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EVOLUTION OF QUATERNARY RIVER TERRACES RELATED TO THE UPLIFT OF THE CENTRAL PART OF THE BOHEMIAN MASSIF

B. Balatka, J. Kalvoda: *Evolution of Quaternary river terraces related to the uplift of the central part of the Bohemian Massif.* – Geografie–Sborník ČGS, 113, 3, pp. 205–222 (2008). – Fluvial sediments in the Vltava, Berounka, Sázava and Labe valleys are preserved as extensive river terrace sequences. These accumulation terraces originated from an interaction of climate-morphogenetic and neotectonic processes in the late Cenozoic. The palaeogeographical history of the central part of the Bohemian Massif is described. Geomorphological analysis of late Cenozoic fluvial sediments preserved in the Bohemian Massif confirm that in total 7 main terrace accumulations with several secondary levels can be differentiated. A chronostratigraphical scheme of erosion and accumulation periods and their relations to variable uplift rates in the late Cenozoic is suggested. The relative height of the oldest fluvial terraces above the present-day bottoms of river valleys is more than 100 m which indicates the approximate depth of erosion in the Quaternary.
KEY WORDS: palaeogeographical history – Quaternary geomorphology – river terraces – Bohemian Massif.

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Introduction

The record of river terraces and related fluvial deposits along the Labe and Vltava rivers in Czechia is traditionally used as the basis for the Quaternary stratigraphy of the region. It is also realised that the terrace system, which is widespread along the major rivers, has developed its form because of uplift of the region. When studying the terrace system and evolution of river valleys, the following procedures have been applied (Balatka, Sládek 1962a, b; Balatka, Loučková 1992; Balatka, Kalvoda 1995): a) evaluation of the existing regional literature, b) analysis of longitudinal profiles of rivers, c) a detailed geomorphological survey of valleys, d) reconstruction of river terraces in both long and transverse valley profiles, e) fitting the established terrace system in the studied valley into the regional terrace system; f) an outline of the main stages of the valley evolution during the Upper Cenozoic. The results of geomorphological research allow one to establish the longitudinal profiles of fluvial terrace accumulations and Neogene sediment localities, the structure of transverse profiles of river valleys and important occurrences of planation surfaces (e.g. Záruba et al. 1977; Tyráček 2001; Tyráček et al. 2004; Balatka, Štěpančíková 2006; Balatka 2007). Moreover, the downvalley profiles demonstrate the positions of pronounced valley margins of straight valley reaches.

Problems of late Cenozoic evolution of the Labe valley in Saxony in relation to Neogene sediments, fluvial terraces and deposits of continental glaciations were explored by German authors at the end of the 20th century (e.g. Eissmann 1975, 1995; Wolf 1980). A correlation with the terrace system of the Labe in the Czech territory has also been suggested (Eissmann 1997; Wolf, Schubert 1992; Tyráček et al. 2004). In the same period, attempted comparisons of the river terraces and evolution of valleys in the Bohemian Massif and the Carpathian region was published (Zeman 1974, Balatka 1992). Analysis of the structure of main terrace systems of the eastern margin of the Bohemian Massif and the western part of the Carpathian region indicated the existence of 12 river terraces and levels of fluvial sediments. From these accumulation landforms are 6 higher terraces of Pliocene age (70–120 m above river level) and the surface of the oldest Quaternary terrace is documented 60 m above present-day valley bottoms.

In this paper, the main features of the palaeogeographical history of the central part of the Bohamian Massif are presented in relation to global climatic changes and neotectonic processes during the Cenozoic. Sedimentary and morphological records of the evolution of antecedent valleys and river accumulation terraces in the central part of the Bohemian Massif are correlated with regional chronostratigraphical stage divisions of the Quaternary.

