city centre was 2.0K in spring, 2.3K in summer, 1.3K in autumn and 1.1K in winter, while for the areas with blocks of flats it was 1.5K, 1.6K, 1.0K and 0.6K, respectively. In Łódź (Fortuniak, 2003), the mean monthly UHI intensity for the night-time in the city centre does not exceed 2.0K in summer and in winter it decreases to about 0.5K. It means that the UHI intensity in Kraków's centre but also in the areas with blocks of flats is much larger than in Wrocław or Łódź, especially in spring and summer.

The mean seasonal values of UHI intensity give only a very general image of the phenomenon. Therefore, seasonal frequency of various UHI intensity was calculated (Fig. 3). In all seasons and at all measurement points, UHI situations occur in more than 90% of the night-time, with the exception of winter at Bema St. and Botanical Garden (Tab. 3). At those two points, an increase in non-UHI situations (i.e. urban cool island) may be observed. High UHI intensity values, i.e. > 3.0K, occur most often in all seasons in the street canyon (from 58.4% in summer to 7.9% in winter) and least often in the areas with the blocks of flats (37.0% and 3.1%, respectively). The comparison with Wrocław and Łódź shows differences again. In Wrocław (Szymanowski, 2004), the UHI intensity > 3.0K in the city centre occurs at 29.2% in summer and at 5.9% in winter, while in Łódź (Fortuniak, 2003) at 2 a.m. its frequency reaches 15% in the city centre in summer and 3% in winter. In Kraków, the non-UHI situations, so-called urban cool island situations, have the frequency comparable to those in Wrocław and Łódź (Szymanowski, 2004), i.e. about 3% for the city centre.

The earlier analysis of thermal conditions in the non-urban areas around Kraków, in which the results of stationary, mobile and vertical profile measurements were combined, proved a significant impact of the relief on local climate, expressed by the occurrence of

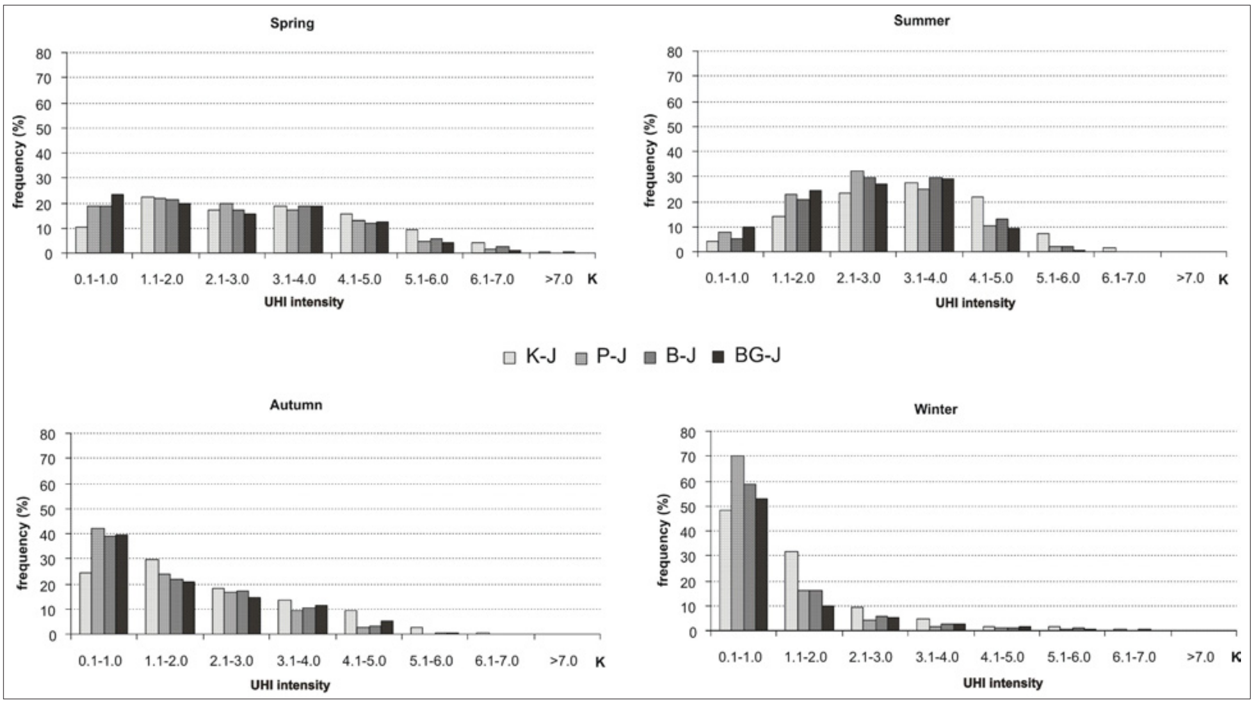

Fig. 3: Seasonal frequency (%) of various UHI intensities (K) during the night-time in the western part of the studied area, in different types of land use in the period from March 2009 to January 2010

Season	K-J	B-J	P-J	BG-J
Spring	97.8	96.7	96.5	95.7
Summer	99.9	99.9	99.8	99.9
Autumn	97.4	94.3	92.4	92.3
Winter	97.0	93.6	85.4	72.6

Tab. 3: Seasonal frequency (%) of UHI situations during the night-time in the western part of the studied area, in different types of land use in the period from March 2009 to January 2010

temperature inversions, katabatic flows and cold air reservoirs in the valley bottom (Bokwa, 2010). Thus, the high UHI intensity values are a result of much cooler thermal conditions in the rural areas at night than in the case of cities located in flat areas. Also, the much higher share of large UHI intensity in Kraków than in Wrocław or Łódź is due to the occurrence of the cold air reservoirs in rural areas around Kraków, not due to extremely high air temperatures in the city centre. The largest air temperature differences in the non-urban areas around Kraków are connected with the occurrence of strong temperature inversion when the temperature at the hill tops may be even 9K higher than in the valley bottom. The mobile measurements revealed the presence of very cold zones at the foothills of the Upland slope and Plateau slope, in the southern and northern city suburbs, particularly exposed to the katabatic flows of cold air during the night. No clear relations between the occurrence of large air temperature differences in non-urban areas and synoptic situation, cloudiness or wind direction were established. Most probably, the main factor controlling those differences is a complicated local air circulation in the valley. According to Oke's model (1987) elaborated for the cities located in flat areas, the maximum UHI intensity in Kraków should reach 7.5K, but the observed value reached 9.9K for the valley bottom. It follows that the difference of 2.5K can be interpreted as a quantitative impact and contribution of the relief to UHI.

The UHI intensity described for Kraków may be compared with the UHI intensity measured in other cities or towns located in the river valleys, i.e. with the local climate also being affected by the relief impact. The maximum UHI intensity in Kraków in the study period, taking under consideration the data from the measurement points in Krasińskiego St. and in Jeziorzany, was 7.7K and occurred during the night from 20 to 21 April 2009. An even larger value, 9.9K was recorded during the night from 29 to 30 April 2009, but it was the air temperature difference between the measurement point near the Słowacki Theatre in the old town and Jeziorzany (Bokwa, 2010). In Calgary (Nkemdirim, 1980), the katabatic cold air flows decreased UHI intensity by about 40%. For Stolberg (Kuttler et al., 1996), the maximum UHI intensity was similar as in Calgary: about 4K and it was also lower than expected. In both Calgary and Stolberg, the katabatic flows were able to enter into the urban areas, which is not the case of Kraków. In Freiburg, Switzerland, the maximum UHI intensity was 5K in all seasons (Roten et al., 1984; Fallot et al., 1986), in Trier 2.6K in winter (Junk et al., 2003), in Graz 4K in winter (Lazar, Podesser, 1999) and in Lisbon 3.5K in winter (Alcoforado, Andrade, 2006). Most of those towns are smaller than Kraków and the UHI intensity depends on the city size and on the number of inhabitants (Oke, 1973, 1987). However, in case of cities located in the valleys, also other factors play significant role. The UHI intensity in Kraków is much larger than in the above-mentioned cities, not only because Kraków is a larger city but also because the katabatic flows do not enter the city interior. In rural areas, the cold air reservoirs are formed and additionally the sensible heat flux is significantly limited there due to the evaporation of river waters (Bokwa, 2010).

5. Conclusion

The phenomenon of UHI is well known, but the role of particular factors controlling it is still the subject of discussion. The results obtained for Kraków (Bokwa, 2010) show the role of relief and location of a city in a wide river valley. The impact of relief is expressed in a much higher UHI intensity in the city part located in the valley bottom (including the city centre) than in cities of comparable size but located in the flat areas. It follows that various models describing relations between the UHI intensity and e.g. the number of inhabitants have to be used carefully in the studies of urban climate in such places or they may simply turn out to be useless. Moreover, just the location in a valley is not a sufficient and uniform criterion, as the size of both the valley and the city/town matters in terms how, for example, the katabatic air flows interact with the urban structures. The results presented above are of preliminary character, as the measurements continue. Further studies are needed to find out e.g. how the UHI intensity in cities located in valleys depends on the atmospheric circulation.

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SOIL AND WATER CONSERVATION WITHIN THE FRAMEWORK OF LAND CONSOLIDATION PROCESS IN THE HUBENOV CADASTRE (CZECH REPUBLIC)

Jana KONEČNÁ, Jana PODHRÁZSKÁ, Petr KARÁSEK, Miroslav DUMBROVSKÝ

Abstract

Some possibilities for the implementation of erosion and flood control measures in an agricultural landscape, by means of the land consolidation process in the Czech Republic, are presented in this paper. Soil, water and environmental conservation are important aspects of every complex land consolidation, particularly for public policy purposes. One successful realization of a designed arrangement is presented for the Hubenov cadastre. Measures applied in the Hubenov cadastre in the framework of land consolidation fully meet the requirements of water and soil conservation. Grassed-over areas, cascades of small water bodies and field boundaries planted with trees, fit well into the character of the highland landscape and improve its aesthetic value.

Shrnutí

Ochrana půdy a vody v rámci pozemkových úprav v katastru Hubenov (Česká republika)

Příspěvek prezentuje výsledky a možnosti prosazení protierozních a protipovodňových opatření v zemědělské krajině prostřednictvím procesu pozemkových úprav v ČR. Ochrana půdy, vody a přírodního prostředí je důležitou a veřejně potřebnou součástí každé pozemkové úpravy. Na příkladu hubenovského katastru je ukázána úspěšná realizace plánu společných zařízení. Můžeme konstatovat, že opatření vybudovaná při pozemkové úpravě v Hubenově zcela splňují požadavky ochrany půdy a vody. Zatravněné plochy, kaskáda malých vodních nádrží, meze osázené dřevinami vyhovují charakteru pahorkatinné krajiny a zvyšují její estetickou hodnotu.

Keywords: *soil and water conservation, land consolidation, protective measures, Hubenov cadastre, Czech Republic*

1. Introduction

Land consolidation is a living process running all over the world with varying intensity. It reflects the country's political, economic and juridical situation in any era. Land consolidation is defined as a planned readjustment and rearrangement of land parcels and their ownership. It is usually applied to form larger and more rational land tenure. Land consolidation can be used to improve the rural infrastructure and to implement the developmental and environmental policy. Its goals and tools vary mainly in dependence on the country's needs and advancement. Creation of conditions for intensive farming to obtain higher basic food production is the main point of view of land consolidation in Asia and Africa. Kilic, Binici and Zulauf (2009) derived a statistically significant relationship between the farm fragmentation and efficiency, which proves the importance of land consolidation program. The optimum size of the farm affects the farm's technical efficiency and issues economy and social benefits (Yao, 2009).

West European countries profitably use land consolidation as a tool to establish public facilities and other projects for a long time (e.g. motorways, dams, canals, etc.). In land use modifications and changes, responsible authorities insist on the observation of ecological aspects. The Ecological Resource Analysis and Assessment is a new approach for the standardized inventory of ecological resources in a land consolidation area and for its integration into further planning projects in terms of ecological sustainability (Oppermann, Krismann, Gelhausen, 2008). Attention is paid to soil, water, flora, fauna, biotopes/conservation areas, landscape features, habitat networks and occasionally also to historical-cultural landscape features.

Land consolidation process in the Western Europe helps to create farmers associations e.g. in Switzerland or France. Miranda, Crecente and Flor Alvarez (2006) declare that land consolidation in Spain has in general made a positive contribution to slowing rural depopulation, improving the agricultural land structure, and reducing the generalized decline in the number of active holdings and in the area of land devoted to agriculture.

There is a number of location-specific conditions in Central and Eastern Europe that challenge the traditional (western) land consolidation approach. These conditions include unfavourable macroeconomic conditions; absentee-owners and co-owners; emotional bonds to land; unsuited infrastructure; and unfinished privatization (Dijk, 2007). Main aim of state-organized consolidation in East European countries is to reduce the previously existing fragmentation of farm holdings and/or lots ownership to improve production and working conditions in rural areas (Reuter, 2008; Cimpoies, 2007; Mihai, Jitea, Rotaru, 2005). Lisec and Pintar (2005) likewise other authors call attention to ecological structures such as hedges, small areas of bushes, trees and water holes in areas of intensive agricultural production, which should be preserved. Since the efficiency of land utilization increases after the implementation of land consolidation, the ecological use of those small areas could be justified.

Land consolidation is primarily a tool for improving the effectiveness of land cultivation and for supporting rural development. In the Czech Republic it is, in addition, also used to remedy the damages and wrongs caused by 40 years of suppressed land ownership (Sklenička, 2006). After the year of 1989, state and cooperative farms were disbanded and the soil came back into private tenure in the Czech Republic. To stimulate new private agricultural businesses and farming it was necessary to clear up the land ownership, to consolidate fragmented and narrow parcels, and to make blocks of fields accessible. For this purpose the process of the land consolidation started. Complex land consolidation in a cadastre is initiated by the land owners´ petition and it is managed by the land offices. The process complies with the land consolidation act No. 139 of 2002, which declares that soil, water and environment conservation is an important and publicly needful aspect of every complex land consolidation. Hence, the land consolidation creates a space for designing and implementing the erosion and flood control measures.

According to the report of the Czech Ministry of Agriculture dated 31st December 2010 there were 1,144 cadastres that had finished the project of the complex land consolidation (i.e. 7% of the country's area). At present, the projects are running in 796 cadastres (5% of the country's area). Although the land consolidation process does not proceed as quickly as requisite, it brings unquestionably positive results. Realized and running projects aim at cadastres with the highest interest of farmers to manage their businesses on available consolidated plots. However, this is only one of the viewpoints. Land use adjustment projects aim at the same time at areas of the significant erosion and flood threat, where the society interest is to enforce and build measures of soil and water conservation.

Land consolidation designs are supported by the state and EU funds are used for the implementation of protective and ecological measures. To judge the efficiency of expended financial resources the Ministry of Agricultural supports the research project No. QI92A012 focused on the evaluation of erosion and flood control measures implemented in rural areas. Hubenov is one of cadastres under view.

2. Material and methods

Hubenov is a small village with the cadastre area of 2.6 km^2 situated in the Bohemian-Moravian Uplands at an average altitude of 560 m a.s.l. The broken relief of the hilly landscape slopes towards the Maršovský potok Brook, which flows into a drinking water reservoir. Humid and cold climatic conditions combined with a steep land implicate a high erosion risk in the area. Soils are Dystric and Stagnic Cambisols, predominantly sandy loam. These soils overlie the granite parent material.

Farming in the cadastre is quite intensive: the proportional share of agricultural land is 69% (Fig. 1). Large blocks of arable land accelerated surface run-off and soil loss by water erosion. It was necessary to eliminate this harmful process and to sustain soil and water protection.

Complex land consolidation in the Hubenov cadastre was started in 1996, based on the owners´ majority application. The project of common facilities was finalized in 2000. The authors had to deal with many environmental risks and to respect farmers' demands for sustainable agricultural production.

The main problem in the area was the process of soil degradation by water erosion. The presence of the drinking water reservoir in the cadastre involved urgent support of water quality. Intensive farming near the reservoir banks was the source of water pollution by soil particles, nutrients and other matters.

The primary adjustment of the lots was respecting protective zones (Fig. 1) declared by the water authority. Large grassed lots interconnect the riparian forests of the reservoir. The greenery prevents soil washing and eliminates products of water erosion from upper lots. Regimes relating to farming in protective zones of the Hubenov drinking water reservoir are:

Protective zone 1 – no admittance, no application of chemicals and barnyard manures, no building and other harmful activities,

Protective zone 2 – no application of pesticides, farmyard manures and other harmful chemicals, no grazing, limited ploughing and restricted management of grasslands.

The state-owned land area being sufficiently large in the Hubenov cadastre, it could be used for elements of common facilities. Lots intended for the purposes of soil, water and environment conservation create a basic framework for the next step of land consolidation – positioning of new adjusted lots (Doležal et al., 2010). The project of common facilities includes whole-area grassing, 3 balks, 3 interceptive reservoirs and exclusion of wide-row crops on threatened slopes (Fig. 2). Efficiency of erosion control measures was evaluated using the universal soil loss equation (Janeček et al., 2005) in the space of geographical information system.

3. Results

Calculated surface soil loss before the land consolidation was compared with the situation after the implementation of the measures. Tolerable soil loss (given by soil profile depth) was taken as a comparative level. The Czech standard (Janeček et al., 2005) stipulates that admissible soil loss by water erosion is 1 $t{\cdot}ha^{-1}{\cdot}year^{-1}$ for shallow soils (< 30 cm), 4 $t{\cdot}ha^{-1}{\cdot}year^{-1}$ for medium deep soils (30–60 cm) and 10 $t{\cdot}ha^{-1}{\cdot}year^{-1}$ for deep soils (> 60 cm). Since the predominant soils in the Hubenov cadastre are medium and shallow soils, the tolerable soil loss level is 2.6 $t{\cdot}ha^{-1}{\cdot}year^{-1}$.

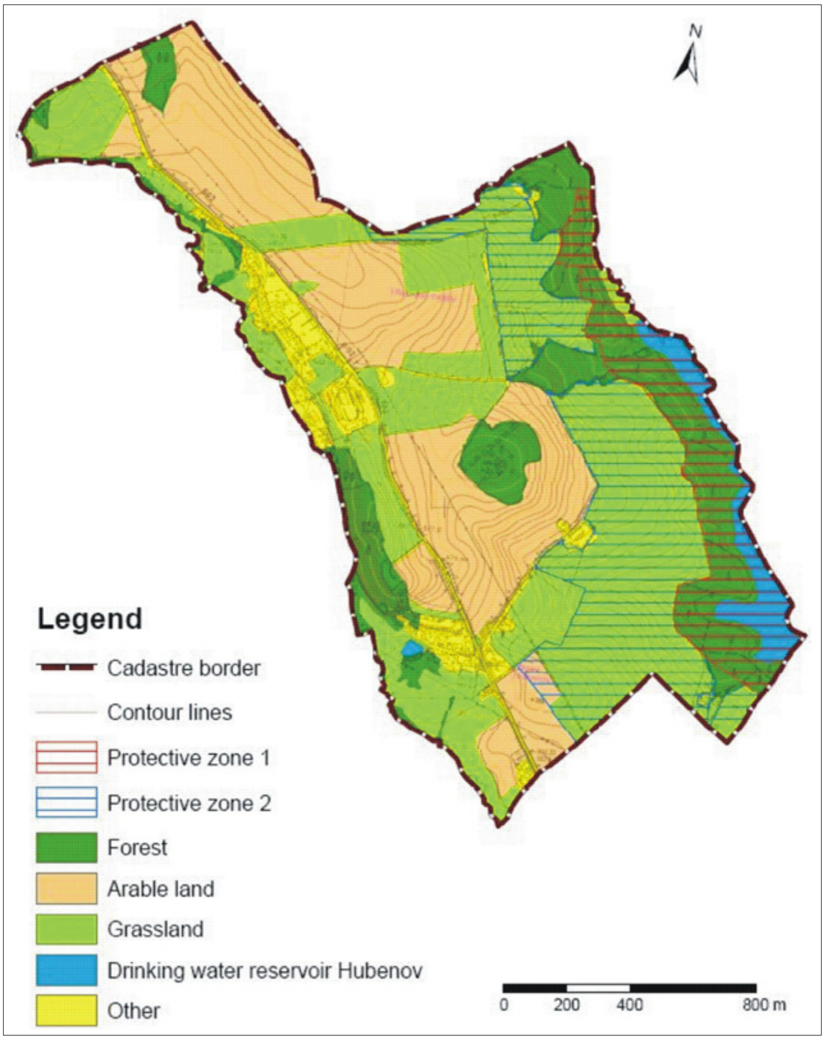

Fig. 1: Hubenov cadastre – land use and protective zones of drinking water reservoir

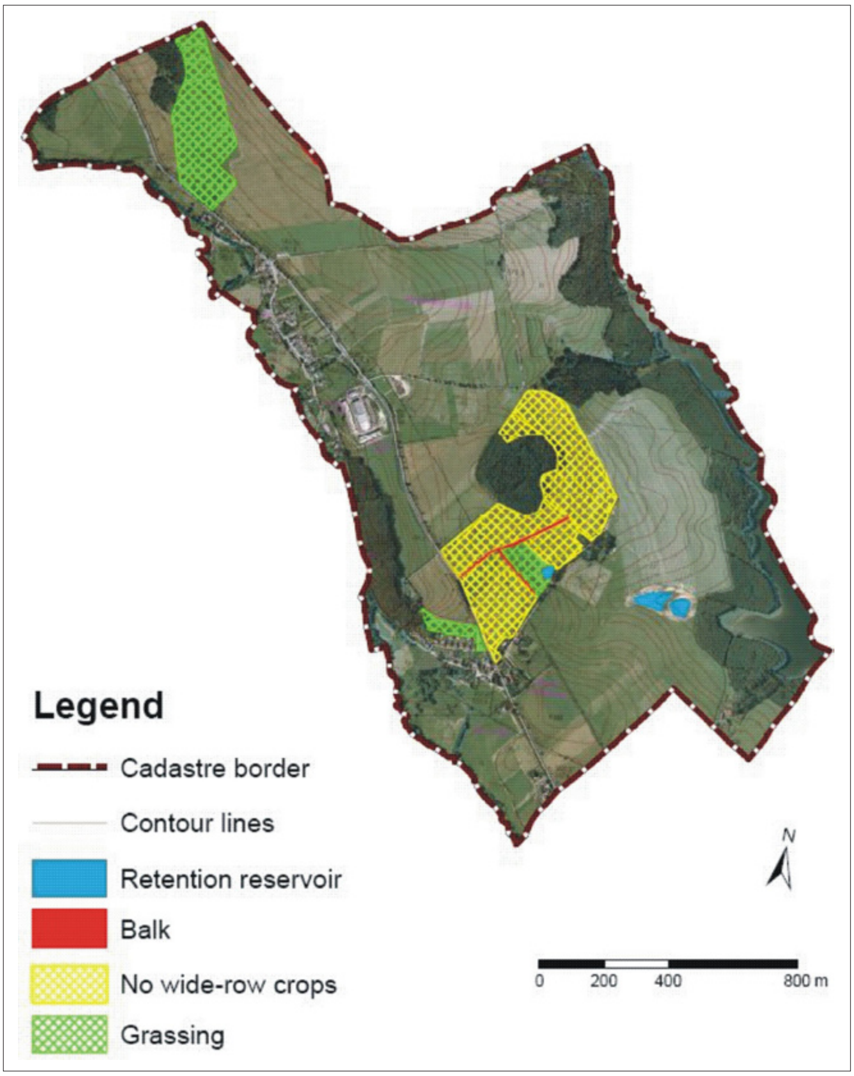

Fig. 2: Soil and water conservation measures realized in the frame of land consolidation

Building-up of the erosion and flood control measures was finished in Hubenov in the year 2003. Interval distribution of soil erosion threat before the land consolidation and after the realization of protective measures is shown in Figs. 3 and 4. Model calculations according to the universal equation show that the soil loss limit was exceeded on more than 14% of the area.