Palaeogeographical history of the central part of the Bohemian Massif

Variscan orogenetic processes shaped the Bohemian Massif as a structurally complicated unit, the central part of which is formed by collision-deformed and metamorphosed crystalline rocks of the Moldanubicum (Buday et al. 1961, Chlupáč et al. 2002). In the late Permian, the relief of the central part of the Bohemian Massif had the appearance of a post-Hercynian planation surface denuded in a semi-arid and very warm climate. Continental Triassic sediments are of kaolinitic type, which gives evidence of warm and wet climate. The Jurassic sea in the Bohemian Massif was a narrow and shallow strait connecting the German and Carpathian seas. During the Cretaceous, intensive weathering under a humid tropical climate resulted in the origin of a thick tropical mantle of kaolinitic and lateritic regoliths (Demek 2004). The altitude of this planation surface was up to 200 m above sea level. The post-Hercynian planation surface was covered by kaolinitic and lateritic regoliths and it is situated beneath the Upper Cretaceous sediments of the Bohemian Cretaceous Basin (e.g. Engel, Kalvoda 2002). The uplift of the Bohemian Massif at the end of the Santonian resulted from the ongoing Alpine and Carpathian orogenesis and marked the retreat of the Upper Cretaceous epicontinental sea.

Neotectonic rejuvenation of the Bohemian Massif occurred during the Laramide faulting phase some 65 million years ago. The Bohamian Massif was uplifted and a system of graben structures and diagonal tectono-volcanic zones was formed. At the beginning of the Tertiary, the climate in the Bohemian Massif was humid and tropical, with a mean annual temperature

Fig. 1 – Neovolcanic hill of Říp (461 m) is composed by a selectively denuded nephelinitic diatreme. It is surrounded by the Quaternary system of river accumulation terraces in a larger area of the Labe and Vltava revers confluence. Photo B. Balatka.

of up to 26 °C and a mean annual rainfall of 2,000–3,000 mm (Malkovský et al. 1985). In the Oligocene the temperature fell to 16 °C with a climate of savannah type with dry winters, and a very dry climate prevailed also in the Middle Oligocene. The late Oligocene was characterised by a permanently wet and warm climate, with subtropical rain forests spreading and remaining until the Middle Miocene. The planation surface was already developed before the Oligocene. This is evidenced by duricrust relics in western and central Bohemia (Demek 2004). At the end of the Oligocene, planation of the relief of the Bohemian Massif was interrupted by tectonic movements (e.g. Malkovský 1979, Ivan 1999, Chlupáč et al. 2002), accompanied in its western and northwestern part by volcanic activity 35–17 million years ago (Fig. 1).

The initial impulse towards the morphographical distinctiveness of geomorphological units was given in the Lower Miocene (Aquitanian to Burdigalian), when tectonic disintegration of the planation surface occurred. The granular character of some fluvial and lacustrine sediments from that time shows that certain morphostructural units were already quite distinctive. The progressive subsidence of the southern and southeastern parts of the Bohemian Massif in the Middle Miocene enabled the sea to penetrate into these regions (Malkovský 1975, 1979). Depressions in the region of the Ohře rift and differential movements of the main fault zones in the Bohemian Massif were also morphotectonically significant. Moreover, the evolution of the relief of the Bohemian Massif was influenced by two neotectonic stages of volcanic activity in the late Miocene (between 9.0 and 6.4 Ma) and from the late Pliocene to the Pleistocene (between 3.0 and 0.17 Ma, Wagner et al. 1998). The granular character of Pliocene river sediments is similar to those of Lower Pleistocene terrace deposits which indicates that the orographic situation of the Bohemian Massif was roughly similar to that of today (Balatka 2006; Kalvoda, Balatka 2006). Neotectonic movements (mainly uplifts) and erosional-denudational processes in the Quaternary only emphasized the morphographical features of geomorphological units.

During the early Miocene, a tropical humid climate with dry periods prevailed in the Bohemian Massif, which later changed to a subtropical wet climate in the late Miocene. Periods of humid climate in the Neogene were characterised by very extensive erosion and denudation of the kaolinitic and

Fig. 2 – Antecedent valley of the Labe river near Litoměřice town is cut through an uplifted horst of crystalline rocks which is an underlier of neovolcanic rocks in the České středohoří Low mountain range. Photo B. Balatka.

lateritic weathering mantle, down to the basal weathering surface. Since the end of the intensive volcanic activity at the end of the Lower Miocene a "post-volcanic" planation surface developed. It was formed under warm, permanently wet or, in some seasons, humid climatic conditions from the Middle Miocene, through the whole Pliocene period (5.3–2.6 Ma) to the lowest Early Pleistocene. The morphostructural features and the internal differentiation of this planation surface of Neogene age were dependent on the rock resistance to weathering under a tropical or subtropical climate.