Grassing and balks have reduced soil loss due to water erosion markedly below or close to the mentioned tolerable value. Harmful effects of soil erosion will be sufficiently solved on more than 90% of the cadastre. Especially the area of arable land with a very high erosion threat (soil loss above 4 $t \cdot ha^{-1} \cdot year^{-1}$) was reduced to minimum (only 2%).

The conducting thalweg in the cadastre was grassed and replenished with a system of three reservoirs. Capacity and outlet parameters of reservoirs were designed to safely transform a centenary discharge of 1.85 $m^3 \cdot s^{-1}$.

Operations of land consolidation have particularly modified the pattern of runoff and its lag time to flow across the cropland. The one-sided tendency to aggregate the lots into larger blocks of arable land may lead to the liquidation of natural greenery, acceleration of soil erosion, soil degradation and other harmful effects. Evrard et al. (2010) found out that erosion could increase dramatically in such cases. Harmful effects of water erosion rose by 1,681 % on average after land consolidation in a catchment of Normandy (France).

We can state that the soil erosion control measures implemented on arable land in the Hubenov cadaster decreased sufficiently soil loss below the fixed admissible value. The cascade of three reservoirs is able to transform discharge from the centenary rainstorm and to trap insoluble particles transported down the thalweg. The type of the common facilities designed in the frame of land consolidation in the Hubenov cadastre was carefully chosen to fit the landscape character and to make up its aesthetics (Figs. 5 and 6 – see cover p. 4).

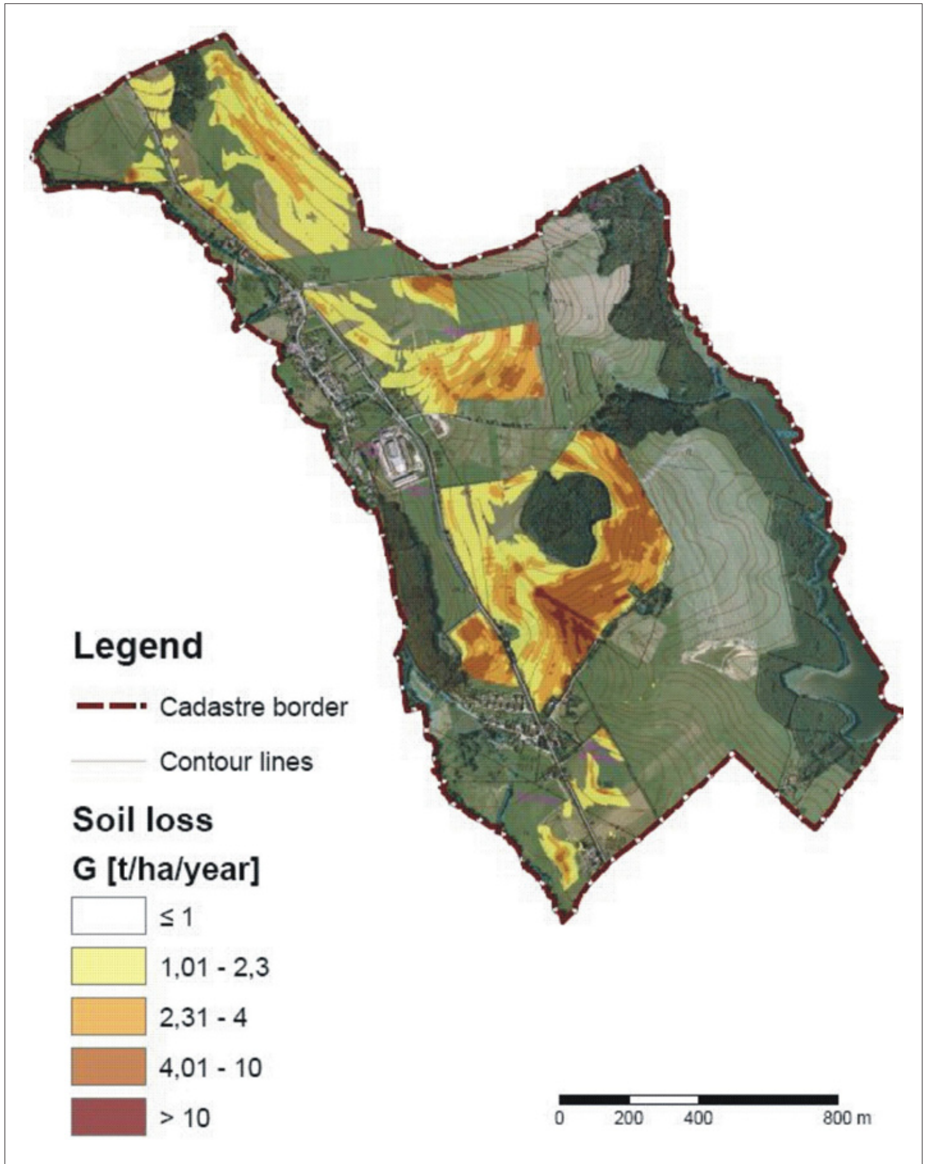

Fig. 3: Model of soil loss before the implementation of measures

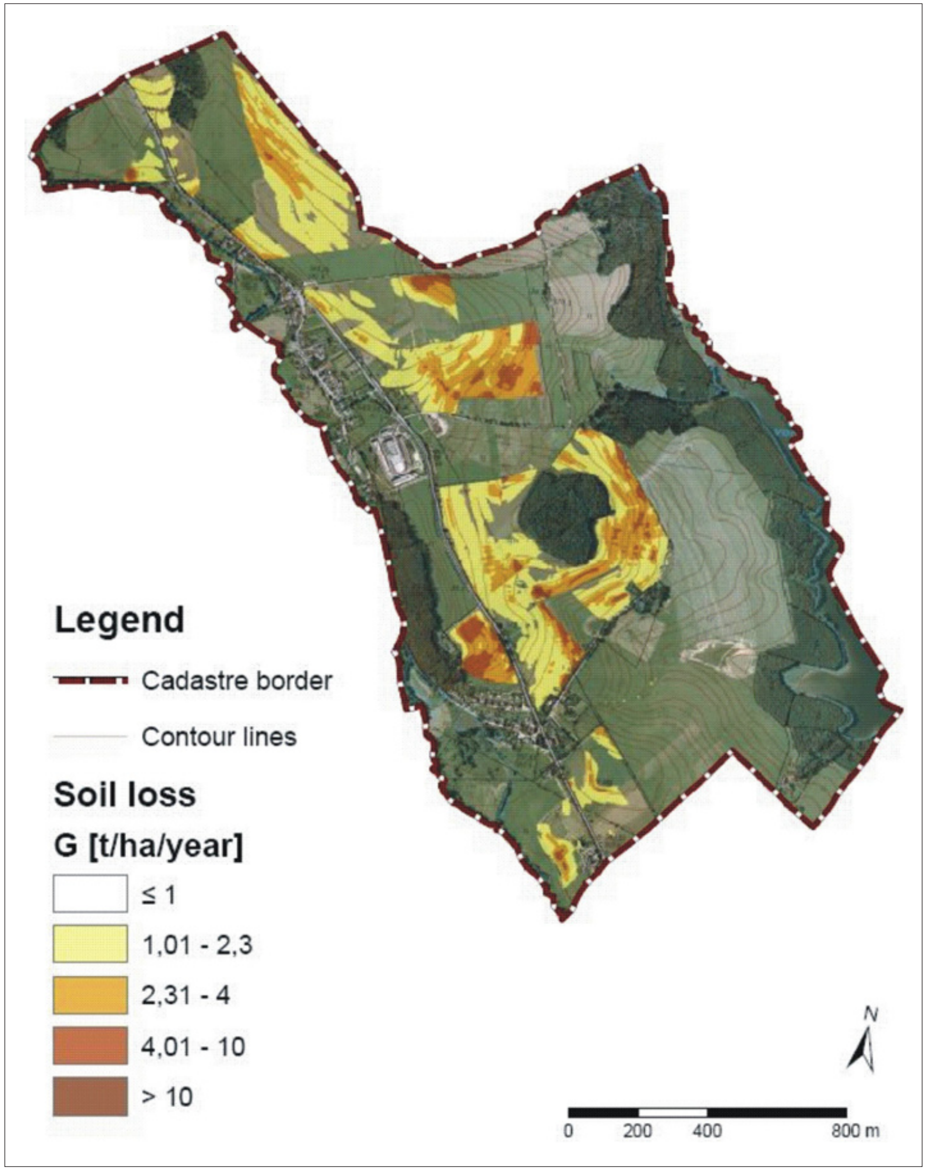

Fig. 4: Model of soil loss after the implementation of measures (= present situation)

4. Conclusions

Land consolidation in the Hubenov cadastre is a good example of combined environmental protection and conditions for sustainable agriculture. It illustrates that land consolidation has a great potential for soil and water conservation.

Of course, it is not possible to cover full area of a cadastre with ecology measures. Resulting solution of the plan of common facilities is always a compromise between proposals of designers and needs of farmers.

The land consolidation process should not be considered only single-purpose. It has an important potential as a process of creating the rural landscape and implementing the environment protection.

The presented analysis is a part of wider research project No. QI92A012 "Evaluation of the Erosion Control and Water Management Arrangements in the Complex Land Use Planning in Light of the Formation and Conservation of the Farming Landscape".

Methods used for Hubenov will be applied for the evaluation of chosen 24 cadastres with realized soil and water protective measures. The main aim of the mentioned project is to create a methodological procedure for the evaluation of results and efficiency of the land consolidation process in the Czech Republic.

Acknowledgement

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LAND USE/LAND COVER CHANGES OF THE PÁLAVA PLA AND THE PROPOSED SOUTOK PLA (CZECH REPUBLIC) IN 1841–2006

Jan MIKLÍN, Veronika SMOLKOVÁ

Abstract

Land use/land cover (LULC) changes in the Pálava Protected Landscape Area (PLA) and in the proposed PLA (pPLA) Soutok are discussed in this paper. The LULC data were obtained from maps (for the years 1841 and 1876) and aerial photographs (1938 and 2006). The general trends in both study areas are as follows: (i) a distinct decrease in grass-covered areas; (ii) an increase in forested areas; (iii) extensive changes in forest management; (iv) almost complete substitution of agricultural land by a mosaic of very small patches in 1938; and, (v) an increase in linear vegetation corridors in 2006. The forest age structure of Soutok pPLA is also analyzed. The results demonstrate distinct changes in both the natural and cultural landscape structures in the study areas, and can be used as a basis for the future management of the protected areas.

Shrnutí

Změny využití krajiny/krajinného krytu v CHKO Pálava a navrhované CHKO Soutok (Česká republika) v letech 1841–2006

Článek se zabývá změnou využití krajiny/krajinného krytu (LULC) v oblasti CHKO Pálava a navrhované CHKO Soutok. LULC data jsme získali z map (roky 1841 a 1876) a leteckých snímků (roky 1938 a 2006). Hlavní trendy změn v období 1841–2006 společné pro obě studované oblasti jsou: i) výrazný pokles rozlohy trvalých travních porostů, ii) nárůst rozlohy lesa, iii) rozsáhlá změna lesního hospodaření, iv) téměř úplné zastoupení zemědělské půdy v roce 1938 mozaikou velmi drobných ploch, a v) výrazný nárůst liniové zeleně v roce 2006. Byla provedena i analýza věkové struktury lesa. Získané výsledky ukazují značnou proměnu přírodních i kulturních struktur krajiny v zájmových oblastech a mohou sloužit jako podklad pro management zvláště chráněných území.

Key words: *land use/land cover, multi-temporal analysis, landscape changes, environmental protection, Pálava PLA, proposed Soutok PLA, Czech Republic*

1. Introduction

The study of changes in landscape structure and landscape development is important both from the scientific and practical points of view and it is widely employed in various areas worldwide (e.g. Rembolt et al., 2000; Mendoza, Etter, 2002) and in the Czech Republic as well (e.g. Demek et al., 2009; Skokanová et al., 2009). With regard to nature conservation, the study of landscape changes helps to answer the questions of biota changes in order to select appropriate area management methods. At the same time, it represents an important argument for the enforcement of selected management methods themselves (Kunca et al., 2005; Falcucci et al., 2006; Olah et al., 2006; Boltižiar et al., 2008; Townsend et al., 2009; AOPK, 2010; Esbah et al., 2010). The two study areas (Fig. 1) belong to the longest populated localities in the Czech Republic. Area management changes occurring due to agriculture intensification, political situation or declaration of protected areas and related restrictions have had a significant impact on the landscape. The area of the Morava and Dyje Rivers confluence called "Soutok" is a typical example. As a result of the deforestation of higher situated parts of both river basins, which induced a periodic occurrence of floods in the past, lowland forests gradually turned into floodplain forests abundant in many hydrophilic species (Vrška et al., 2006). At present, Soutok represents one of the most valuable floodplain landscapes not only in the Czech Republic but even in the entire Central European region. Despite this, the contemporary human activities have

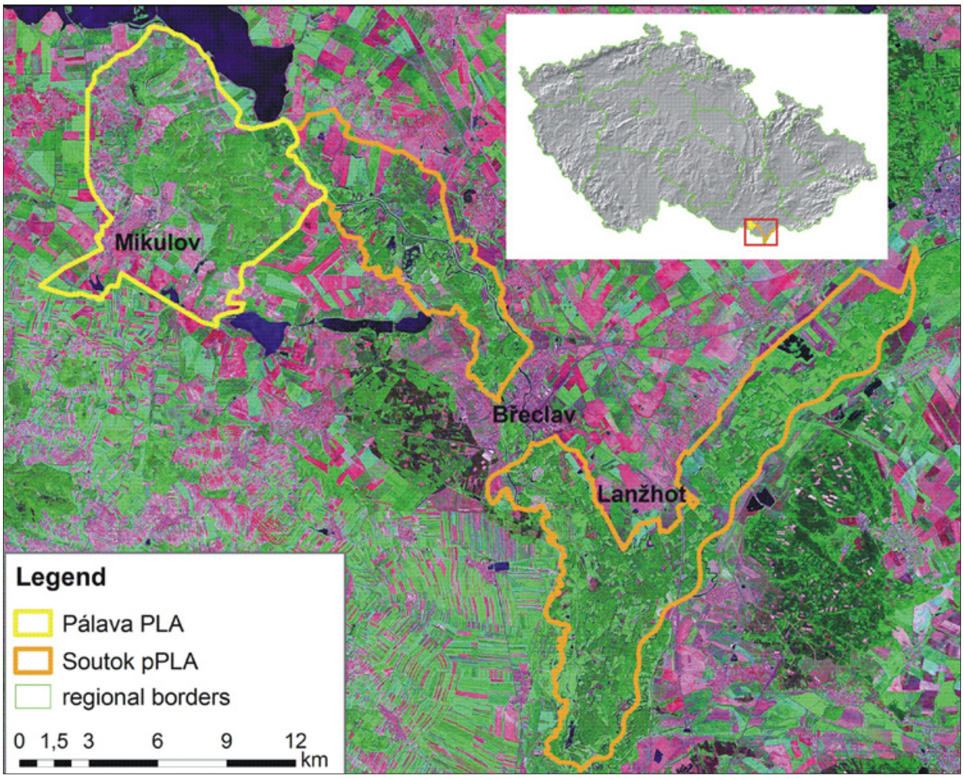

Fig. 1: Localization of study areas in the Czech Republic
Source: SWIR GeoCover Landsat image, NASA 2000

a rather negative effect on the floodplain, the most severe examples of which include

a) present-day intensity of timber harvesting (Vodka et al., 2009),
b) decrease in grass-covered areas, and
c) water management in the form of canalization and regulation of watercourses (Šebela, 2002).

However, the preservation of typical landscape character and biological values requires taking measures towards sustainable use of the area (Olah, 2003). The project of decreeing this area a protected landscape area (PLA) appeared first in the 1980s and although it is discussed again these days, it has not been accepted yet. The main problem of nature conservation in the Pálava PLA is currently forest and shrub invasion in semi-natural grasslands, i.e. steppe biotopes of many protected species (Miklín, 2007). In this case, the process of natural plant succession needs to be regulated by man.

The aim of this article is to quantify and evaluate changes in the horizontal landscape structure including their causes and consequences. The landscape structure is presented by means of land use/land cover spatial patterns of the years 1841–2006. We provide an outline of negative human impact in the Soutok pPLA in the future prognosticating the timber-harvesting intensity in the next 110 years. Results and conclusions of the study can be used in practical management of the study areas in connection with nature protection.

2. Regional Settings

2.1 The Pálava PLA

The Pálava PLA (Fig. 1) was decreed in 1979 with the area of 83 km^2 (AOPK, 2006). Natural and landscape values were also appreciated by the enlistment of the Pálava PLA into the UNESCO Man and Biosphere program (Biosphere reserve), Ramsar site and Special Protection Area (SPA). There are 14 small protected areas within the PLA, five of which belong to categories with the highest degree of protection (Čtyřoký et al., 2007).

From the geological point of view, the PLA is built by Jurassic limestones of the Pavlovské vrchy Hills and Cenozoic sedimentary rocks of the Milovická vrchovina Hills. A small portion of the area is occupied by floodplains with corresponding sediments (Grulich et al., 2002). The highest point is the Děvín Mt. (550 m a. s. l.), whereas the lowest point is the Dyje River outlet (170 m a. s. l.).

As compared with the rest of the Czech Republic, the whole area is relatively hot and dry with the mean annual temperature of 9.6 °C and the mean annual rainfall reaching 524 mm in Mikulov (Čtyřoký et al., 2007). Due to the orographic barrier of the Pavlovské vrchy Hills, there is a very strong effect of windward and leeward slopes (Buček et al., 1990). From the hydrological point of view, the most important stream is the Dyje River at the northeastern border of the PLA, accompanied by a few unimportant watercourses in the remaining part of the area.

Due to its location in the Pannonian biogeographical province and close to the Hercynian biogeographical province, a variety of species that are considered rare in the rest of the Czech Republic can be found in the PLA. Typical ecosystems are grasslands (with e.g. porcupine grass, *Aurinia saxatilis*, *Iris pumila*, *Iris humilis arenaria* and endemic *Dianthus lumnitzeri palaviensis*), thermophilous oak woods, scree woods and floodplain ecosystems (Buček et al., 1990; Grulich et al., 2002; Čtyřoký et al., 2007).

The area of the Pálava PLA was populated a long time ago, which is illustrated by e.g. archaeological findings of the settlements of mammoth hunters coming from 34 to 25 ka BC, including the famous sculpture of the Věstonická Venuše. Between 1300 and 950 BC, fortifications on the Stolová hora Mt., Kotel Mt. and Děvín Mt. were built (Grulich et al., 2002). Subsequently, the Celts, Germans, Romans and Slavs occupied the area at the beginning of the first millennium A.D. (Grulich et al., 2002).

2.2 The proposed Soutok PLA

The landscape in the Soutok pPLA (Fig. 1) is mainly formed by floodplain forests and meadows along the lower reaches of the Morava and Dyje Rivers including their confluence. Nowadays, the area is declared the Dolní Morava (Lower Morava) Biosphere Reserve, which overlaps partly with the Dyje R. Floodplain Site of Community Interest (SCI) and the Soutok-Podluží SCI. The area of the pPLA is ~140 km^2. The relief of the area is very flat and built by fluvial sediments. The area itself is used as a dry polder to capture floods. Climatic characteristics of the area are very similar to the Pálava PLA, with a more balanced portioning due to the non-existence of an orographic barrier.

Typical ecosystems of this area are represented by floodplain forests (Fig. 2 – see cover p. 2), watercourses and oxbow lakes (both permanent and periodical) and floodplain meadows (Grulich et al., 2002; Hrib, Kordiovský, 2004).

Archaeological investigations revealed Great Moravian fortified settlements in Pohansko and Mikulčice coming from the 6th–10th century A.D. Pollen analysis (Opravil, 1978) shows prevailing Elm-Oak woods mixed with the European beech (*Fagus sylvatica*), and a small participation of soft floodplain woody species such as alder and willow. This fact points to drier conditions and non-existence of larger floods, which was most likely supported by Slavonic agriculture based on a mosaic of small fields where various types of crops were grown (Lipský, 2000). As the amount of rainfall increased in the medieval times, the mountain areas became colonized and deforested. As a result, more intensive periodic floods started to appear, followed by the evolution of floodplain ecosystems and sedimentation of overbank deposits whose thickness is < 4 m (Vrška et al., 2006).

3. Materials and Methods

The sources of data comprised historical maps from the 2nd and 3rd military mapping (1841 and 1876), black-and-white aerial photographs from 1938 and a color orthophotomap from 2006. Land cover data of the two historical maps were provided as vector shapefiles by the Silva Tarouca Research Institute for Landscape and Ornamental Gardening. The thematic content is divided into 8 following classes: arable land, grassland, orchards, vineyards, forest, water areas, built-up areas and others (Tab. 1). The vectorization was carried out at a 1:25 000 scale, whereas the linear objects were not vectorized and the area size of each polygon had to be at least one hectare.

Aerial photographs from 1938 were provided by the Military Geographic and Hydrometeorologic Office in Dobruška as scanned photos with the resolution of 1,209 DPI (~0.4 m at ground). Real resolution depends on the quality of every image and it is lower than 0.4 m in most of the cases. Fifteen images were needed in case of the Pálava PLA, while 39 images in case of the Soutok pPLA. All the images were georeferenced using identical points from the orthophotomap published at the map server of the Czech Environmental Information Agency. The process of image georeferencing was affected by high elevation differences at the Pálava PLA (mean error of identical points ranged from 1.0 to 5.7 m per image) and by the absence of precise identical points (absence of infrastructure) at the Soutok pPLA (mean error of identical points ranged from 0.2 to 4.4 m per image).

In order to classify the landscape horizontal structure on aerial photographs we used a legend based on the CORINE Land Cover classification (Commission of the European Communities, 1994). Due to specific needs of nature conservation, some categories (mainly urbanized land) were integrated, while others (e.g. wooded land) were divided using land use characteristics; hence the land use/land cover (LULC) classification. The final legend comprises 23 categories grouped into five classes (Tab. 1). LULC data were obtained from both the sets of aerial photographs by means of visual photointerpretation at a scale of 1:5 000 and practically without generalization.

1938-2006 Class	1938-2006 Cathegory	1841-1876 Class
1. Urbanized Land	1.1 Continuous Built-up Area	Built-up Area
	1.2 Uncontinuous Built-up Area	
	1.3 Industrial, Commercial or Agricultural Zone	
	1.4 Mining Area	Other
	1.5 Urban and Suburban Vegetation	Orchard
	1.6 Recreational Area	Other
	1.7 Transportation, Communications and Utilities	
2. Agricultural Land	2.1 Arable Land	Arable Land
	2.2 Vineyard	Vineyard
	2.3 Orchard	Orchard
	2.4 Mosaic of Fields, Meadows, Vineyards and Orchards	Mosaic
	2.5 Permanent Grassland	Grassland
3. Forest Land	3.1 Forest	Forest
	3.2 Open Forest	
	3.3 Shrub	
	3.4 Clearcut Area	
	3.5 Afforested Clearcut Area or Young Forest	
	3.6 Linear Vegetation	Other
4. Barren Land	4.1 Exposed Rock or Bare Land	
5. Water and Wetland	5.1 Swamp or Marsh	Grassland
	5.2 Lake or Reservoir	Water Area
	5.3 Stream	Other
	5.4 Flood-plain Cannal or Oxbow	

Tab. 1: Conversion between land use/land cover categories used in the study

Since two different sources of the LULC data were used (maps and aerial photographs), the data had to be arranged for a mutual comparison. Aerial photographs categories were joined into military mapping classes in order to make a general comparison of the whole studied period (Tab. 1). Some of the categories failed to be converted (e.g. Transportation, Communications and Utilities or Linear Vegetation). It is also necessary to consider another scale (generalization) of the two data sets.

In order to compare the LULC extent between the years 1841–1876–1938–2006, differences in the Class Area (ha) and in the Percentage of Landscape (PLAND, %) after Leitão et al. (2006) were used.

Ecological stability of the study areas was evaluated using the Weighted Coefficient of Ecological Stability (CES) after Miklós (1986), which takes the form

(1) $$C_{ES} = \frac{\sum (A_c \cdot C_{ESI})}{A_T};$$

where AC is the class area, CESI is the coefficient of ecological significance of the class and AT is the total area. In each class CESI was used after Lipský (2000) as follows: 0.1 Built-up Areas; 0.3 Orchards; 0.14 Arable Land; 0.3 Vineyards; 0.65 Grasslands; 1 Forest; 1 Water Areas and 0.2 Others. The CESI value varies from 0.1 (the least ecologically stable area) to 1.0 (the most ecologically stable area). Lipský (2000) does not consider the Mosaic class (see Chapter 5.3), which was specific for most of the agricultural land in Central Europe in the first half of the 20^{th} century. The CESI value of the Mosaic class was set to 0.25 as based on the ecological significance of the LULC types creating the mosaic and on the sensitivity tests of the equation (1).

4. Results

4.1 Relative and absolute LULC changes in the Pálava PLA

Spatial distribution of the LULC classes in the studied years is presented in Fig. 3 – see cover p. 3. The most striking increase was recorded in the Orchards class, whose area decreased at first between 1841–1876, but the contemporary area size is 15 times larger than in 1938 (Tab. 2). The category of Built-up Areas follows with an increase of 73.7% in all municipalities

Class	1841		1876		1938		2006		Difference 1841–2006	
	ha	%	ha	%	ha	%	ha	%	ha	%
Built-up Area	283.50	3.29	289.00	3.36	338.62	3.93	492.62	5.72	209.12	73.71
Orchard	23.42	0.27	17.40	0.20	59.65	0.69	361.52	4.20	338.10	1,443.18
Agriculture Area	5,661.18	65.73	5,848.14	67.90	5,497.90	63.82	4,346.13	50.44	−1,315.05	−23.25
Forest	2,521.61	29.28	2,445.84	28.40	2,600.79	30.19	3,003.57	34.86	481.96	19.08
Water Area	123.69	1.44	11.72	0.14	3.60	0.04	70.02	0.81	-53.67	−43.41
Other	0.00	0.00	1.30	0.02	114.63	1.33	342.08	3.97	342.08	a
Total	8,613.40	100.00	8,613.40	100.00	8,615.19	100.00	8,615.94	100.00		
Agriculture Area										
Arable Land	3,250.25	37.73	3,569.75	41.44	380.59	4.42	2,682.26	31.13	−567.99	−17.50
Mosaic	0.00	0.00	0.00	0.00	4,842.72	56.21	0.00	0.00	0.00	0.00
Vineyard	1,323.33	15.36	1,388.14	16.12	18.09	0.21	1,400.37	16.25	77.04	5.79
Grassland	1,087.60	12.63	890.25	10.34	256.50	2.98	263.50	3.06	−824.10	−75.78

Tab. 2: Land use/land cover in the Pálava PLA in 1841–2006. Note: a – percentage difference could not be calculated; differences between total area are caused by unequal data source

(Tab. 2, Fig. 4a). A specific situation is observed in the Others class in case of both the Pálava PLA and the Soutok pPLA (Tabs. 2, 3, Figs. 4a, c), where the relative increase is enormous because its area was zero in the first year and because of different methods of the LULC data obtainment (see Chapter 3). A significant relative decrease was observed in the class of Water Areas whose extent is nowadays almost by a half lower. Relatively important changes can also be seen in the category of Agricultural Land (Tab. 2, Fig. 4b). The highest relative decrease was recorded in the class of Grasslands, which is by 75.8% smaller. The area of Arable Land is now by 17.5% smaller than in 1841, whereas the area of Vineyards increased slightly. The Forests increased by 19.1% (mainly at the expense of Grasslands), which was the highest absolute increase (482 ha). On the contrary, the highest absolute decrease was recorded in Agricultural Land (−1,315.1 ha), mainly Grasslands and Arable Land (Tab. 2).

4.2 Relative and absolute LULC changes in the Soutok pPLA

The spatial distribution of LULC classes in the studied years is presented in Fig. 5. The highest relative increase (apart from the class of Others) was recorded in Arable Land, whose area increased nearly five times between 1841–2006 (Tab. 3). A relatively high increase can be observed also in Water Areas and Orchards, whose current area size is three times larger than in 1841. The Built-up Areas increased by 77.9%, whereas the area of Grasslands is by a half smaller.

The highest absolute changes were recorded in the category of Grasslands (decrease by 2,912 ha) and Arable Land (increase by 2,183.9 ha). The extent of Agricultural Land decreased by 729.9 ha in total. There was also a high absolute increase in the classes of Others and Water Areas (by 589.3 ha and 171.7 ha, respectively; Tab. 3).

4.3 Processes of the 1841–2006 LULC change

The comparison of individual LULC classes between 1841 and 2006 in the two areas enables the specification of general processes changing the landscape horizontal structure. We have identified the processes of urbanization (change from any of the classes into Built-up Area), intensification (changes from Forest, Grasslands or Water Areas into Arable Land, Vineyards or Orchards and changes from Vineyards and Orchards into Arable Land), abandonment (change from Arable Land, Vineyards or Orchards into Grasslands), afforestation and irrigation. Other processes comprise e.g. changes from Arable Land to Vineyards or Orchards. The values of inter-class changes are listed in Tabs. 4 and 5.

The share of LULC change processes (Fig. 6) is similar in both study areas. No LULC change was recorded in 59.4% of the Pálava PLA area, whereas in the Soutok pPLA it was recorded in 63.2% of its area. Urbanization affected 3.0% of the Pálava PLA and 0.6% of the Soutok pPLA area. This small value relates to the delimitation of the pPLA outside the built-up areas. Abandonment was observed in 1.0% of the Pálava PLA area and in 0.5% of the Soutok pPLA area. Another minimal size was identified in connection with the irrigation (0.2% of the Pálava PLA area, 1.6% of the Soutok pPLA area). Relatively significant values relate to afforestation: 9.2% in the Pálava PLA and 7.8% in the Soutok pPLA.

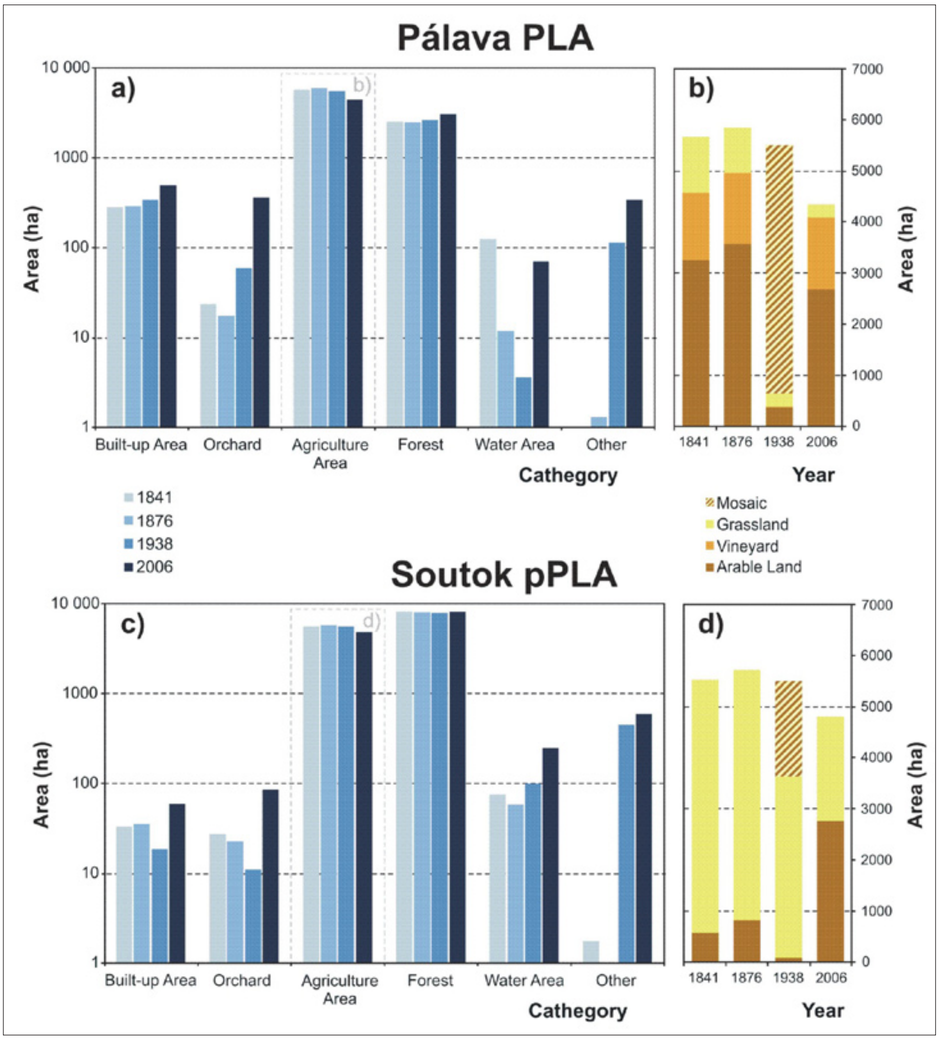

Fig. 4: Land use/land cover changes in the Pálava PLA and the Soutok pPLA in 1841–2006: a) all classes in the Pálava PLA (logarithmic scale); b) agriculture areas in the Pálava PLA; c) all classes in the Soutok pPLA (logarithmic scale); d) agriculture areas in the Soutok pPLA

Class	1841		1876		1938		2006		Difference 1841–2006	
	ha	%	ha	%	ha	%	ha	%	ha	%
Built-up Area	32.86	0.24	35.09	0.25	18.53	0.13	58.56	0.42	25.70	77.88
Orchard	27.20	0.20	22.47	0.16	10.87	0.08	85.13	0.61	57.93	212.40
Agriculture Area	5,537.04	39.94	5,715.88	41.23	5,505.79	39.64	4,807.19	34.61	−729.85	−13.34
Forest	8,189.73	59.07	8,032.64	57.94	7,807.58	56.21	8,100.81	58.32	−88.92	−1.27
Water Area	74.76	0.54	57.24	0.41	98.21	0.71	246.42	1.77	171.66	229.00
Other	1.74	0.01	0.00	0.00	448.16	3.23	591.03	4.26	589.29	3,3804.12
Total	13,863.33	100.00	13,863.32	100.00	13,889.14	100.00	13,889.14	100.00		
Agriculture Area										
Arable Land	572.81	4.13	826.32	5.96	82.49	0.59	2,756.71	19.85	2,183.90	380.37
Mosaic	0.00	0.00	0.00	0.00	1,878.02	13.52	0.00	0.00	0.00	0.00
Vineyard	1.74	0.01	0.00	0.00	0.00	0.00	0.00	0.00	−1.74	−100.00
Grassland	4,962.49	35.80	4,889.56	35.27	3,545.28	25.53	2,050.48	14.76	−2,912.01	−58.76

Tab. 3: Land use/land cover in the Soutok pPLA in 1841–2006
Note: differences between total areas are caused by rounding or by unequal data source

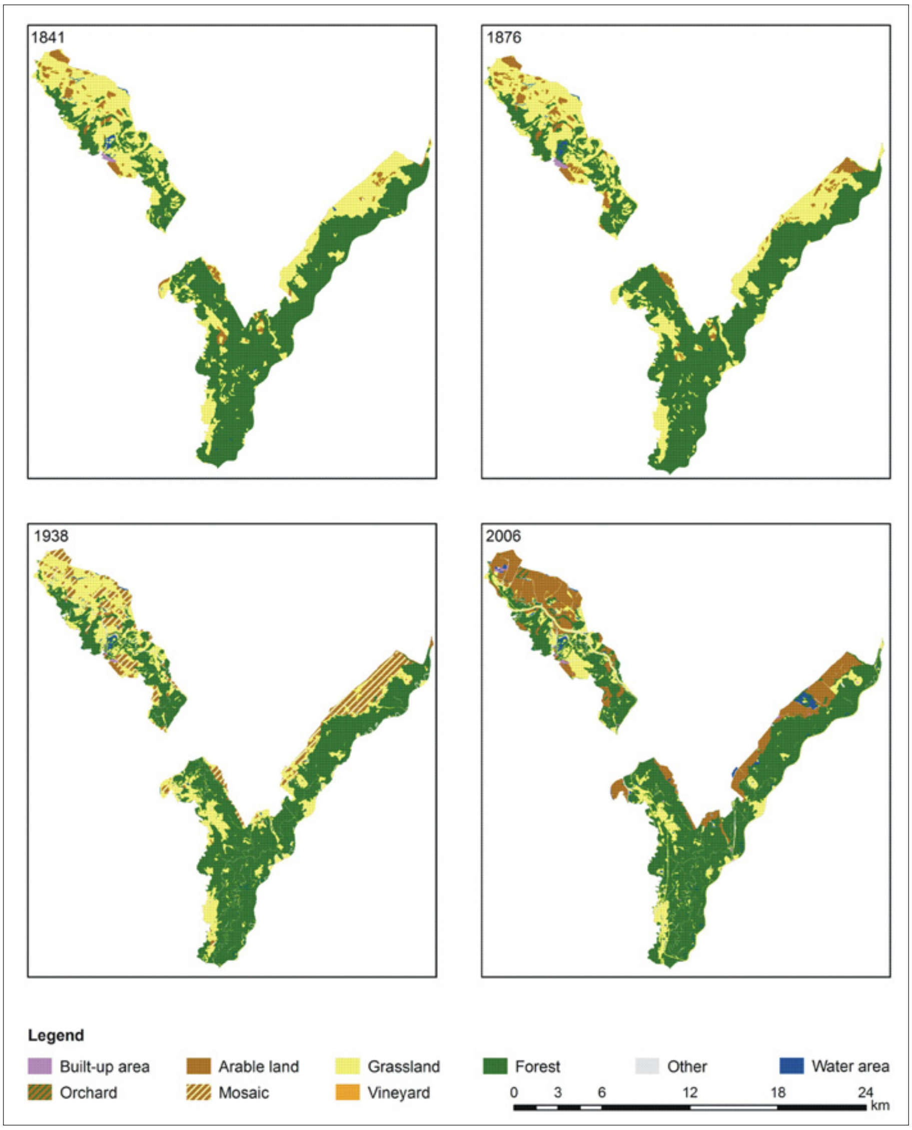

Fig. 5: Land use/land cover in the Soutok pPLA

The most important process within the 1841–2006 LULC change was intensification, which affected 11.2% of the Pálava PLA area and 17.5% of the Soutok pPLA area. Without adequate management of the Soutok area, ensured by the PLA status, the acceleration of negative processes could have been expected.

5. Discussion on the causes of LULC changes

Changes in LULC and landscape management observed in the study areas show both general trends typical of the whole area of the Czech Republic (Lipský, 2000) and specific trends given by the character of each study area.

5.1 Built-up Areas and Orchards

Similarly as other regions, the Czech Republic of the 20th century witnessed a distinct increase in built-up areas (Lipský, 2000). In both study areas, the increase in the built-up area was similar (~75%). The highest rate of the increase was observed between the years 1938 and 2006 (Tabs. 2 and 3). Built-up Areas increased mainly at the expense of Arable Land and Grasslands (Tabs. 4 and 5), which corresponds to the general trend of agricultural land being occupied in connection with urban development.

The size of Orchards decreased between 1841 and 1876 in both study areas. This decrease continued in the Soutok pPLA until 1938, whereas in the Pálava PLA, the area of orchards increased, most likely due to a higher proportion of urbanized areas to which orchards are closely related. What is common to both areas is a huge increase in the size of orchards in the period between 1938 and 2006. This was caused by the existence of a mosaic of agricultural land in 1938. Small fields of the mosaic, including fruit trees, became coupled directly to the built-up areas. On the other hand, the currently existing residential areas are separated from agricultural land by a zone

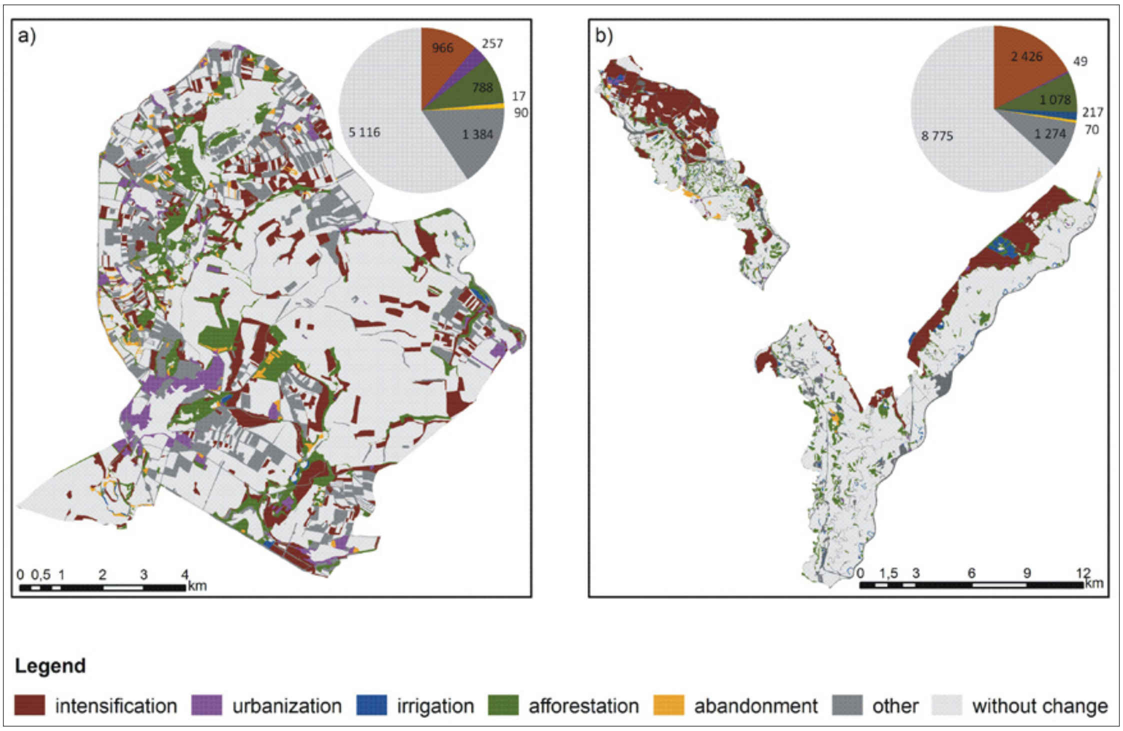

Fig. 6: Main processes of the 1841–2006 land use/land cover changes in a) Pálava PLA and b) Soutok pPLA

of orchards and gardens. Moreover, agricultural management changes after World War II – agricultural land consolidation – brought an enormous increase in extensive orchards.

5.2 Grasslands

The situation of grasslands experiencing both absolute and relative decrease confirms negative trends mentioned by other authors (Miklín, 2007; AOPK, 2010). In both areas, the decrease was caused mainly by the process of intensification (change into arable land – 286 ha, i.e. 26.3% in the Pálava PLA and 2,196.3 ha (!), i.e. 44.3%(!) in the Soutok pPLA – Tabs. 4 and 5) and afforestation (432.1 ha, i.e. 39.7% (!) in the Pálava PLA and 964.5 ha, i.e. 19.4% in the Soutok pPLA – Tabs. 4 and 5). The intensification was connected with the communist collectivization after 1948 and regulation of watercourses, which enabled using former floodplain meadows as arable land. Despite the water regime regulations, many of such areas were frequently flooded or waterlogged and after 1989, they were converted to grasslands again (Skokanová, 2009). As for the afforestation of grasslands, there were more reasons. The main causal factor in both areas was the limitation of traditional pratotechnical methods such as pasture management and grass-cutting. The declaration of Pálava as a PLA in 1979 brought the prohibition of agricultural management (pasture and grass cutting) in the name of nature conservation (no management but rather leaving the nature to its 'natural' evolution – Kostkan, 1996). In the Soutok pPLA, an important role was played by intentional afforestation along with the existence of the state border area – the so-called 'Iron Curtain', which represented a wide zone of the forbidden entry. Starting with shrubs and continuing with trees, the forestation was spontaneous. Considering both the steppe biotopes in Pálava and floodplain meadows in Soutok, grasslands represent ecosystems requiring active management necessary for their preservation. Meadows in the Soutok pPLA are cut mechanically. For the last few decades, sheep grazing and mechanical and chemical disposal of self-seeding wood species have been performed in the Pálava PLA (AOPK, 2006). Yet, it is an infinite fight and forestation can only be retarded but not stopped because of the shortage of money and the presence of tenacious invasion plants (e.g. *Robinia pseudoacacia* or *Ailanthus altissima*).