In the Oligocene and the Miocene, the main European watershed between the epicontinental sea in the north-west and the basins of the Para-Tethys in the south-east crossed the Bohemian Massif approximately along the north-western margin of the central Bohemian pluton, then turned to the northern part of the Českomoravská vrchovina Highlands, and from there it continued to the north (Chlupáč et al. 2002). The oldest indications of the disposition and changes of the river network of the Bohemian Massif are preserved in the sedimentary record of the Miocene. In the Middle and late Miocene, southern Bohemia was still drained to the south, which is corroborated by both relics of fluvial and lacustrine sediments and secondary finds of river-transported moldavites in the adjacent part of Austria. The period of their impact is radiometrically dated as 14.3 million years. In the late Cenozoic, the regionally differentiated tectonic uplift and changes of the European climate are the evolution of the fluvial network of the Bohemian Massif. Important changes in its overall system occurred with significant manifestations of epigenetic and antecedent evolution of river valleys (Fig. 2) through deep, lateral and headward erosion, as well as related reconstruction of the large area of fluvial sedimentation.

River terraces related to uplift of the Central Bohemia during the Quaternary

The reconstruction method adapted in characterising the terrace system was based on the assumption that the main terrace elements, i.e. the base-level and the topographic surface, form stable gradients of their long profiles

Tab. 1 – Chronostratigraphical correlation of river terraces in the central part of the Bohemian Massif related to North West Europe stratigraphical stages of the Quaternary

Regional stratigraphical stage/substage divisions of the Quaternary (Gibbard et al. 2004)	SÁZAVA Balatka, Štěpančíková, (2006); Balatka (2007); Kalvoda (2007a)	BEROUNKA Balatka, Loučková (1992)	VLTAVA – LABE confluence area Balatka, Sládek (1962)	VLTAVA Záruba et al. (1977)	VLTAVA and LABE system Tyráček (2001), Tyráček et al. (2004)
Late Pleistocene Weichselian	Pikovice Terrace (VII)	Lipence Terrace (VIIa) Dobřichovice Terrace (VIIb)	Hostín Terrace (VIIa, b, c, d)	Maniny Terrace (VII)	Maniny Terrace (Weichselian) Hostín 1 Terrace
Middle Pleistocene Saalian (Warthe)	Poříčí Terrace (VI)	Kazín Terrace(VI)	Mlčechvosty Terrace (VIa, b, c)	Veltrusy Terrace (VI)	Veltrusy Terrace (Warthe)
Middle Pleistocene Saalian (Drenthe)	Městečko Terrace (V)	Liblín Terrace (Va) Poučník Terrace (Vb)	Cítov Terrace (Va, Vb)	Dejvice Terrace (V)	Dejvice 1 and 2 Terrace (Drenthe)
Middle Pleistocene Saalian (Fuhne)	Týnec Terrace (IV)	Zbraslav Terrace (IVa) Hýskov Terrace (IVb)	Hněvice Hill Terrace (IV)	Letná Terrace (IV)	Letná Terrace (Fuhne)
Middle Pleistocene Elsterian	Buda Terrace (IIIb)	Srbsko Terrace (IIIb)	(IIIb)	Vinohrady Terrace (IIIB)	Vinohrady Terrace (Elster)
Middle Pleistocene Cromerian complex (Glacial c)	Chabeřice Terrace (IIIa)	Tetín Terrace (IIIa)	Straškov Terrace (IIIa)	Kralupy Terrace (IIIA)	Kralupy Terrace (Cromerian C)
Middle Pleistocene Cromerian complex (Glacial c)	Český Šternberk Terrace(II)	Pohořelec Terrace (IIa) Hlince Terrace (IIb)	Ledčice Terrace (II)	Pankrác Terrace (II)	Pankrác Terrace (Cromerian C)
Middle Pleistocene Cromerian complex (Glacial b)	Hvězdonice Terrace (Ib)	Řevnice Terrace (Ib)		Suchdol Terrace (IB)	Suchdol Terrace (Cromerian B)
Middle Pleistocene Cromerian complex (Glacial a)	Střechov Terrace (Ia)	Skryje Terrace (Ia)	Krabčice Terrace (I)	Lysolaje Terrace (IA)	Lysolaje Terrace (Cromerian A)
Early Pleistocene Bavelian (Dorst) Menapian			Rovné Terrace		Rovné Terrace (Dorst) Vráž Terrace (Menapian)
Early Pleistocene Eburonian – Menapian	Niveau B Radvanice	Niveau B		Zdiby Stadium (Pliocene)	Zdiby Terrace (Eburonian – Menapian)
Early Pleistocene Tiglian					Stříbrníky Terrace (upper Tiglian)
Neogene	Niveau A Bojiště	Niveau A		Klínec Stadium	