5.3 Agricultural mosaic

A very interesting situation is observed in connection with agricultural land in 1938 (Figs. 3 – see cover p. 3, 4b, 4d, 5). Despite a few exceptions, there was a mosaic of very small and elongated fields characterized by temporal changes in their use (e.g. arable land, grasslands accompanied by orchards, vineyards and solitary trees). As an LULC category, the agricultural mosaic is defined as an area of at least five small (~0.5 ha), narrow (max. 20 m wide) parallel fields, often with scattered trees. The origin of the mosaic is given by long-term changes in land ownership (Öhm, 1931; Váchal et al., 2005). As early as in the medieval times, small landholders could lease

2006	Built-up Area		Orchard		Arable Land		Vineyard		Grassland		Forest		Water area		Other		Total in 1841
1841	ha	%	ha	%	ha	%	ha	%	ha	%	Forest	Forest	ha	%	ha	%	ha
Built-up Area	235.94	83.19	28.59	10.08	1.48	0.52	4.50	1.59	1.40	0.49	ha	ha	0.00	0.00	4.51	1.59	283.60
Orchard	2.19	9.35	2.25	9.60	8.08	34.49	0.43	1.84	0.07	0.30	7.18	7.18	0.00	0.00	1.64	7.00	23.43
Arable Land	171.45	5.27	121.99	3.75	1,873.95	57.66	652.67	20.08	55.89	1.72	8.77	8.77	4.35	0.13	141.32	4.35	3,250.25
Vineyard	34.86	2.63	132.01	9.98	318.98	24.10	642.14	48.52	32.37	2.45	228.63	228.63	2.00	0.15	82.47	6.23	1,323.33
Grassland	42.48	3.91	75.33	6.93	286.01	26.29	84.37	7.76	92.26	8.48	78.50	78.50	9.97	0.92	65.25	6.00	1,087.74
Forest	1.93	0.08	0.62	0.02	184.25	7.31	16.19	0.64	61.54	2.44	432.07	432.07	0.71	0.03	41.25	1.64	2,521.82
Water area	3.19	2.58	0.76	0.61	8.58	6.94	0.01	0.01	19.49	15.76	2,215.33	2,215.33	52.98	42.83	5.76	4.66	123.69
Total in 2006	**492.04**		**361.55**		**2,681.33**		**1,400.31**		**263.02**		**32.92**	**32.92**	**70.01**		**342.20**		**8,613.86**

Tab. 4: Land use/land cover changes in the Pálava PLA between 1841 and 2006

2006	Built-up Area		Orchard		Arable Land		Grassland		Forest		Water area		Other		Total in 1841
1841	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha
Built-up Area	9.86	30.02	10.43	31.75	0.25	0.76	3.39	10.32	5.99	18.23	0.00	0.00	2.93	8.92	32.85
Orchard	0.99	3.64	0.99	3.64	10.70	39.34	5.86	21.54	2.71	9.96	1.07	3.93	4.88	17.94	27.20
Arable Land	14.08	2.46	15.96	2.79	382.66	66.80	40.98	7.15	89.01	15.54	14.76	2.58	15.37	2.68	572.82
Vineyard	0.00	0.00	0.00	0.00	1.74	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.74
Grassland	25.82	0.52	54.22	1.09	2,196.29	44.26	1,313.19	26.46	964.47	19.44	143.52	2.89	264.98	5.34	4,962.49
Forest	7.72	0.09	3.53	0.04	150.98	1.84	679.89	8.30	7,016.67	85.68	57.81	0.71	273.12	3.33	8,189.72
Water area	0.08	0.11	0.00	0.00	12.39	16.57	6.1	8.16	20.12	26.91	29.1	38.92	6.97	9.32	74.76
Other	0.00	0.00	0.00	0.00	1.70	6.17	1.07	3.88	1.84	6.68	0.17	0.62	22.78	82.66	27.56
Total in 2006	**58.55**		**85.13**		**2,756.71**		**2,050.48**		**8,100.81**		**246.43**		**591.03**		**13,889.14**

Tab. 5: Land use/land cover changes in the Soutok pPLA between 1841 and 2006

fields that became gradually subdivided into two halves as a result of inheritance proceedings. In the name of primitive tillage, the land used to be subdivided along the longer side of a rectangle, which led to the system of absurdly narrow and long patches of fields (up to 20 × 10,000 m). Further land fragmentation occurred with the abolition of serfdom in the 1840s when the originally leased land passed into private hands. Individual landholders commonly owned as many as a hundred plots, in extreme cases this number could increase to 800 plots. The ownership structure including a relevant land use type was already recorded in Stabile Cadaster Maps of Moravia and Silesia in 1824–1836. This means that the mosaic of agricultural land existed in the two studied years (1841 and 1876); however, the state of agricultural land in maps of the second and third military mapping is generalized. Owing to the collectivization process, the plots along with the land use type became united into larger areas. The mosaic of agricultural land returned to its original state merely in the questions of ownership, namely via restitutions after 1989, nevertheless, the land use management did not reflect in the mosaic itself.

In order to illustrate the mosaic internal structure in 1938, we vectorized all partial fields in several representative areas (delimited by the orientation of the fields or paths). An average area of one part of the mosaic was calculated to 0.444 ha in the Pálava PLA, or 0.478 ha in the Soutok pPLA. Considering 4,842.7 ha as a total area of the mosaic in the Pálava PLA in 1938, the number of partial fields could have been expected to total 11,000. In 2006, there were 2,332 fields (in the Agricultural Land class) in the area of the 1938 mosaic, which is 21.3% of the number of fields existing in 1938. A similar situation can be seen in the Soutok pPLA, where the 1938 mosaic area was 1,878 ha and the total number of partial fields was nearly 4,000. In 2006, there were 469 fields (11.9%).

5.4 Vineyards

Although there were no large-area vineyards in the Pálava PLA in 1938, vineyards were included as small patches in the agricultural mosaic (Fig. 3 – see cover p. 3), which can be explained by decreased wine consumption in the second half of the 19th century (Kraus et al., 1999). In connection with the industrial revolution, the drinking of beer and spirits became very common. Also, after the abolition of customs frontier between Austria and Hungary and together with the development of railways, Moravian wines lost their competitive strength and therefore technical crops started to be grown instead (Jílek et al., 1984).

The decline of wine and large vineyards in southern Moravia was accelerated by the massive spread of vine fretter and other wine diseases at the turn of the 19th and 20thcenturies (Doležal, 2001) and also by the Czech Land Reform in the period from 1919–1935 (Balcar, 2000). During the reform, 30.34% of land held mainly by the aristocracy or by Church became parceled out among small landowners (Pavel, 1938).

Vineyards were less attractive for small farmers and landowners because of low profitability and impossibility to alternate crops in the area of vineyards (Jílek et al., 1984). A small extent of vineyards persisted until the 1960s when the restoration of vineyards accelerated with the establishment of new vineyards accessible to mechanization and the implementation of new cultivation methods (Kraus et al., 1999). The highest increase in the area of vineyards was recorded in the 1990s. The current area of vineyards is slightly larger than in 1841 (Tab. 2).

5.5 Forests

An important change was observed is the transformation of forest management. Traditional ways of forest management near settlements included maintaining cattle pastures and managing forests as coppices or coppice-with-standards woodland (Vera, 2000), which means structured, open-canopy and sunny stands with coppice and standard trees – mainly very old and colossal oaks (Konvička et al., 2005). Forest pastures were officially prohibited in 1754 but in the floodplain forest of the Soutok area they persisted until 1873 (Vrška et al., 2006). At that time, the conversion of coppice forests into even-aged stands with closed canopy and clear-cutting management started. Such a change inside the Forest class can only be observed based on aerial photographs, not in the historical maps. In 1938, the open woodland occupied an area of 1,301.6 ha (300 ha more than the closed canopy forest) in the Pálava PLA and 651 ha in the Soutok pPLA.

Nowadays, the area size of clear-cuts has doubled (1,221.2 ha), if compared with 1938 (629.1 ha) in the Soutok pPLA and open woodlands have ceased to exist in the two study areas. Moreover, the forest management changes became reflected in the decreasing number of solitary trees (mainly oaks) on meadows (Fig. 7 – see cover p. 2). The number of solitary trees decreased from 1,329 (in 1938) to 644 (in 2006). Forest character changes (even-aged stands, clear-cutting management, decrease in the number of standard and old trees) have a negative effect on many endangered and protected species, such as Hermit beetle (*Osmoderma barnabita*), Great Capricorn beetle (*Cerambyx cerdo*), Jewell beetle (*Eurythyrea quercus*) and others (Vodka et al., 2009; Čížek, Hauck, 2008; Čížek, Zábranský, 2009).

5.6 Water Areas

The development in the Water Areas class reflects some general trends. As for the Pálava PLA (Fig. 4a), it was mainly the changes of fishponds that were observed. In 1841, the size of water areas was largest in the studied period (123.7 ha). During the next hundred of years, almost all fishponds dried out and changed into agricultural land (meadows and arable land) – as it was documented in 1938 when the Křivé jezero Lake (3.6 ha, Tab. 2, Fig. 3 – see cover p. 3) represented the only water body in the Pálava PLA. Almost all the ponds were renewed during the second half of the 20th century. However, the original size of water areas is irretrievably lost since their current area is by 43.4% smaller than in 1841. The Soutok pPLA was affected mainly by measures aimed at water resources control, by canalization and regulation of watercourses. In the period from 1938–2006, the Dyje and Morava Rivers were shortened by 4.6% (Dyje) and by 39.6%(!) (Morava). Many former river meanders changed into slacking water (increase by 150.9%).

5.7 Landscape stability

Ecological stability and its changes in the study areas were evaluated using the CES landscape metric index (Miklós, 1986). The results are shown in Table 6. According to the CES values, the area of the Soutok pPLA is ecologically more stable than the Pálava PLA, which is connected with the proposal of non-urbanized and less agriculturally managed areas as a PLA. The trends in CES are different in each of the areas.

In the Pálava PLA, CES decreased between the years 1841 and 1876 mainly due to the decrease in Water Areas and Grasslands and the increase in the size of Arable Land. From 1876 to 2006, there was a slow increase in CES, main reasons being the decreased size of all forms of agriculture land, renewal of ponds and increase size of the forest area. Afforestation as a process considered to increase ecological stability of an area in the CES methodology, is paradoxically perceived as a major negative process in the context of nature conservation in the Pálava PLA.

In the studied time span, the CES value constantly decreases in the Soutok pPLA where two main processes act against each other: afforestation as a positive effect and intensification (turning grasslands into arable land) as a negative effect.

5.8 Analysis of timber harvesting intensity in the next 110 years in the Soutok pPLA

The amount of harvested timber is one of the most discussed topics related to the Soutok pPLA. Considering the area of the forest of a certain age usable in the prognosis for timber harvesting within

Year	Coefficient of ecological stability	
	Pálava PLA	Soutok pPLA
1841	0.492	0.835
1876	0.463	0.822
1938	0.478	0.777
2006	0.495	0.736

Tab. 6: Coefficient of ecological stability in 1841–2006

a given decennium, the forest age-structure was analyzed. The analysis was based on forest maps from 2009.

The acquired results (Fig. 8) clearly show that the forest age-structure is very uneven and the percentage of area occupied by each age interval varies between 2.75% and 14.27%. The threshold of equable portion (concerning 15 age intervals) can be represented by arithmetic mean, i.e. 6.66% of the area per decennium (red line in Fig. 8). The portion of clear-cuts and forests less than 10 years old (i.e. timber harvested in the last decennium – between 1999 and 2009) is 14.27%, which is more than twice the equable portion and it reflects an alarming amount of timber harvested in the given decennium.

The portion of forest reaching exploitable age in the next decennium is 26.1% with a predominant species of oak whose exploitable age is 120 years. This fact points to (even in case of reduced timber harvesting in the next four decennia) a rapid decrease in old stands that are necessary for many endangered and protected fauna species (Miklín et al., 2010).

With respect to other negative practices such as exceptions from the size of clear-cuts or full-area soil preparation (rotary tillage of clear-cuts), the present status of nature conservation of this extremely biologically valuable area is insufficient and indicates a failure of the controlling state administration.

6. Conclusions

The most important LULC changes identified in the study areas of Pálava PLA and Soutok pPLA in 1841–2006 were as follows:

1. decrease in the size of grasslands due to the intensification of agriculture (conversion of grasslands into arable land) and afforestation;
2. increase in forest area;
3. specific representation of agriculture land (arable land, vineyards, orchards, meadows and pastures) in 1938 as a mosaic of very small and elongated fields void of large-scale vineyards;

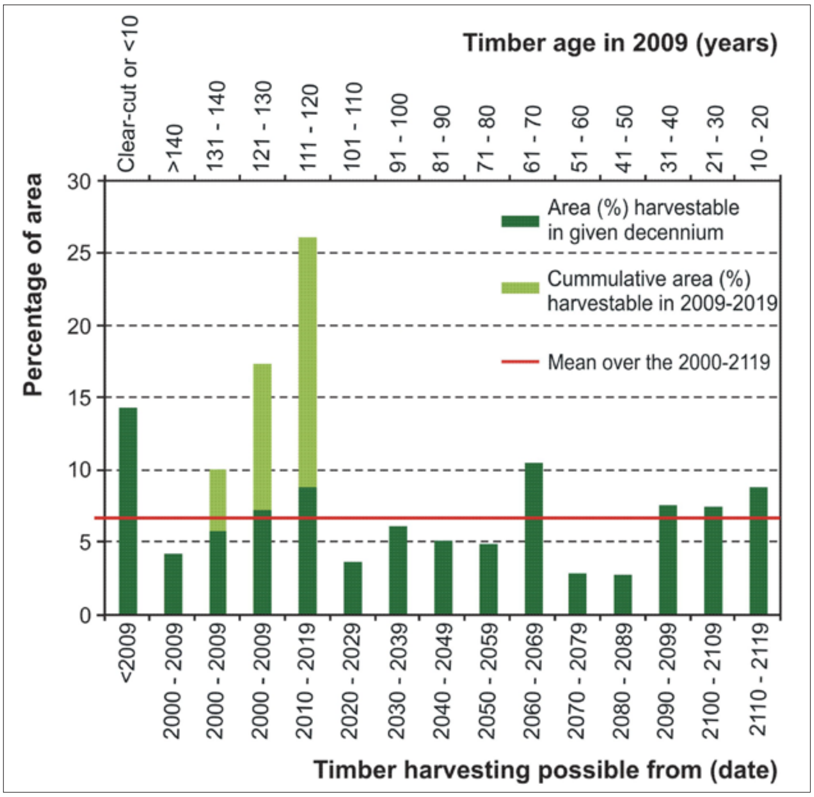

Fig. 8: Timber age structure and harvesting prognosis in the Soutok pPLA for the next 120 years

4. changes in forest management from open pasture woodland (coppice forests with standards) to clear-cut areas.

In respect of nature conservation, the most serious problem in the Pálava PLA, i.e. the afforestation of natural grasslands, has now been resolved through a set of management measures adopted by the PLA Administration. However, despite the mentioned management measures, the average annual rate of afforestation is still increasing, as shown in Miklín, 2007. In order to preserve typical ecosystems such as grasslands, the intensive spread of forest and invasive plants needs to be prevented. This is a matter of money and the present budget of the PLA administration, which is extremely low.

As recorded in the LULC and CES changes, the current management processes in the Soutok pPLA can be considered unsuitable with respect to the area's biodiversity preservation. The extent of forest timber harvesting in the last decennium highly exceeded sustainability. At the same time, if we consider the age structure of forest stands, the current forest management represents a direct threat to many unique species. The current protection of the SCI area is virtually insufficient and many of the authoritative decisions made by the competent organ (South Moravian Regional Authority) are in conflict with the principles of SCI conservation. In order to preserve the species and biotopes of this area, it is necessary to ensure real and effective conservation and sustainable management e.g. by decreeing the Soutok area as a PLA.

The proposed management should comprise i) changes in forest management (e.g. a decrease in the annual amount of harvested timber in order to preserve the proportion of old stands; in some parts a decrease in stocking in order to simulate open woodlands common in the last centuries or substitution of coppice forest with pasture), ii) more intensive grass-cutting in order to stop forest and brush spreading, iii) planting solitary trees in order to stop rapid decrease in their number and iv) turning arable land in flooded areas into grasslands.

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AN APPLICATION OF STREAM THERMOMETRY IN SMALL DRAINAGE BASINS

Leoš PELIKÁN, Vladimír HERBER

Abstract

The utility of the thermometry method in small drainage basins (less than 10 km^2) is described and has been effectively verified in this paper, for case studies of the Bunčovský and the Sloupečník streams in the Czech Republic. Using non-parametric Kruskal – Wallis Analysis of Variance (ANOVA) methods and other statistical procedures, the influence of relief and rock type on groundwater flow has been demonstrated. The majority of the points of groundwater stream inflow have been identified in rugged relief and sandstone. Given the factors mentioned above, different types of groundwater flow cycles, characterized by varying depth and velocity, have been detected.

Shrnutí

Aplikace termometrie povrchových toků v malých povodích

V práci byla ověřena použitelnost termometrických metod v malých povodích o ploše do 10 km^2. Pomocí neparametrické Kruskal – Wallis ANOVY a dalších statistických postupů se podařilo prokázat vliv reliéfu a vlastností hornin na proudění podzemních vod. Většina přítoků byla odhalena v členitém reliéfu, z hornin pak na pískovcích a slepencích. V závislosti na výše uvedených faktorech byly identifikovány oběhy podzemních vod s odlišnou hloubkou a rychlostí v různých částech povodí.

Keywords: *thermometry, rock type, relief type, water temperature, electrical conductivity, Bunčovský stream, Sloupečník stream, Czech Republic*

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1. Introduction

There are numerous tools for research into groundwater flow. The goal of this work is to test the application of the thermometry method in small drainage basins. Measuring water temperature is one of the oldest measurements used in hydrogeology (Zajíček et al., 2009). The underlying principle of thermometry is to determine the influence of relief and geological environment on the groundwater flow. The basic assumption is that water temperature in streams is different from temperature of groundwater, which drains into the streams.

This situation is most obvious in winter. Water changes its temperature and electric conductivity (EC) when in touch with rock bodies. Inflows of groundwater are best to trace when this happens. We may say that water is one of non-conservative tracers (Milanović, 2001). It is also possible to detect groundwater inflows into streams (Constanz, 1998). If we have information concerning air temperatures, temperatures of spring and atmospheric precipitation, we are able to assess the depth and rate of groundwater flow.

The method of thermometry was applied among others by the following authors in the Czech Republic: Kukačka et al. (2004) in Branná; Rukavčicová (2006) describes thermometry as one of methods for the hydraulic testing of rock bodies; Bubík et al. (2006) used thermometry for research of Miocene sediments found within the premises of the SAKO incinerator in Brno. Mikita and Vybíral (2007) describe thermometry as one of indication methods in the investigation of contaminated areas. Within international research, Anderson (2005) mentions the use of this method.

2. Material and methods

Two basins of areas smaller than 10 km^2 were chosen for our research. It is the Sloupečník stream (left tributary of the Svitava River) and Bunčovský stream, which belongs in the Morava River basin (Fig. 1). The study areas exhibited different relief and rock types whose influence we tried to interpret by using the thermometry methods. The two small basins are drained by the rocks of different age and development. The Sloupečník stream flows on the crystalline rocks

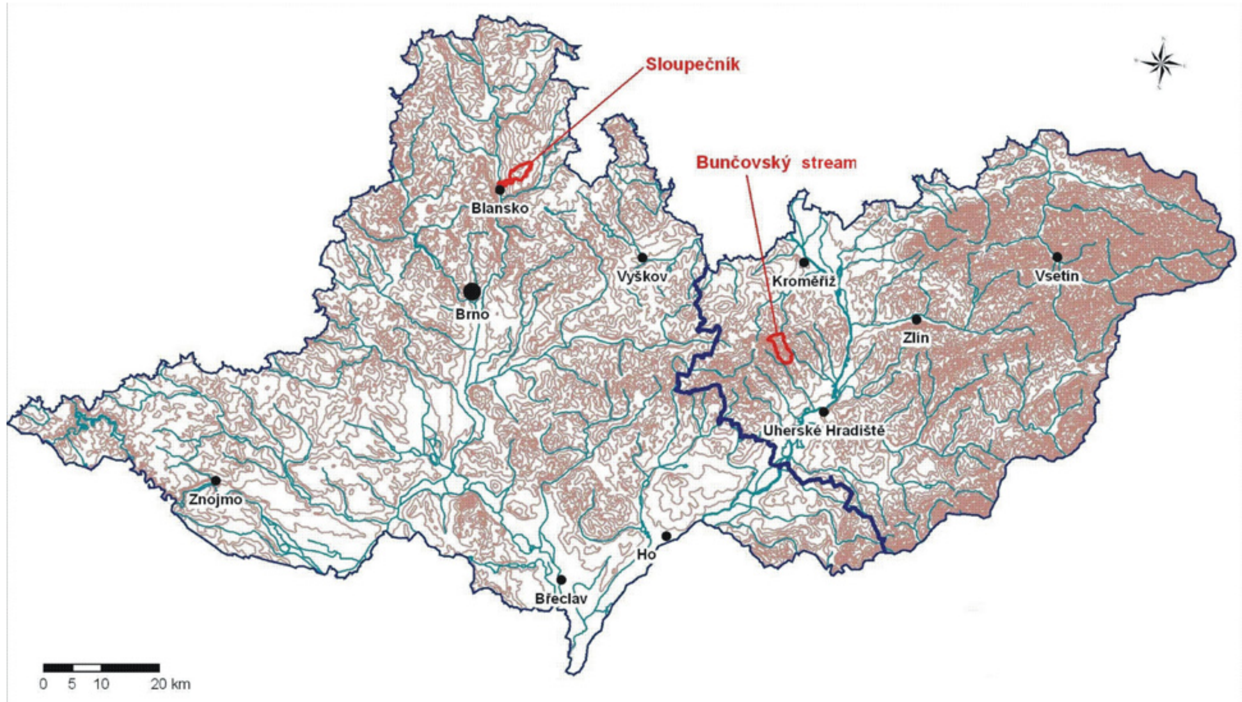

Fig. 1: Location of the Bunčovský and Sloupečník streams
Source: The map was created using ArcGIS 9.2, 2006

of Paleozoic and Proterozoic age while the Bunčovský stream drains aquifers in the flysch rocks of Tertiary (Paleogene) age. These factors have a significant influence on the underground flow formation in both of the basins. Thanks to the detailed research, it is possible to detect groundwater flow cycles of diverse depths and flow velocities predominant in individual parts of the drainage basin.

Fieldwork was carried out in cold weather at the beginning of February 2011. Temperature and conductivity measurements were taken at 346 points on a total area of 18.3 km^2. The total length of measured flows was 21.34 km. Detected groundwater inflows amounted to 65. The measurements were made by using the WTW Multi 340i measuring assembly with the conductometric probe WTW TetraCon® 325 by sections of 10–50 m. Each point was localized by GPS (Garmin GPS 50) with accuracy up to 5 m. The measured point values were subsequently converted to the .shp format by using ArcGIS 9.2 programme and used for further analyses.

The database of values received was split into individual groups based on two factors: relief type and rock type. Depending on altitude and superelevation in certain parts of the basin, relief types were divided into flat, steep and rugged. Rock types were divided into five groups: hornblende – biotite granodiorite, biotite granodiorite, diorite to tonalite, sandstone and claystone, out of which the first three groups belong to crystalline rocks. These types of rocks are typical of low water permeability and they show higher permeability in the subsurface weathering zone and in fault systems (Čurda et al., 2000). Sandstones of higher permeability and claystones of lower permeability belong to flysch rocks. The main aquifers are the subsurface weathering zone and the deeper reaching fissure zones. We studied the median of water temperature and electric conductivity because it reflects the actual situation better than the arithmetic mean in this case. The observed data namely include extreme values as well as a great dispersion.

Values differentiated by the above-mentioned factors were tested by Kruskal – Wallis ANOVA in STATISTICA 9 programme. For each factor we created a box diagram. Kruskal – Wallis ANOVA is based on the order of values and median position testing. A statistical hypothesis is tested of the frequency distribution correspondence by which the influence of outliers is eliminated. The null hypothesis is refused if the p-value is lower than the chosen level of significance (typically 0.05). In such a case, we can claim the difference in the distribution of frequencies to be statistically significant. Kruskal – Wallis ANOVA is particularly useful when the set of values does not correspond to normal distribution pattern and displays a great number of extreme values.

3. Results and discussion

Basic statistics of the measured set of values we can see in Tab. 1. The sets of temperature and conductivity values were tested by Kruskall – Wallis ANOVA, which

Variable	Mean	Median	Min.	Max.	Quantile 5%	Quantile 95%
EC (μS/cm)	493.7	416.0	301.0	1030.0	330.0	788.0
T (°C)	0.6	0.3	0.1	7.2	0.1	2.3

Tab. 1: Basic statistics of measured points (February, 2011), where EC = electric conductivity, T = water temperature
Source: Statistical evaluation in Statistica programme, version 9, 2010

showed that the critical value p = 0.05 was exceeded only once, namely in the category of temperatures within the factor of Relief type. In the other cases, we refuse the null hypothesis and we maintain that a statistically significant difference exists between at least two groups in the distribution of frequencies in the set of temperatures resp. conductivities (see Tab. 2).

The highest percentages of groundwater inflows of temperature exceeding 1 °C were detected in the rugged relief (20%) and in the steep relief (9%). The centre of groundwater inflows in all relief types was within the temperature interval < 0.5 °C where even 100% of all values measured in the flat relief occurred. Inflows detected in the rugged relief had a significant representation (33%) within the temperature interval 0.5–1 °C.

A detailed analysis revealed that the frequency of groundwater inflows was increasing with the increasing relief articulation, which corresponds to Toth's theory of geohydrodynamic systems (1963). The frequency of groundwater inflows in the broken relief is 5.9 · km while in the flat relief it is only 1.4 · km.

The highest median temperature was recorded in the rugged relief (0.4 °C) and was followed by the steep relief with 0.3 °C and the flat relief with 0.2 °C. Maximum

Kruskal – Wallis ANOVA				
factor	**H**		**p**	
	EC	T	EC	T
relief	10.813	2.149	0.005	0.342
rock	45.823	12.129	0.000	0.016

Tab. 2: Results of Kruskal – Wallis ANOVA, where H = test criterion, p = level of significance
Source: Statistical evaluation in Statistica programme, version 9, 2010

Factor	**Frequency**	
	Number	**%**
Relief type		
flat	7	11
steep	15	23
rugged	43	66
Rock type		
b. granodiorite	10	15
h.-b. granodiorite	13	20
tonalite	11	17
sandstone	28	43
claystone	3	5

Tab. 3: Distribution of groundwater effluents in the research area according to factors (Source: author)

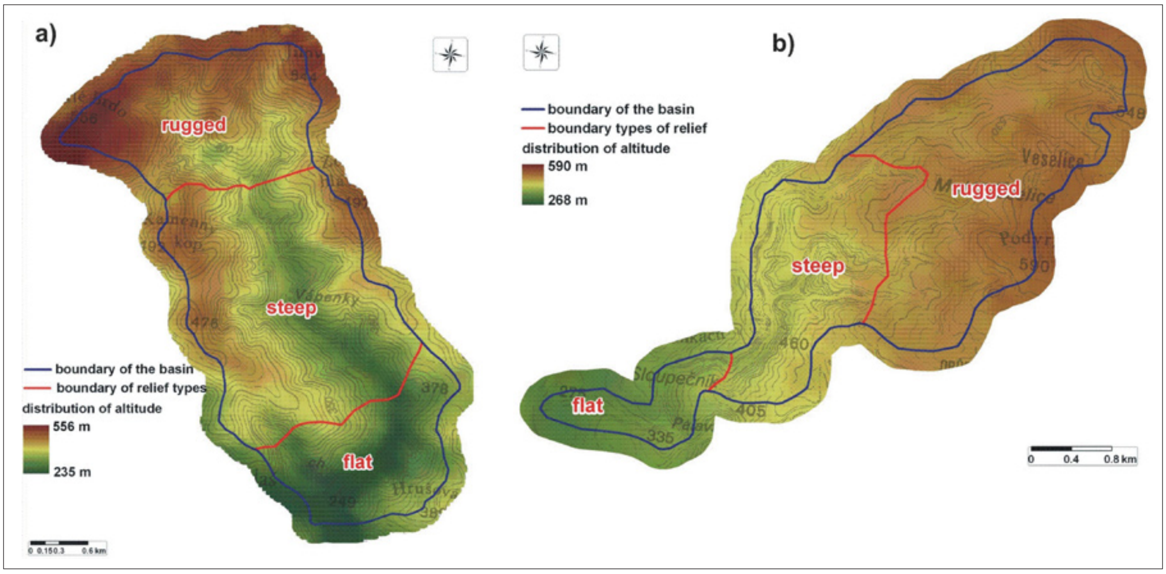

Fig. 2: Relief types of the Bunčovský stream (a) and the Sloupečník stream (b)
Source: The map was created using ArcGIS 9.2, 2006

temperatures measured in the rugged and steep relief reached 7.2 °C and 6.0 °C, respectively (Fig. 3a) and correspond to the springheads. The situation is exactly opposite in the values of conductivity (see Fig. 3b). The highest median was recorded in the flat relief (615 μS · cm) and the values of steep and rugged relief amounted to 561 μS · cm and 408 μS · cm, respectively. Higher temperatures and lower conductivities were detected in the rugged relief, thus documenting deep and rapid groundwater cycling. The higher frequency of inflows points to a greater importance of the local groundwater cycling (Říčka, 2010).

In our research, the flat relief predetermines a shallow groundwater flow (low temperatures of inflows) with low hydraulic gradients. The low hydraulic gradients are then responsible for longer retention of draining groundwater within the rock environment and its greater enrichment with minerals. The phenomenon results in higher groundwater conductivity in these areas. The low frequency of inflows in the flat relief then indicates a dominant role of the regional groundwater flow.

Another assessed factor was the effect of rock type. Diorite to tonalite reached the highest density of inflows per kilometre (4.9·km). Sandstone showed another high value (3.9·km). The lowest density of inflows was shown by biotite granodiorite (2.2·km). Biotite granodiorite and sandstone exhibited the highest percentage of groundwater inflows (20% and 18%, resp.) within the temperature interval > 1 °C. The centre of groundwater inflows in claystone was within the temperature interval 0.5–1 °C (6%). The temperature of inflows in other rock types occurred mainly within the temperature interval < 0.5 °C.

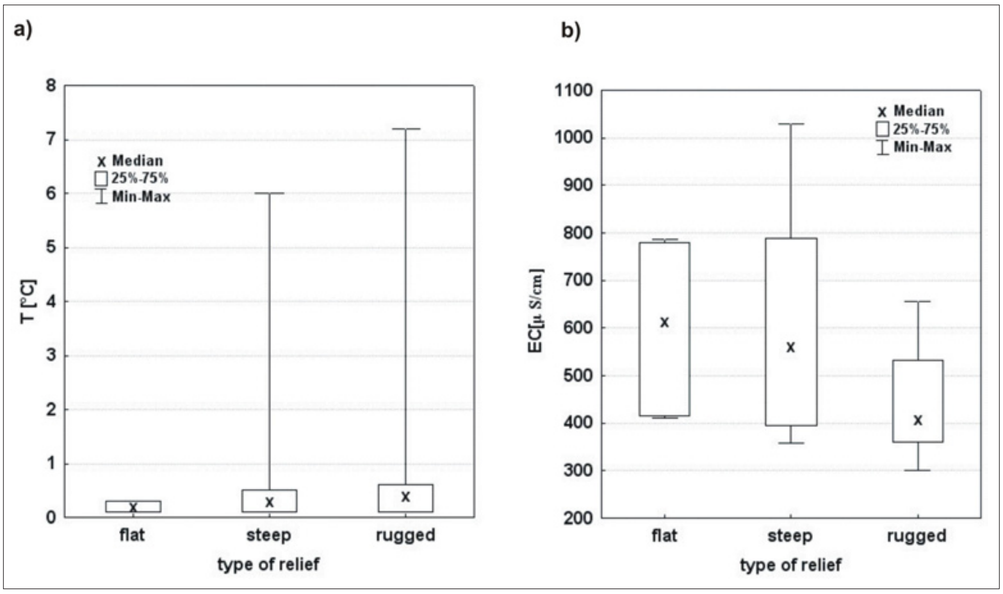

Fig. 3: Box diagrams of temperature (a) and EC (b) in dependence on the relief type
Source: Statistical evaluation in Statistica programme, version 9, 2010

Approximately 78% of the inflows were found within larger rock bodies unaffected by tectonics. This method makes it possible to diversify the influence of relief type and rock type on the distribution of groundwater inflows. The percentage ratio of the frequency of inflows and the stream length is rarely constant within individual rock and relief types. The least notable effect of relief type on the frequency of inflows was observed in sandstone. The greatest dependence on the location according to relief type was recorded in the crystalline rocks. In the flat relief, the percentage share of inflows in the crystalline rocks was zero and growing with the increasing relief articulation.

The highest median of temperature and EC values was found in sandstones and claystones. The temperature median was in the two groups 0.5 °C and the EC median was 568 μS · cm for sandstones and 575 μS · cm for claystones. The remaining three groups of rocks exhibited lower temperature medians (see Fig. 4a, 4b). The lowest median of temperature was observed in hornblende – biotite granodiorite (0.1 °C). The lowest median of EC was recorded in biotite granodiorite (358 μS · cm). The absolutely highest temperature of 7.2°C was measured in biotite granodiorite. Another high value of 6 °C was recorded in a formation of sandstones with conglomerates.

The above results of measurements suggest that crystalline rocks are more permeable to groundwater than flysch formations. The finding is inconsistent with the original presumption of higher permeability in flysch rock bodies, sandstones and conglomerates

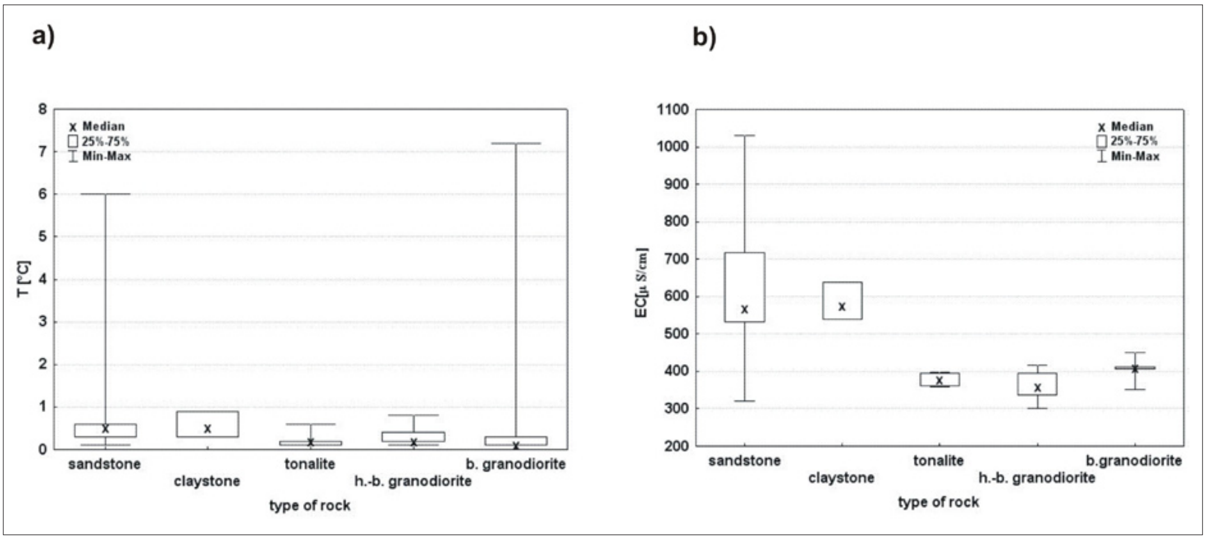

Fig. 4: Box diagrams of temperature (a) and EC (b) in dependence on the rock type
Source: Statistical evaluation in Statistica programme, version 9, 2010

in particular (up to by two orders), which is also corroborated by Doležal, Kvítek, Soukup, Kulhavý, Tippl (2004). The lower permeability of flysch rocks is likely due to the typical alteration of permeable and impermeable layers, which may cause longer retention of water within the rock environment and hence the increase of its conductivity. In the case of deep flow cycling, the groundwater temperature increases too. In crystalline rocks, the splitting of the subsurface weathering zone may play a role, which accelerates groundwater cycling in this layer. This is why in crystalline rocks we suppose rather rapid flow in shallow aquifers.

4. Conclusion

It can be concluded that thermometry is a useful method in interpreting the influence of some factors on groundwater flow. Therefore, we can claim that groundwater flow in the drainage basins of small streams can be successfully investigated by using thermometry methods.

The influence of relief was clearly demonstrated, which is to a certain extent decisive for the cycling of groundwater in the surveyed basins. As documented by the measured values of electric conductivity and temperature, a rather deeper and more rapid groundwater discharge takes place in the rugged relief of the upper parts of the catchment. On the other hand, the flat relief showed a slow and shallow groundwater flow. The depth of groundwater cycling depends on local characteristics of the relief. This hydraulic system is partly modified by the properties of individual rock types.

Crystalline rocks in the research area are drained into the stream by a relatively shallow and rapid groundwater flow within the subsurface weathering zone. Flysch rocks exhibit a slightly deeper and slower groundwater cycling, which is likely to result from the alteration of permeable and impermeable layers of sandstones and claystones.

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ANGLERS' CHOICE OF FISHERIES IN THE CZECH REPUBLIC

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Abstract

The spatial pattern of anglers' movements among fisheries was analyzed using detrended correspondence analysis (DCA), canonical correspondence analysis (CCA) and gravity modelling. Anglers choose, on the national level, a destination fishery mainly according to its spatial position, as longitude and latitude are the primary significant factors revealed by the forward selection procedure of CCA (the first two DCA axes explain 5.9% and the first two CCA axes 5.3% of variability). Distance as a spatial attribute is not only the main factor determining travel to all of Czech fisheries but also travel to specific tourist fisheries. Distance travelled is also influenced by the type of fishery – trout fisheries (Beta coefficient = 1.725) and fisheries on reservoirs larger than 80 ha (Beta coefficient = 1.760) are attended by anglers from the more distant local organizations. The mobility of anglers also varies with the number of inhabitants of their domicile – the impact of distance between the local organization and fishery is strongest for the smallest towns (up to 500 inhabitants, Beta coefficient = 2.456) and weakest for large cities (with more than 50 thousand inhabitants, Beta coefficient = 1.923).

Shrnutí

Výběr rybářských revírů sportovními rybáři v České republice

Prostorová struktura pohybů rybářů po revírech byla analyzována detrendovanou korespondenční analýzou (DCA), kanonickou korespondenční analýzou (CCA) a gravitačním modelem. Na národní úrovni rybáři volí revír především na základě jeho polohy, protože hlavními signifikantními vysvětlujícími proměnnými vybranými metodou dopředného výběru CCA byly zeměpisná šířka a zeměpisná délka polohy revíru (první dvě osy DCA vysvětlují 5,9 % a první dvě osy CCA 5,3 % vysvětlitelné variability souboru). Vzdálenost však není jen hlavním faktorem návštěvy revírů všeobecně, ale taktéž hlavním faktorem návštěvnosti specifických turistických revírů. Vliv vzdálenosti na výběr revíru je však taktéž závislý na typu revíru – z větších vzdáleností jsou navštěvovány revíry pstruhové (beta koeficient = 1,725) a revíry na velkých nádržích (beta koeficient = 1,760). Mobilita rybářů je závislá na počtu obyvatel místa jejich obvyklého pobytu. Vliv vzdálenosti mezi revírem a sídlem místní organizace odkud rybář pochází je největší pro malá sídla (do 500 obyvatel, beta koeficient = 2,456) a nejmenší pro velká města (nad 50 000 obyvatel, beta koeficient = 1,923).

Keywords: *recreational fisheries, angling, tourism, gravity models, DCA, CCA, Czech Republic*

1. Introduction

Recreational fishing is one of the most significant water-based recreational activities in the Czech Republic (Navrátil, Švec, 2008) as well as in other countries (e.g. Upneja et al., 2001; Arlinghaus et al., 2002). It has been linked to a wide range of environmental issues (Arlinghaus, 2006a) as well as recreational issues (Navrátil et al., 2009). There are numerous social benefits that result from the recreational fishing (Floyd et al., 2006) as well as economic benefits (Oh et al., 2005a).

Human dimensions of recreational fishing

Research into the human dimensions of recreational fishing has focused on many fields, among them, in particular, since the first half of the 1970's (as mentioned e.g. by Morgan, 2006) different approaches to the characterisation of recreational anglers in terms of: the numbers of fish caught, numbers of fish kept or the art of angling (e.g. Lockwood et al., 2001; Marta et al., 2001; Vigliano et al., 2000), socio-psychological characteristics of recreational anglers (Mangun, O'Leary, 2001; Wilde, Pope, 2004), economic aspects of recreational fishing looking at the fisherman's expenditures, or the revenue gained by establishments offering recreational fishing (e.g. León et al., 2003; Oh et al., 2005a; Toivonen et al., 2004). There are several typologies of anglers elaborated e.g. according to their motivation and satisfaction with angling

(Holland, Ditton, 1992), the specialization of angler (Oh, Ditton, 2006), the link with a favourite place of angling (Hammitt et al., 2004) or angler's consumptive orientation (e.g. Kyle et al., 2007). Because the recreational fishing is considered foremost as a male recreational activity, gender issues are also of interest (e.g. Toth, Brown, 1997; Schroeder et al., 2006). Special attention is paid to angler preferences in order to inform management options (reviewed e.g. by Oh et al., 2005b) especially with respect to the environment and natural resources protection (summarized e.g. by Arlinghaus, 2006a).

Recreational fishing is considered to be not only recreational, but also popular tourist activity (Wilson et al., 2001; Ditton et al., 2002). It has been found that in some cases non-resident anglers represent an important part of the angling community, not only in marine areas (León et al., 2003), but also on inland fisheries (Butler et al., 2009). It could play an important role in specific inland tourist destinations, seeing that angling related activities are one of those criteria used by destination managers to

1. diversify tourist opportunities and services of their region by making packages of individual tourist attractions and
2. tie local communities with visitors by supporting special fishing activities (Wilson et al., 2001).

Recreational fishing related information is also utilized to promote a region by respective destination management (Cawley et al., 2002). Ditton et al. (2002) summarizes the known differences between local and non-resident anglers, which are similar to those reported also from Canada (Fisheries and Oceans Canada, 2007).

Anglers' destinations

As recreational fishing is closely bound to tourism, the fishing site choice is one of the most important topics for managers (Hunt, 2005). The fishing site choice is studied using two main approaches. (literature review on site choice see Song, Li, 2008; Nicolau, Más, 2008). The main aim of researchers is to identify factors affecting decisions to travel when analyzing large databases of statistical data using, especially, ordinary least squares estimations or multinomial logit models (Lyons et al., 2009) or analyzing data gathered by specialized questionnaire surveys based, above all, on different discrete choice models (last summarized by Albaladejo-Pina and Díaz-Delfa, 2009).

Different types of choice modelling are popular also in recreational fishing site choice, which encompasses most of all the travel cost method (Hunt, 2005). Thus, the recreational fishing has a spatial dimension. The other modelling variables are fishing quality, water area, water quality, aesthetics and presence of a boat ramp (Hunt, 2005). These analyses (as many others) are entirely based on surveys of anglers, where preferences of each randomly sampled angler are crucial for these models (Arlinghaus, 2006a). However, large-scale data dealing with anglers' communities rather than with anglers as individuals (small scale), gathered from different types of national household surveys are also interesting for the management of recreation fisheries (Aas, 1996) and are often used by researchers to address the issue of predicting future angling participation – literature review on this topic is provided by Walsh et al. (1989) for the older publications and by Arlinghaus (2006b) for the latest ones. Thus, the site choice is possible to study on a large scale. Information retrieved from anglers' national surveys were formerly studied, especially the specific geographical dimension e.g. by Aas (1996) or Ditton et al. (2002). However, there are only two such anglers' national surveys in the Czech Republic for years 2003 (Spurný et al., 2003) and 2009 (Spurný et al., 2009) and both did not study the destinations of anglers as tourists. The data on recreational fishing and spatial consequences of angling can be obtained from the summaries of fish kept on fisheries (Pivnička, Rybář, 2001; Smutný, Pivnička, 2001; Humpl et al., 2009; Jankovský et al., 2011), in particular, the data concerning the spatial pattern of anglers' movements, distance travelled and differences among the types of fisheries and differences among the types of anglers' residence. The advantage of the database is its completeness, so the parent population is available.

As mentioned recently, there is still a lack of studies focused on fishing patterns in the inland recreational fisheries (Pereira et al., 2008). Spatial consequences of recreational fishing have not been studied in Europe since the work of Aas (1996), with the exception of urban-rural consequences (Arlinghaus, Mehner, 2004; Arlinghaus et al., 2008; Arlinghaus, Mehner, 2003). That is why we set up the following two objectives for this paper:

1. to analyze the spatial pattern of anglers' movements to the fisheries, and
2. to test determinants of spatial fishery choice on a large scale based on fish kept summaries.

Our hypotheses are:

- Hypothesis 1 (H1): travel of anglers to fisheries is not independent of space but continuously changes with its gradients.
- Hypothesis 2 (H2): fishery choice is determined by the character of fishery.
- Hypothesis 3 (H3): fishery choice is determined by the urban-rural character of anglers' residence.