corresponding to the so-called equilibrium profile. Under these conditions, the mean water volume of the stream is in equilibrium with its transportation capacity and the river neither erodes nor accumulates sediment but applies all its energy to the transfer of transported material (Novák 1932; Krejčí 1939; Záruba-Pfeffermann 1942; Záruba et al. 1977). The equilibrium state may be disturbed by differentiated tectonic movements and discharge oscillation, also by an increased quantity of transported matter brought to the river by intensive cryogenic processes during the Pleistocene. Then a huge accumulation (so-called "climatic aggradation") occurred and the channel occupied a new equilibrated profile. Formation of huge aggradations was largely influenced by marked steps in the gradient of the stream; these represent the front of backward erosion which proceeded upstream during the valley downcutting phase. They also represent places reached by the accumulation stage of the respective terrace.

The oldest river terrace accumulations in central Bohemia are situated above the margins of the canyon-like valleys of the Vltava, Berounka and Sázava Rivers (e.g. Záruba et al. 1977, Kovanda et al. 2001). Relics of Miocene gravels and sands at the Sulava locality, near Radotín town have their surface lowered by erosion at 358 m a. s. l. and their base at 314 m a. s. l., i.e. 163 m or 119 m above the Berounka level. Other relics of these sediments of Miocene and Pliocene ages are recorded from the neighbourhood of Slivenec, near Suchomasty and on Bílá Hora (380 m a. s. l.). The surface of Early Pleistocene sands and gravels up to 40 m thick, between Kobylisy and Sedlec on the Zdibská plošina Plateau, is situated at 300 to 325 m a. s. l., i.e. 125 to 150 m above the Vltava level, and 35–60 m below the Ládví touchstone ridge (359 m a. s. l.). Northwards from these Pliocene spreads on the Zdibská plošina Plateau, up to 20 m thick sediments (with their surface 112 m above the Vltava level) are present, dating, within the so-called Lysolaje group of terraces, from the Pleistocene (for stratigraphical positions see Tab. 1). They also include rounded pebbles and boulders of crystalline rocks from the regions of Kutná Hora, Říčany and Kouřim towns (Záruba-Pfeffermann 1941).

In the Early Pleistocene, the Vltava and its affluents were still freely meandering in shallow and large valleys formed on Neogene planation surfaces. Even as late as in the Middle Pleistocene, the lower limit of which is the Matuyama / Brunhes palaeomagnetic boundary 780,000 years ago, new terrace steps were being progressively formed (70 to 100 m above the present water courses) together with a relatively rapid epigenetic and antecedent deepening of the river network. For example, the Suchdol Terrace is situated up to 2 km west of, and 96 m above the Vltava valley (Tab. 1).

The Straškov (IIIb) Terrace of Balatka, Sládek (1962a, b) is now ca 70 m above the Vltava river near Račiněves in the neighbourhood of Říp mountain. It is described by Tyráček (2001) as the Straškov 2 Terrace and as an equivalent of the Vinohrady Terrace in Prague (Tab. 1). During aggradation of the Straškov 2 Terrace, the Vltava flowed west of the Oligocene – Miocene volcanic neck of Říp, subsequently diverting to its present-day position east of Říp. The fluvial deposits of the Straškov Terrace are comprised of a coarse lower unit and a finer upper unit (Tyráček et al. 2004). It is overlain by loess and slope deposits that include palaeosols representing probably two warm stages. The 12–14 m thick lower fluvial units with stratified sands and gravels indicate a cold-climate braided-channel environment. The 0.5–2 m thick upper fluvial unit is composed of sand and fine sandy gravel, disturbed by cryoturbation. It has yielded thermophilous mammals, interglacial