2. Methods

Study area – recreational fishing in the Czech Republic

The execution of fishing rights in the Czech Republic is implemented by the fisheries. Fishing rights in the fisheries are executed by the fishery users or owners, especially by organizational units of fishing unions. There are two main fishing unions in the Czech Republic and a small number of other ones, which are incomparably smaller.

The biggest fishing union in the Czech Republic is the Czech Anglers Union with about 220,000 adult and 50,000 youth members registered as at the end of 2002, which was more than 2.2% of the total population of the Czech Republic (Czech Anglers Union, 2009). The Czech Anglers Union operates 35,200 hectares of fisheries, where the Union members crop approximately 3,200 tons of different fish species each year. The second biggest union is the Moravian Anglers Union (for spatial distribution of both unions see Fig. 1).

To be allowed to angle in the fisheries operated by the Union, a fisherman has to hold a fishing license and to buy a permit to fish.

The members are obliged by the Fishing rules to file all fish kept in a prescribed way. Particular fisheries are operated by basic organization units, which are local organizations of the Union, created on a territorial basis. A member of the Union is a member of a local organization, usually at the town of or in proximity to his permanent address.

Data set

This paper is based upon data from the Czech Anglers Union that supplied information from the year 2002 (Czech Anglers Union, 2003). The database contains for each fishery (n = 1,103) the numbers of fish kept by members of each local organization (n = 371) separately. This information is an appropriate substitution for attendance of anglers to the fishery since the number of attendances was well correlated ($R = 0.92$; $p < 0.001$) with the numbers of fish kept for the same period for fisheries and local organizations of the Moravian Anglers Union (2003). Memberships in local organizations were considered as the anglers' origin point in the sense of permanent address. This database was complete with available data on fisheries and local organizations characteristics.

Three typologies of fisheries were adopted. First, the fisheries were classified into types based on information cited in the list of fisheries. Water reservoirs were divided into two categories according to the area size of fishery – the area of 80 hectares was taken as a boundary. The category of reservoirs up to 80 hectares includes a majority of ponds, technical reservoirs, pools, river branches and flooded mines.

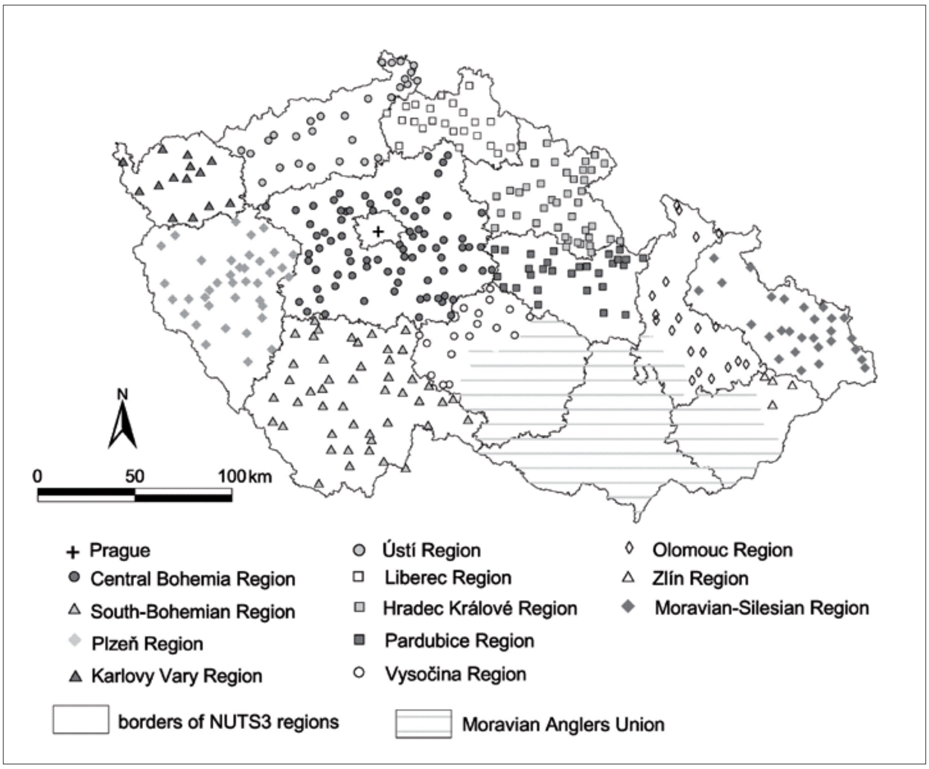

Fig. 1: General map of the Czech Republic with local organizations of the Czech Anglers Union according to their location within NUTS 3 regions of the Czech Republic

The category of reservoirs over 80 hectares includes dam reservoirs, flooded gravel-pits and sand-pits. Watercourses were also divided into two categories. A watercourse body having an area in hectares of at least 1.5-multiples of its length in kilometres was labelled as a river; other watercourses were classified as brooks. Second, the fisheries were divided according to the list of fisheries into trout waters and non-trout waters. Third, the fisheries with the highest (> 300 pieces) and lowest number of fish (< 40%) kept by members of local organizations located in the same district (NUTS 4 region as the main spatial pattern of geographical organization of the Czech Republic) were picked out from the whole dataset and labelled as a tourist fishery. The numbers of inhabitants of local towns were added to local organizations.

The locations of local organizations and fisheries were digitalized to point layers in the geographical information system (GIS) JANITOR J/2 (Pala, 2008). All the above mentioned data were interconnected spatially in GIS ArcView 3.2 (ESRI, 1999). The main reason to do this was to find for each fishery local organizations that are 'close' to each fishery. The closeness was considered on three geographic levels – for each fishery were found:

1. local organization operating the fishery;
2. local organizations in the same district (NUTS 4) as the fishery;
3. local organizations in the same region (NUTS 3) as the fishery.

Data analysis

The dataset forms a seemingly incomprehensible and impenetrable mass of information in which we wanted to uncover the relationships (if there were any) among anglers and destinations. Multivariate data analyses techniques are considered to evaluate this state (Podani, 2000).

Our objective is to assess relations between the angler's origin and the fishery where he angles. It applies, that

1. there are anglers from different local organizations fishing in each fishery and
2. the anglers from one local organization angle in different fisheries.

The structure of anglers in particular fisheries could be then considered as an analogy to the structure of plant and/or animal species in different types of habitats. The structure of anglers in a fishery corresponds to the character of the site. Changes in the composition of a community in different sites have a character of gradients. Our goal is to identify those gradients (if they ever exist).

Thus, the overall variations in anglers' origins among all fisheries of the Czech Anglers Union was examined by gradient analysis. We are looking for the greatest variability that could be visualized using the ordination diagrams for the fisheries (destinations) and local organizations (origins) (ter Braak, Šmilauer, 2002). Unconstrained ordination based on the unimodal response model with detrending second and higher axes by segments (Hill, Gauch, 1980) – Detrended Correspondence Analysis (DCA) was performed by CANOCO 4.5 package (ter Braak, Šmilauer, 2002). The numbers of fish kept were log-transformed and some local organizations were down-weighted (those local organizations, whose members kept small numbers of fish). The data were analysed analogically as the communities of organisms in ecology (the object of the analysis is the anglers' structure according to their origin in particular fisheries, which is quantified by the number of fish kept).

We used the canonical correspondence analysis (CCA) to test the ability of independent factors (latitude of fishery, longitude of fishery, type of fishery, urban/rural type of respective local organization) to explain variation in fish amounts kept in fisheries. To find the main factors involved in the constrained ordination model, forward selection was used and factors were stepwise added into the model with a threshold of $p < 0.001$ to entry (Lepš, Šmilauer, 2003; Navrátilová et al., 2006; ter Braak, Šmilauer, 2002). The effects of all canonical axes were tested by the permutation test – 999 permutations, full model (Navrátilová et al., 2006).

The same DCA as the above-described analysis was performed for tourist fisheries as a partial DCA (DCAt).

Two approaches were used to reveal the determinants of spatial fishing site choices. First, the differences among fishery types were investigated by One-way ANOVA with the Tukey unequal N HSD test. Differences between the whole data set and tourist fisheries among the fishery types were searched using the chi-square test.

The significance of distance on the choice of the fishing site is in our interest as a key concept of space (Knox, Marston, 2001). The distance decay parameter (Beta value) is thus calculated from doubly constrained gravity model with power function (Robinson, 1998) performed by iterative algorithm of Flowmap software 7.3 (Breukelman et al., 2009). Higher Beta values indicate a stronger impact of distance on travel behaviour (Robinson, 1998). Beta values were calculated for

1. each type of fishery to test the impact of attributes of fisheries and

2. for five types of local organizations divided according to the number of inhabitants in its locality (up to 500; from 500 to 5,000; from 5,000 to 15,000; from 15,000 to 50,000; 50,000 and more) to test the urban-rural pattern.

Convergence criterion was set to 0.1% and Beta values were calculated according to the logarithmic distance of the observed average trip length (Breukelman et al., 2009).

3. Results

Spatial pattern of anglers movement

The overall variation in anglers' origins for all fisheries of the Czech Anglers Union was examined by gradient analysis. The explained variability of the first two DCA axes is 6% (Tab. 1). The first DCA axis is markedly longer than the other axes (Tab. 1, Fig. 2); we can thus consider it to be the most important gradient according to which the fisheries differentiate one from the other. The gradient along the first axis can be designatet as geographical because the fisheries of the western part of the Czech Republic (Karlovy Vary Region, Plzeň Region) have separated along this gradient from the Moravian fisheries of the eastern part of the Czech Republic (Olomouc Region, Zlín Region, Moravian-Silesian Region). Between these quite outstanding groups, we can find the fisheries of eastern Bohemia (Hradec Králové Region, Pardubice Region) and a more extensive grouping of northern Bohemia (Liberec Region, Ústí Region), middle Bohemia (Prague, Central Bohemia Region) and southern Bohemia (South-Bohemian Region). The first DCA axis thus represents a territorial gradient in the attendance of fisheries in the sense of longitude, as the scores of the first DCA axis was very well correlated with the longitude of the fishery location (Fig. 3a).

There have been quite significantly separated northern Bohemian fisheries from the fisheries of southern Bohemia alongside the second axis. Therefore, we can consider even the second axis as the axis of the geographical gradient, this time in the sense of latitude as the scores of the second DCA axis were well correlated with the latitude of fishery location (Fig. 3b). Its importance in the dataset is however markedly lower than that of the first axis.

CCA was applied to test a hypothesis about the influence of space on the variation of anglers' origin on fisheries (H1). The variation of anglers origin

	Axis	DCA	DCAt
Eigenvalue	1	0.776	0.602
	2	0.397	0.242
	3	0.344	0.168
Total inertia		19.859	4.913
Length of gradient	1	10.635	6.417
	2	5.804	3.538
	3	6.444	3.411
Cumulative percentage variance of fisheries data	1	3.900	12.300
	2	5.900	17.200
	3	7.600	20.600

Tab. 1: Summary of detrended correspondence analysis (DCA) of all 1,103 fisheries of the Czech Anglers Union, canonical correspondence analysis (CCA), and partial detrended correspondence analysis (DCAt) of 49 tourist fisheries (DCAt)

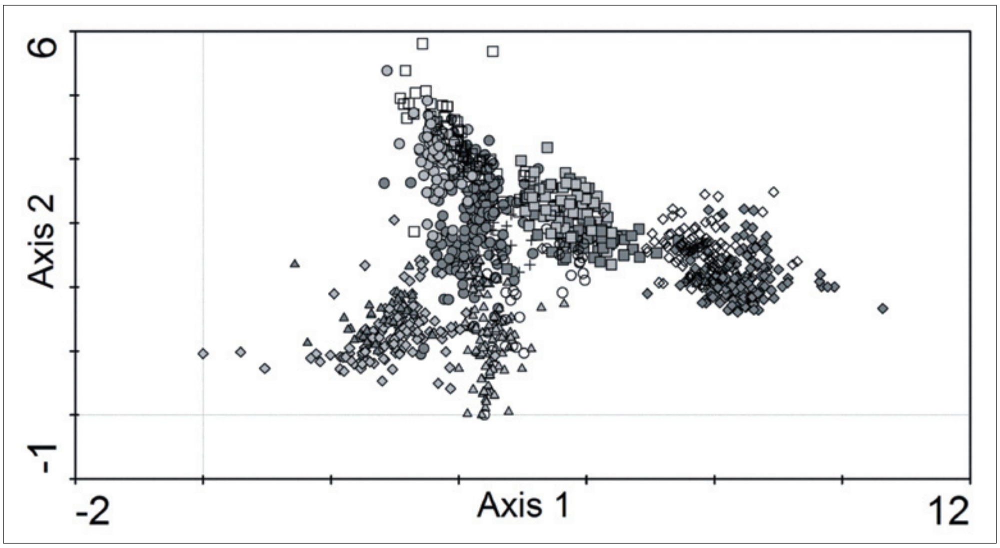

Fig. 2: Position of fisheries in the ordination diagram based on DCA. Fisheries categorized according to their location in regions of the Czech Republic (for legend see Fig. 1)

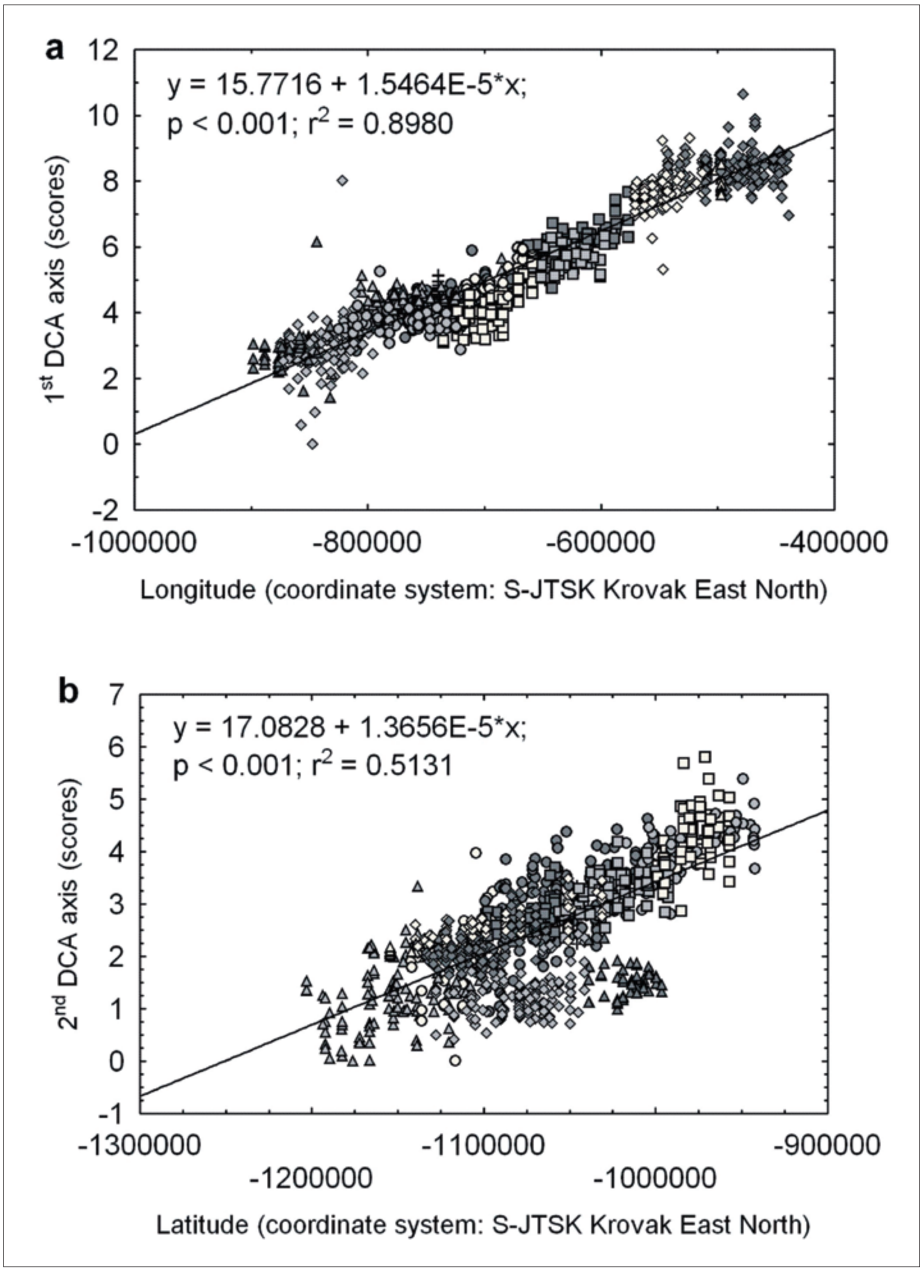

Fig. 3: Correlation of the location of fisheries between DCA axes coordinates and geographical coordinates for 1st DCA axis and longitude (a) and for 2nd DCA axis and latitude (b) (for legend see Fig. 1)

is significantly explained by longitude, latitude, non-trout and trout type of fishery. Together they explained for 5.8% of total variability. All four axes were significant ant thus the relationship between the anglers' origins and the fishery location was highly significant. Eigenvalues of the first two axes in CCA are only slightly smaller than in DCA, this indicating that the variables included in CCA really captured much of the variation in the anglers' origin data (Navrátilová et al., 2006).

The same DCA was performed for tourist fisheries. Even in that category, there is one main gradient (Tab. 1) – geographic in the sense of the longitude (Fig. 4a). The second gradient can be labelled as an 'impact of the capital Prague'. The third axis has then a significance of a geographic gradient in the sense of the latitude (Fig. 4b).

Determinants of spatial fishery choice on the large scale

The differences in the share of members of a respective local organization on the numbers of fish kept between trout and non-trout fisheries (Tab. 2) were found as well as differences among particular fishery types (Tab. 3). In the trout fisheries, the members of the respective local organization take a lower share of the fish kept than in the non-trout waters. With the increasing geographical generalization, the differences between the trout and non-trout fisheries are decreasing but still remain significant. Within the defined fishery

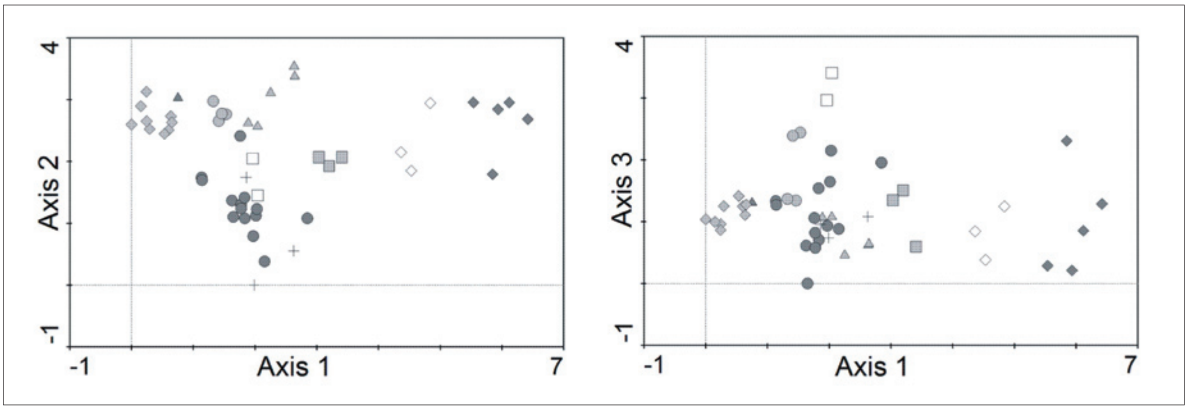

Fig. 4: Position of tourist fisheries in the ordination diagram based on DCAt according to the 1st and 2nd axes of DCAt (a) according to the 1st and 3rd axes of DCAt (b). Tourist fisheries categorized according to their location in regions of the Czech Republic (for legend see Fig. 1).

types, differences exist in the shares of members of respective local organizations on the fish kept as well. To the highest degree, members of respective local organizations account for the fish kept in the up-to 80 hectares water reservoirs, to the lowest degree they account for the fish kept in the over 80 hectares reservoirs. Between the two cited groups, we can find rivers and brooks that differ from the both types of reservoirs but they do not differ one with another. The differences among the particular types decrease when enlarging the geographical unit.

Similar are results of Beta value of distance-decay rate (Tab. 4). Beta value counted for trout fisheries is lower than Beta value for non-trout fisheries. Beta values lower than 2 were found in the reservoirs over 80 hectares and in the rivers. By contrast, the highest values were found in the reservoirs of up to 80 hectares.

A difference in the representation of particular types of fisheries was found between tourist fisheries and all fisheries ($\chi^2 = 75.206$, $p < 0.001$). In the group of tourist fisheries, the representation of the fisheries on over 80 ha reservoirs and rivers is significantly higher. No differences were found in the representation of the trout and non-trout fisheries.

Attendance distance is manifested by a decrease on the part of members of these local organizations who are furthest away from fisheries based on a count of the

Type of fisheries	Geographical generalization →		
	% share of home local organizations	% share of districts' local organizations	% share of regions' local organizations
	mean (S.E.)	mean (S.E.)	mean (S.E.)
Non-trout	65.10 (1.02)	78.23 (0.84)	89.48 (0.59)
Trout	56.21 (1.52)	71.02 (1.33)	84.45 (1.08)

Tab. 2: Percentage shares of the members of local organizations originating from identical geographical units where a fishery is situated. Means in all three cases differ significantly (Tukey unequal N HSD test, p > 0.05).

Type of fisheries	Geographical generalization →		
	% share of home local organizations	% share of districts' local organizations	% share of regions' local organizations
	mean (S.E.)	mean (S.E.)	mean (S.E.)
River	61.02^{a} (1.65)	72.89^{a} (1.52)	86.70^{a} (1.11)
Reservoirs up to 80 hectares	70.64^{b} (1.47)	83.75^{b} (1.10)	91.63^{b} (0.81)
Brook	58.21^{a} (1.29)	72.58^{a} (1.13)	85.72^{a} (0.88)
Reservoirs over 80 hectares	39.07^{c} (4.85)	59.69^{a} (3.97)	84.87^{ab} (3.14)

Tab. 3: Percentage shares of the members of local organizations originating from identical geographical units where a fishery is situated – types of fisheries. Means with the same letter do not differ significantly (Tukey unequal N HSD test, p > 0.05).

total fish kept (Fig. 5). This impact varies according to the number of inhabitants in the town of the local organisation. The impact of distance is more important in cases involving rural local organizations rather than urban ones. The lowest Beta value of distance-decay rate was found in large towns and it was increasing stepwise up to the highest value in rural local organizations (Tab. 4).

	Beta value
Type of fishery	
Trout	1.725
Non-trout	1.952
Type of fishery	
Brook	2.075
Reservoirs up to 80 hectares	2.148
River	1.830
Reservoirs over 80 hectares	1.760
Number of inhabitants of a LO quarters	
Up to 500	2.456
From 500 to 5,000	2.323
From 5,000 to 15,000	2.223
From 15,000 to 50,000	2.156
Over 50,000	1.923

Tab. 4: Beta values for the urban-rural gradient of local organizations (LO) and types of fisheries

4. Discussion

Spatial pattern of anglers' movement

Hypothesis 1 (H1) was that the travelling of anglers to fisheries does not depend on space but continuously changes with its gradients. If anglers' choice of a fishery depends mainly on natural, economic, aesthetic, social and other similar conditions, the result of our gradient analysis would be with no obvious gradient and it would come to the mixing of fisheries in the ordination diagram. Indeed, if a spatial relation as a main characteristic has appeared, it is obvious that, it plays a main role in the choice of a fishery by anglers on the level of the whole Czech Republic. The main gradient is represented by a geographical position significantly correlating with the longitude. The reason for it is the extension of the form of the Czech Republic in an East-West orientation. Thus, the country forms the longest possible gradient. As the second main (independent) gradient significantly correlates with the latitude, they both form together a model of the real spatial pattern of fisheries (compare Fig. 1 and Fig. 2), which is close to the anamorphous map based on an angler's spatial behaviour (Golledge, Stimson, 1997). These dependences are statistically confirmed by the results of CCA.

The explained variability of the whole set of fisheries is not high. It is because of the excessive heterogeneity of the data – there are many local organizations whose members kept no fish on many fisheries – so the gradient of the first axis is very long (Lepš, Šmilauer, 2003). In other words, many fisheries are of local importance only and anglers travel most often to their closest fisheries.

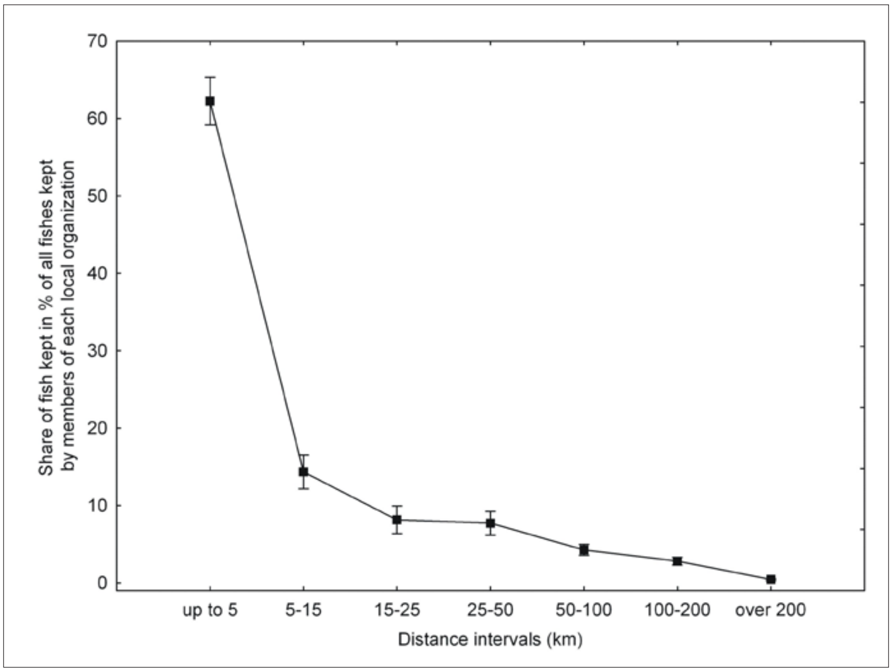

Fig. 5: Share of fish kept by members of local organizations in fisheries according to the distance of a fishery of the respective local organization (n = 371). The figure presents averages and 0.95 confidence intervals

Regarding data from all fisheries, it seems to be a trivial finding because the pattern is given by the fact "an angler travels to and around the closest fishery". However, if we set eyes on the analogical analysis performed with only data from tourist fisheries, we learn that the pattern stays similar. On a national scale, anglers choose a fishery mainly according to the spatial position. The tourist fisheries are similar according to the origin of anglers fishing there, although they are different in size, hydrological character and also even in the fish stock (Humpl et al., 2009). It can result even from the relatively high spatial diversity of fisheries all over the Czech Republic – in the majority of the territory, the fisheries of all types are accessible within one-day of car travel. The tourist fisheries have thus a spatial character on the regional principle and no special fishery exists to which anglers from all over the Czech Republic would travel.

Spatial closeness is notable above all at the level of NUTS 3 regions (see Fig. 2). It might be due to the most widespread type of fishing licenses. They are valid within the territorial units of the Czech Anglers Union, which are larger than NUTS 3 regions of the Czech Republic. The same fishing license as in the anglers domicile, the anglers use (with no need of extra payment) also during their weekend recreation at weekend houses that are most often localized in the hinterland of towns (Muller, 2002; Mottiar, 2006). In the case of the Czech Republic, this means within a region of NUTS 3 (Fialová, 2001) and therefore territorial units of the Czech Anglers Union, too. Anglers quite often use weekends for fishing close to their weekend houses that are very often close to a body of water (e.g. Muller, 2002; Fialová, 2001), which is a phenomenon well known in other parts of Europe (e.g. Sipponen, Muotka, 1996).

Highly notable is the impact of anglers travelling from the capital city, Prague, to all regions surrounding middle Bohemia. The reason is the highest concentration of inhabitants in the Czech Republic and the highest amount of travels in absolute numbers (as in Ditton et al., 2002).

Determinants of spatial fishery choice

The spatial pattern of anglers' movements analyzed on the basis of the number of fish kept according to the local organization is influenced by the character of particular fisheries (see Tab. 2, Tab. 3), thus hypothesis 2 (H2) was confirmed.

The higher share of fish kept by members of other local organizations in trout fisheries than in non-trout fisheries, as well as the lower Beta value, could have been caused by its location, especially in mountain and submontane areas and, thus, at relatively large distance from urban centres. Likewise, it is caused by the different species structure of fish stock, which is a strong motivator to participate in recreational fishing as a form of tourism (Fisheries and Oceans Canada, 2007).

The fishery size is an important identifier of the tourism importance as well (see Tab. 3, Tab. 4). Of the highest importance in tourism are big reservoirs. It holds generally that big natural or artificial reservoirs belong to the most important recreational areas of inland territories (Ritchie, Crouch, 2003) and in the Czech Republic the reservoirs beside the mountain areas are the most important recreational areas for domestic tourism (Navrátil, Švec, 2008). The big reservoirs are also related to the largest commercial offer of accommodation for anglers in the Czech Republic (Navrátil, 2004); analogically, it is valid for large fisheries on the watercourses as well.

We can see a common impact of friction of distance (e.g., Haggett, 2001; Knox, Marston, 2001) in the increase of the share on the fish caught by the territorially respective anglers for the bigger territorial units (Tab. 2, Tab. 3), which is very important also in tourist activities (e.g. Jensen, Korneliussen, 2002; Prideaux, 2002; Zilinger, 2007), as confirmed in this study (Tab. 4).

Small reservoirs are most often attended by members of their local organization at all geographical levels. That could be a demonstration of the quality of offer that generally decreases the weakening impact of distance on human activity (e.g. Haggett, 2001) reported also for recreational activities (Becken, 2001). Bigger fisheries are always recreational areas – therefore better equipped with recreational and also angling infrastructures, including the more diversified and superior fish stock.

The lowest value of the distance-decay parameter in case of the largest towns would confirm a high mobility of urban anglers (Arlinghaus et al., 2008) in combination with high pressure on fisheries. The values of the distance-decay parameter decreasing simultaneously with a decrease of the number of inhabitants in point of the local organisation headquarters could be evidence of lower mobility of rural population (e.g. Haggett, 2001) and confirm our third hypothesis (H3).

5. Managerial implications

Based on the analysis of fish kept in the fisheries of the Czech Anglers Union it was proved that some impacts of space and place were of big importance. Among the main findings with the importance for fishery management in relation to anglers we have to cite:

- important spatial closeness of movement among the fisheries,
- non-negligible existence of angling as a tourist activity,
- higher mobility of attendants of trout fisheries compared to the attendants of non-trout fisheries,
- importance of big reservoirs as a main destination for angler-tourists.

Acknowledgement

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A TYPOLOGY OF EU COUNTRIES IN TERMS OF POPULATION GROWTH IN THE PERIOD FROM 1990 TO 2009

Ivan ŠOTKOVSKÝ

Abstract

Changes in population growth in the EU countries in the last twenty years are presented in this article. Death rates, birth rates and migration were investigated for the period from 1990 to 2009. The role of population growth in this study is directed to all 27 members of the European Union retrospectively to 1990, even though at that time the EU consisted of only twelve member countries. The dynamic spatial typology is presented on the basis of a series of values of the following three basic demographic indices: the crude rate of natural increase (CRNI), crude rate of net migration (CRNM), and crude rate of total population increase (CRTPI).

Shrnutí

Typologie států Evropské unie podle změn populačního růstu v letech 1990 až 2009

Článek přináší výsledky výzkumu změn populační velikosti členských států Evropské unie za posledních dvacet let. Význam úmrtnosti, porodnosti a migrace je sledován v období mezi roky 1990 a 2009. Výzkum populačního růstu se zaměřuje na všech současných 27 členů Evropské unie a to zpětně k roku 1990, i když tehdy tvořilo EU 12 států. Dynamická prostorová typologie je provedena na základě dvacetileté řady hodnot tří základních demografických ukazatelů: hrubé míry přirozeného přírůstku (hmpp), hrubé míry migračního salda (hmms) a hrubé míry celkového přírůstku populace (hmcpp).

Key words: *population size, total population increase, crude rate of natural increase, crude rate of net migration, crude rate of total population increase, European Union countries*

1. Introduction

Human resources (in the sense of human labour) belong to four basic sources of economy, or in other words to the decisive factors of production next to the soil which represents natural resources, capital and technology. The importance of all the three most important subjects (households, establishments, state) corresponds closely with the population growth. Economists designate physical and mental efforts that people put into producing goods and services as work. Hence, the growth of the population as well as its change in time is a very significant coefficient of social and economic processes. The population plays an important role in all fundamental economic activities, i.e. production, consumption and barter. That is why a long-time controlling of the number of inhabitants, its change in time (dynamics), distribution and basic structures are very important (Woods, 1982).

The present study is directed especially to evaluating the differences of the population growth in 27 EU countries. Changes in population growth in the last two decades since 1990 are analysed. These two decades of may be considered as a long-time analysis of the phenomenon enabling us to recognize a number of regularities and relations. A detailed analysis elaborates data of the European Union, in the framework of which it is provided to its statistical office, called Eurostat. The European statistical office has its headquarters in Luxembourg, the capital of the state of Luxembourg. Eurostat was established in 1953 and when the European Community was founded in 1957, it became a Directorate-General (DG) of the European Commission (more on: http://epp.eurostat.ec.europa.eu/portal/page/portal/about_eurostat/corporate/introduction).

The total population change depends on the size of natural increase and migration (Woods, 1986). The population growth is primarily caused by natural increase, that is, the excess of births over deaths. But in any particular region, migration will cause population growth when the amount of immigration exceeds the amount of emigration. And in the present European Union migration is a more significant cause of population growth than the natural increase. Both population growth and migration can affect the quality of the natural environment, likelihood of conflicts, and social cohesion between ethnic groups. From our point of view, the significance of both population growth and migration is often underestimated by governments and by non-governmental organisations.

The European Union was formally established when the Maastricht Treaty came into force on 1st November 1993. The European Union (EU) is an economic and political union of 27 member states (Fig. 1). EU has developed a single market through a standardised system of laws which is applied in all member states including the abolition of passport controls within the Schengen area. Today the EU generates approximately 28% of the global economy (as per the global nominal GDP), or 21% when considered in terms of purchasing power parity (global GDP). In 2002, € notes and coins replaced the national currencies in 12 of the member states (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain). Since then, the eurozone (officially the euro area) has increased to encompass seventeen countries: Slovenia (2007), Cyprus (2008), Malta (2008), Slovakia (2009) and Estonia (2011).

We can see that the process of spreading of the European Union was very dynamic in the last more than fifty years (Tab. 1). Nowadays nearly 73% of the whole European population live there. And the area of that region represents 42% of European continental territory. Fifteen countries have less than ten million inhabitants while four countries have more than fifty million inhabitants (Germany, France, United Kingdom and Italy). Malta has only 0.5% of the number of German population and less than 0.1% of the French metropolitan area population.

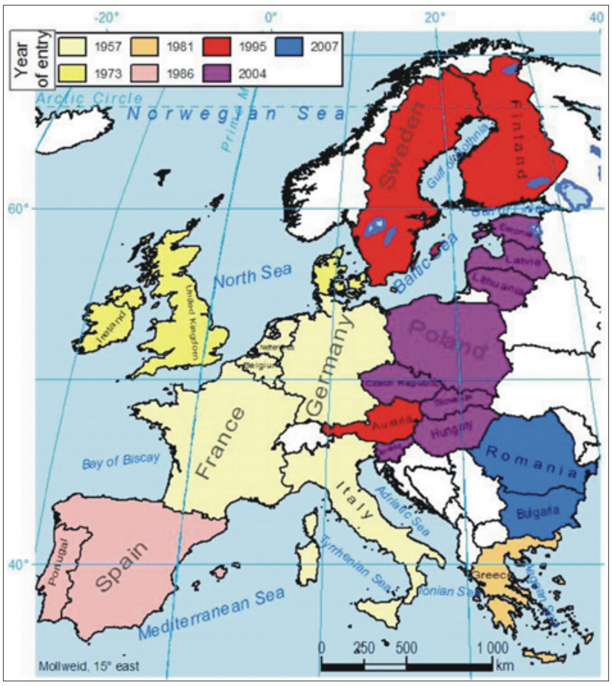

Fig. 1: Member states of the European Union
Source: author

The population of the present area of the European Union increased from 403.4 million in 1960 to nearly 501 million in 2010, while during the period from 1990 to 2009 the increase of the population in the present European Union is about nearly 30 million or 6.2% (Fig. 2). It is projected that this increasing will further go on reaching 521 million in 2035 and then it begins to decline slowly up to 506 million in 2060 (Fig. 3). Since 1992 the net immigration contributed more to the total population growth than its natural increase was. The biggest differences between them were observed during the years 2002 and 2003.

2. Analytic approaches and methodology of the socio-demographic process

The processes of natality and mortality belong to basic declarations of the vitality (Newel, 1994). The quality of their mutual conditionality in terms of reproduction activity is expressed by the indicator of the natural increase (NI). The natural increase is the rise in population caused by the birth rate (B) exceeding the death rate (D) and excludes any population change due to migration. Crude rate of natural increase (CRNI) is the number of persons added to the population due to natality and mortality over a given time period (e.g. 1, 5 or more years) and divided by the total mid-year population (P) and multiplied by 1,000 (equation 1). We can say that CRNI is equal to the difference between the crude birth rate (CBR) and the crude death rate (CDR).

EU (year)	Member states	Area (sq km)	Population (mil.)	Density (inh/sq km)
1957	6	1,284,482	228,461	178
1973	9	1,640,749	297,708	181
1981	10	1,772,706	308,828	174
1986	12	2,370,680	362,387	153
1995	15	3,242,647	384,866	119
2004	25	3,991,651	459,387	115
2007	27	4,326,987	488,824	113
2010	27	4,326,987	497,533	115

Tab. 1: Basic characteristics of the EU
Source: Eurostat data

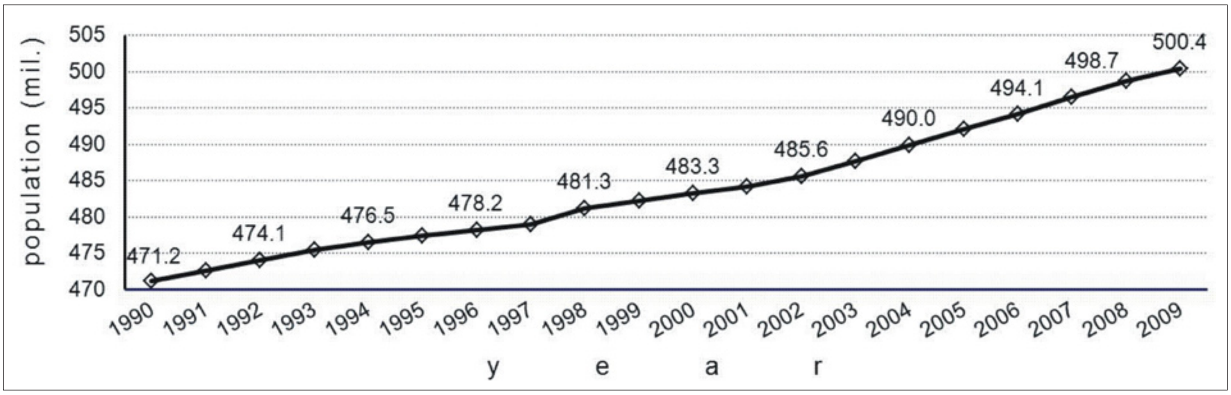

Fig. 2: Development of the European Union population size
Source: Eurostat data

(1) $$CRNI = \frac{NI}{P} \times 1000 \ [‰] \quad \text{or}$$

$$CRNI = \frac{B-D}{P} \times 1000 \quad \text{or}$$

$$CRNI = CBR - CDR$$

The population change in an area is determined partly by the level of natural increase (NI) and partly by the level of net migration (NM), the difference between the numbers moving in (immigrant, I) and moving out (emigrant, E). Crude rate of net migration (CRNM) is simply the net migration in a year divided by the total population at mid-year and multiplied by 1,000 (equation 2). That is:

(2) $$CRNM = \frac{NM}{P} \times 1000 \ [‰] \quad \text{or}$$

$$CRNM = \frac{I-E}{P} \times 1000 \ [‰]$$

The population change (the total population increase, TPI, equation 3) over time can be quantified as a number aggregate of the natural increase (NI) and net migration (NM):

(3) $$TPI = NI + NM$$

In many cases, it is better to work with the relative weight of this process. We can use the indicator "crude rate of total population increase" – CRTPI (equation 4).

(4) $$CRTPI = \frac{NI + NM}{P} \times 1000 \quad \text{or}$$

$$CRTPI = CRNI + CRNM$$

For the illustration of the territorial diversity of natural increase values, net migration and total population increase we will use the cartogram method. All data used come from the statistical office of the European Union (EUROSTAT), their section "Statistics" and the theme "Population and social conditions" (part „Population"). Analyses on this spatial level are working with the cartogram method for processing the demographic data. We can use ArcGIS 9.3 and its version ArcMap 9.3 as a complete system for authoring, serving, and using geographic information for better processing of the spatial data by means of the cartogram method. We use SPSS software (version 19.0) for the typology of the natural, net migration and total population change, especially the possibilities of the „time series clustering" classification system.

We finally suggest to work with the method of hierarchical cluster analysis by using dendrogram techniques and averaged distances between the groups, because we compare less then 30 spatial units. We work with the method of „centre moving average" for three-year periods too. This is why the time axis of the chart covers the time period from 1991 to 2008. It is a method suitable for dynamic typology of the population growth in EU countries (Šotkovský, 2009).

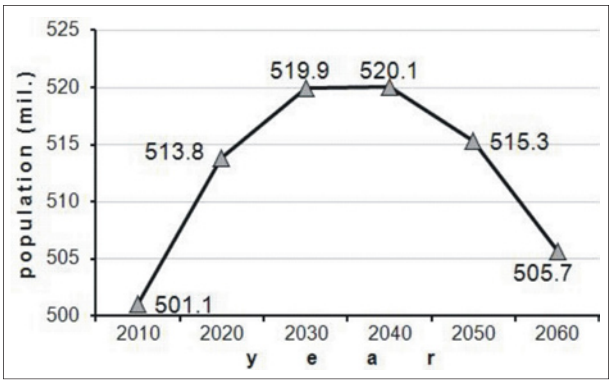

Fig. 3: Population projection of European Union
Source: Eurostat data, 1st January of the year

3. Analysis of the natural increase

We have three different groups as a result of the dynamic spatial typology of the natural population change (Fig. 4, Fig. 5) for the last two decades. The first group of the natural change aggregates the regions of Ireland, Cyprus, Malta, the Netherlands, Luxembourg and France with the minimum values of CRNI 4‰. Actually, Ireland has CRNI over 10‰ (year 2009).

The most numerous group is the second one. Lithuania, Czech Republic, Romania, Germany, Sweden, Slovakia, Poland, United Kingdom, Finland, Spain, Denmark, Belgium, Portugal, Austria, Italy, Slovenia and Greece have positive CRNI, but less than 2‰.

The worst situation is in Estonia, Hungary and especially Latvia and Bulgaria. Bulgaria has lost nearly 13% of the population during the last twenty years. The value of the natural increase of this group is negative for the last two decades (Fig. 4).

It is true that since the beginning of the period under consideration the CRNI value for the whole EU was slightly decreasing. However, the difference between the maximum (2.0‰) in 1990 and minimum (0.2‰) in 2003 was not big. The average value of CRNI was 0.8‰ for the period 1990–2009. World average rate was 14.2‰ at the same time. The population growth in the European Union was very poor and the numerical value was about 1‰ in 2010. The world value was less than 12‰ in the same year. We can forecast that the natural increase in the European Union can be slightly positive approximately until 2020. Especially the United Kingdom, France, the Netherlands, Ireland and Finland have an essential influence on the EU population growth today in connection to the natural increase.

On the other hand, there are four countries: Bulgaria, Latvia, Hungary and Estonia, in which the population was decreasing almost twenty years (Fig. 5). Germany, Italy and Romania have a substantial influence on the EU population behaviour in relation to natural decrease.

The average value of CRNI during the last twenty years was −1.3‰ for the German population, −0.2‰ for the Italian population and −1.2‰ for the Romanian population. The population development of the EU is at more than 74% dependent on the population development of six biggest European countries: Germany (16.4% of the EU population), France (12.5%), UK (12.4%), Italy (12.0%), Spain (9.2%), Poland (7.6%) and Romania (4.3%).

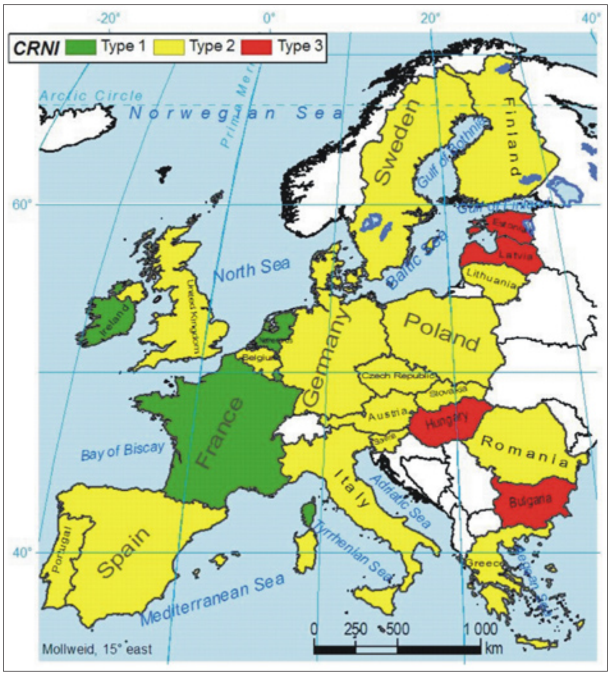

Fig. 5: Cartogram of the type of CRNI in EU countries (1990–2009). Source: Eurostat data

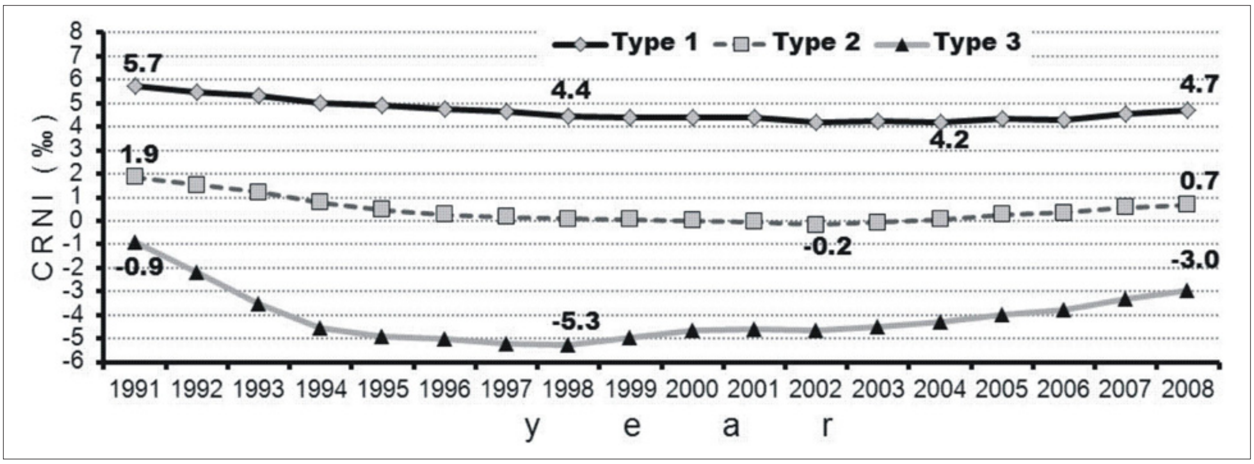

Fig. 4: Types of the natural change of the European Union countries (dynamic typology) Source: Eurostat data

4. Analysis of the migration behaviour

The population growth is primarily caused by the natural increase. In any particular region, migration will cause a population growth when the amount of immigration exceeds the amount of emigration. The continually increasing immigration has social consequences. In the present European Union, migration is twice greater weight of population growth than the natural increase. The average value of the crude rate of net migration was 2.2‰ in the European Union for the last twenty years. Now it is less than 2‰. The greatest population growth owing to migration was between the years 2002 and 2007 in the EU. The value of CRNM exceeded the level of three per mile. The maximum was achieved in 2003 (4.2‰). The typology of migration is as follows (Figs. 6, 7):

We have two groups with positive net migration for the last twenty years (twenty two countries). The best situation is in these countries: Cyprus, Luxembourg, Spain and Ireland. Their net migration was more than 5.0‰ (type 1, Fig. 6).

The second group is the most numerous with eighteen countries: Greece, Slovakia, Poland, the Netherlands, Germany, Austria, Italy, Portugal, Slovakia, Czech Republic, Malta, Sweden, Belgium, United Kingdom, France, Denmark, Hungary and Finland. The indicator crude rate of net migration (CRNM) ranged from 2.0–4.9‰.

An expressively non-perspective situation was typical of the following five EU members: Romania, Bulgaria, Lithuania, Latvia and Estonia. Their annual value of CRNM was negative from −9.0 to −1.0‰.

We have seven EU countries with a significant population growth caused by net migration in the last time. These countries (Luxembourg, Greece, Sweden, Italy, Belgium, Spain and Denmark) exhibit CRNM ≥3‰ (Fig. 7). Today, a greater CRNM decrease occurs in Cyprus and Ireland.

5. Analysis of the total population increase

Human population has an essential impact on the environment quality. This impact depends on the population density (partly on the population size), affluence or per capita consumption and technology. This means that the population growth is a very important and reliable subject of research. The importance of reducing the population growth is not appreciated equally in the EU territory. The maximum

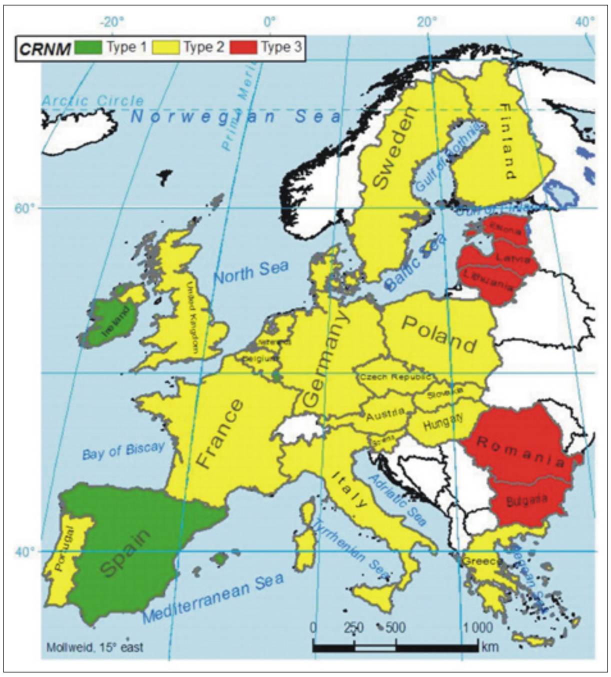

Fig. 7: Cartogram of the type of CRNM in EU countries (1990–2009)
Source: Eurostat data

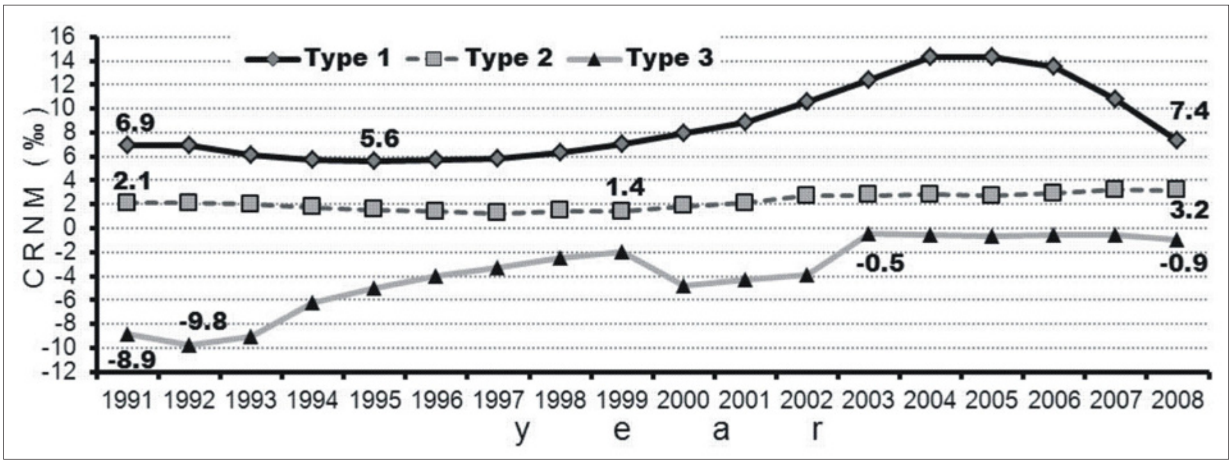

Fig. 6: Types of the net migration change in the European Union countries (dynamic typology)
Source: Eurostat data

total population growth in the EU territory was achieved during the period 2002–2008 (ca. 4.4‰). The average crude rate of total population increase in the whole period from 1990 to 2009 was 3‰ in the European Union. If we analyse the total population change by means of the crude rate of total population increase (CRTPI) in a longer-term perspective of the last 20 years, we can distinguish three groups (type 1, type 2, type 3, Fig. 10).

The first group of the population size change is represented by four countries (Fig. 9): Cyprus, Luxembourg, Ireland and Spain. Their annual population growth was more than 10.0‰ (Fig. 8).

The second group includes countries with a remarkable growth between 1.0 and 5.0‰ (Belgium, United Kingdom, Denmark, Finland, Sweden, France, Austria, Italy, Portugal, Greece, Malta, the Netherlands, Czech Republic, Slovenia, Poland, Slovakia, Germany and Hungary).

Only Malta, the Netherlands and France were countries with a higher weight of the natural increase. This shows that more than eight EU member countries grew due to net migration. However, we can say that the size of the natural increase in Malta, the Netherlands and France was significantly affected by a long-term positive net migration. Only a negligible growth was recorded in the following countries: Germany, Slovenia, Slovakia, Czech Republic and Poland.

We can indicate the territory of Romania, Lithuania, Bulgaria, Estonia and Latvia as critical regions (third group).

Sixteen countries from northern, western a southern Europe grew more intensively than the whole EU. Eleven countries from the central and south-eastern Europe (Šotkovský, 2008) however, had no or very mild population growth (Germany, Slovenia, Slovakia, the Czech Republic and Poland), or even a visible decrease of population (Hungary, Romania, Lithuania, Bulgaria, Estonia and Latvia). The worst situation was observed in the Baltic States, with annual decline indicator CRTPI previously at a level of −7.2‰, with present value between −4 and −5‰.

6. Conclusions

The world's current growth rate (overall as well as natural) is about 11.4‰, which represents a double increase in 61 years. We can expect the world's population of 6.9 billion to become 9 billion by the

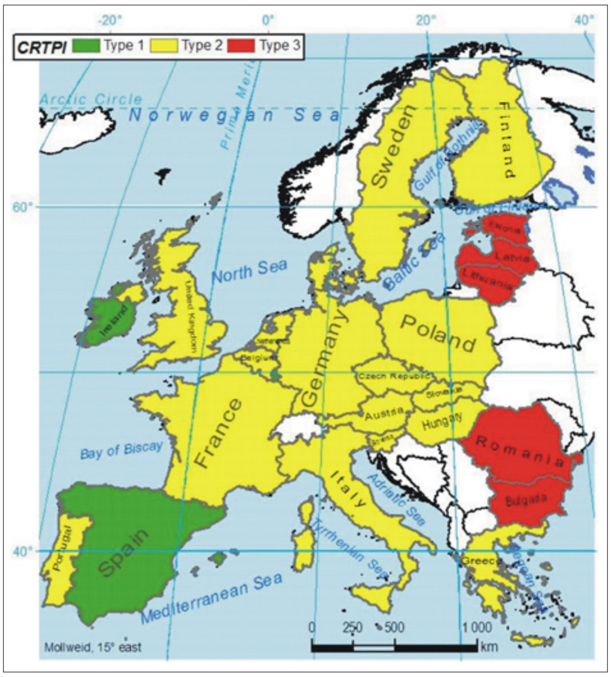

Fig. 9: Cartogram of the type of CRTPI in EU countries (1990–2009)
Source: Eurostat data

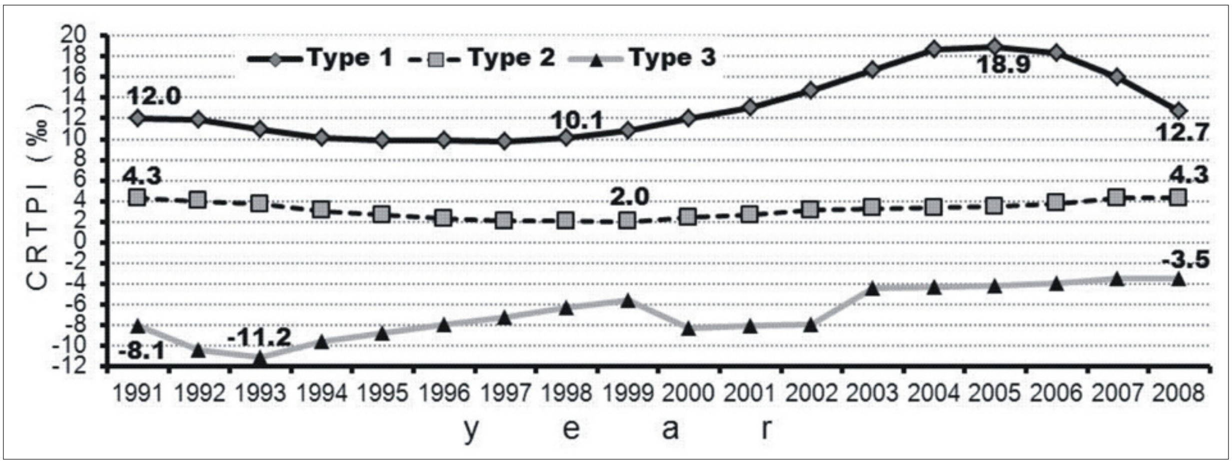

Fig. 8: Types of the total population increase in the European Union countries (dynamic typology)
Source: Eurostat data

year 2050 if the current growth continues. The world's growth rate culminated between 21—22‰ and in 35 years it doubled towards the end of the 1960s. Many Asian and African countries have high growth rates. Afghanistan has a current growth rate of 48‰, which is a double increase in just 14.5 years! As you can see, it is more useful to take into account the population growth percentages for short term projections. The current world population projections show a continued increase of population (but a steady decline in the population growth rate) which is expected to reach 7.5–10.5 billion in 2050.

The global human population is projected to grow from 6.9 billion in 2010 to 9.15 billion in 2050 against the median-variant. This "median-variant" scenario of the UN Division remains almost the same today as it was five years ago - predicting a world with 9.2 billion people (medium variant) in the mid 21st century, from nearly 6.9 billion of today. This means an annual population growth of 3.4‰ in 2050. The value of CRTPI is 2.8‰ in the European Union today (Fig. 10) and will be almost 2‰ around the year 2060 according to the medium variant of the population projection. Migration is decisive for the evaluation of the population growth in the European Union with nowadays weight of the two-thirds. The decline of the population size in the EU countries will be appreciable due to very low values of natural increase in the mid-21st century. This will be an important natural decrease of the population.

Almost two-thirds of EU member countries have to define their migration policies, especially immigration policies. They are affected by the flow of international migration and therefore the European Commission has made proposals for developing this policy, most of which have now become EU legislation. The main objective is to cope better with the migration flows by a coordinated approach, which takes into account the economic and demographic situation of the EU. Not only economic migration is consequential problem but demographic situation too. Immigration into a country significantly contributes to the total population growth, as it is in most of the EU countries. For a sparsely populated country, population growth can bring true benefits. Nevertheless, beyond a certain point the continued population growth caused by net migration has a potential to create tensions and even conflicts among groups within countries and between countries. It is not the same when population growth results from the natural increase or from net migration because both have a different impact on the size from a certain point.

The fit line of migration in Fig. 10 shows the growth of the crude rate of net migration exceeding 200% for the last twenty years. The fit line of the natural increase in Fig. 10 shows the drown trend up to a half for the last twenty years.

It is true that the population growth is diminishing due to the demographic transition and the peak of the world population size will be probably achieved during the 21st century (around 2070). The peak of the European Union population has to be achieved much earlier (around 2035). A big problem can be the migration behaviour, namely the international migration.

At present, the migration in the European Union is twice higher than the natural increase. Net immigration is projected to continue to be the main cause of the population growth. Since the 1980s, political decisions concerning migration increasingly

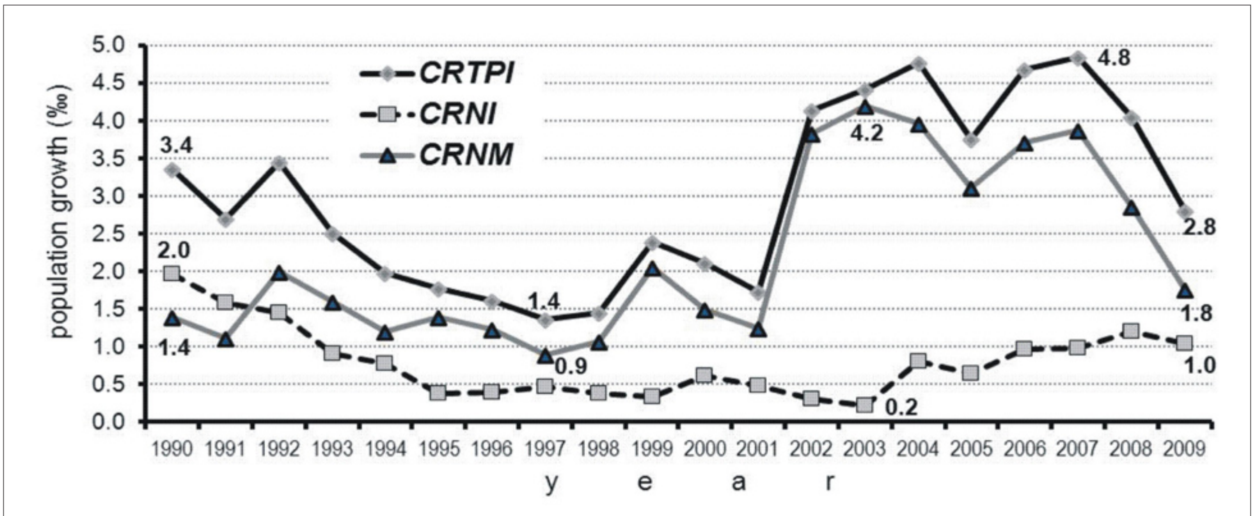

Fig. 10: Indicators of the European Union population growth during the period 1990–2009
Source: Eurostat data

consider the destabilizing effects of migration on domestic integration and represent a danger for the public order. The Third Pillar on Justice and Home Affairs of the Schengen Agreements and the Dublin Convention most visibly indicates that the European integration process is implicated in the development of a restrictive migration policy and social construction of migration into a security question. However, the political process of connecting migration to criminal and terrorist abuse of the internal market does not occur in isolation. It is related to a wider politicization in which immigrants and asylum-seekers are portrayed as a challenge to the protection of national identity and welfare provisions.

Considering the human welfare on the planet Earth, the population growth and especially the migration are very important subjects. The population change evoked by international migration (not the population growth due to natality rate) can contribute to political instability and conflicts. The main cause of the population growth in the European Union in recent years is immigration, not the natural increase. This situation is likely to be a decisive power for whole 21st century in the EU. Even more significant it will be in the natural decrease of population. This scenario is forecast for the whole Europe and primarily for EU countries after the year 2035. Now we can see that dynamic typologies are the same in terms of the crude rate of net migration and crude rate of total population increase. The influence of the natural increase on the population growth is decreasing. On the other hand, net migration shows an increasing trend.

Acknowledgement

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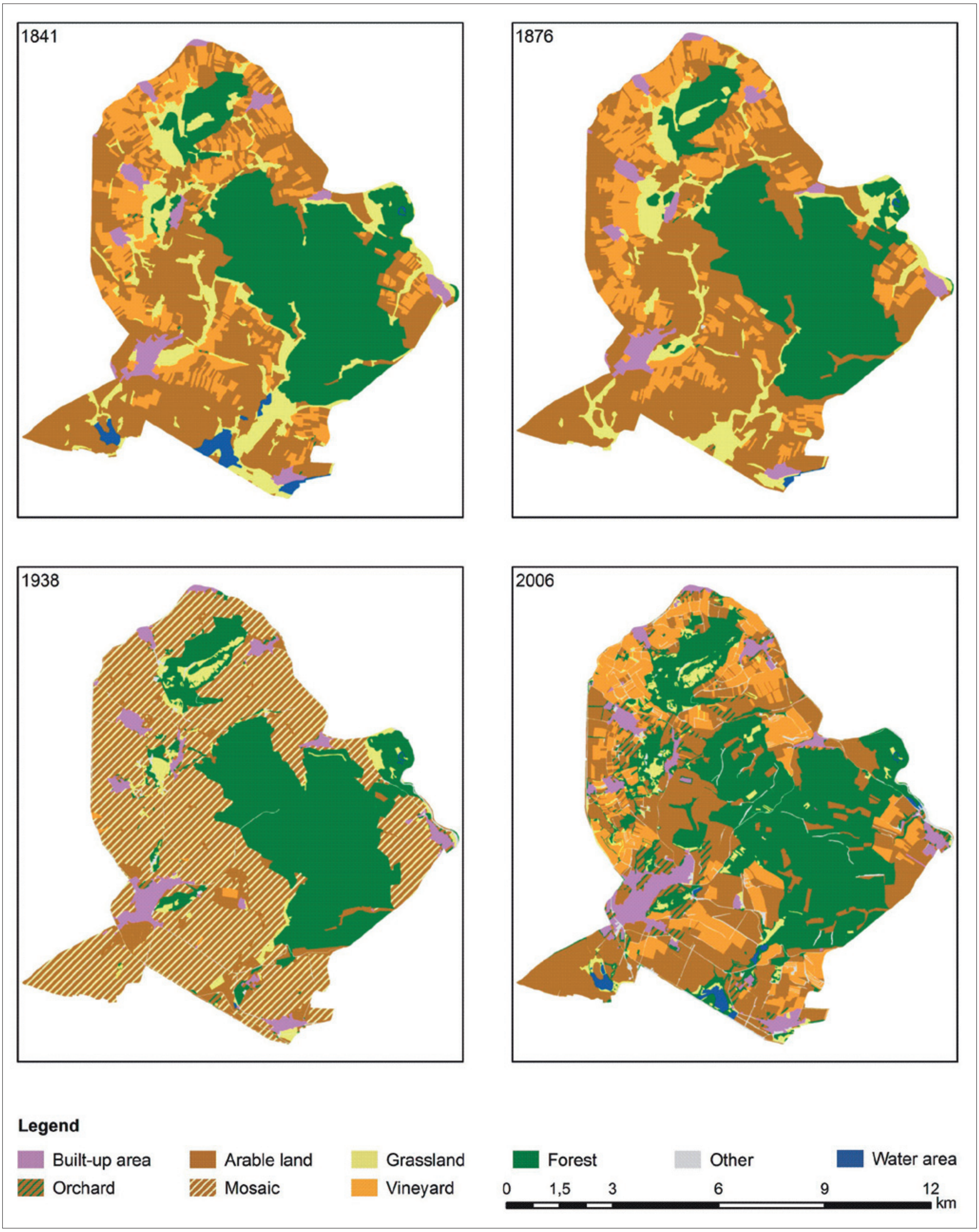

Fig. 3: Land use/land cover in the Pálava PLA

Illustrations related to the paper by J. Miklín and V. Smolková

Fig. 5: Hubenov countryside after land consolidation - the balk

Fig. 6: Hubenov countryside after land consolidation – the retention reservoir

Illustration related to the paper by Jana Konečná, Jana Podhrázská, Petr Karásek and Jaroslav Dumbrovský