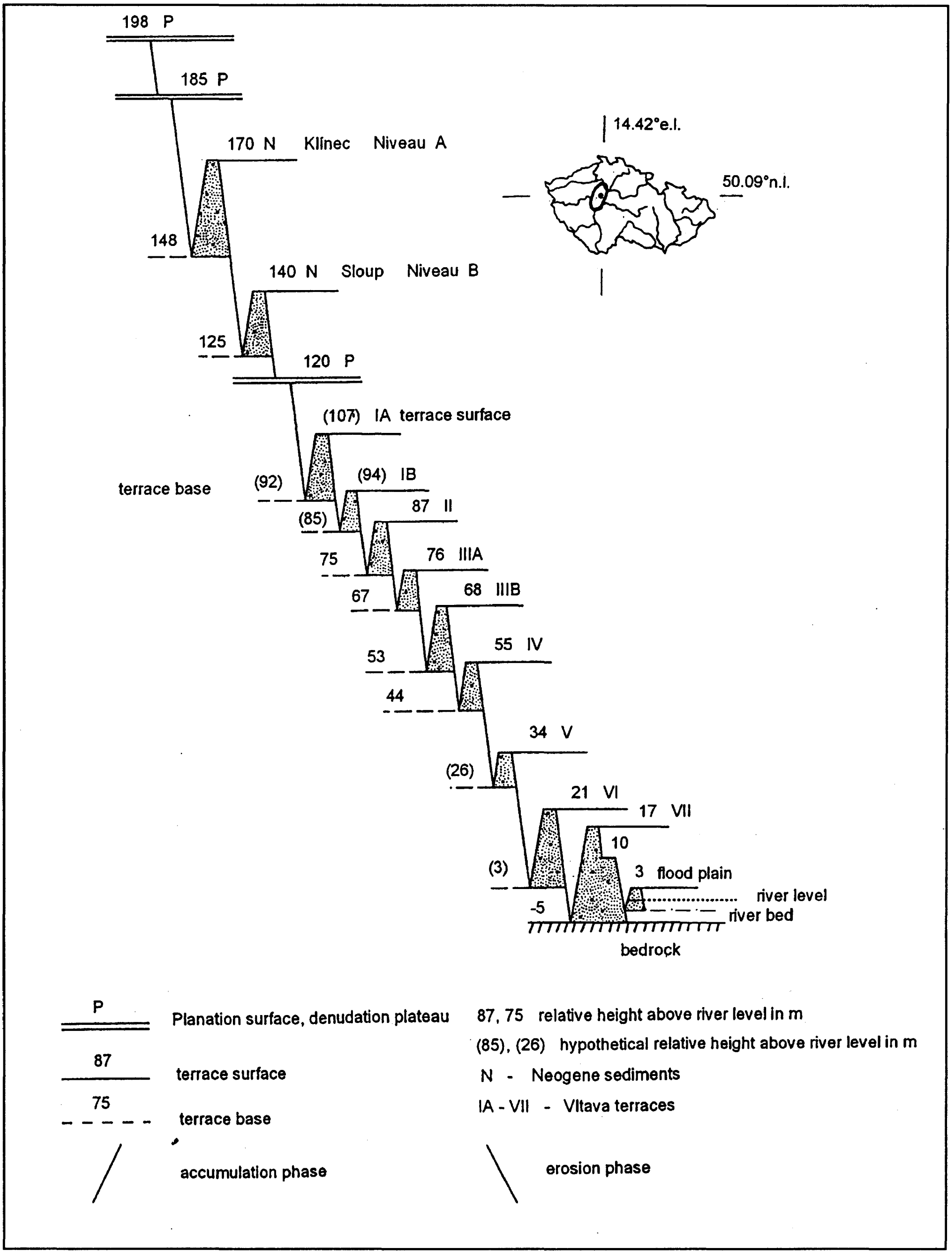

Fig. 3 – Position of river accumulation terraces in the Vltava valley between mounths of the Sázava and Berounka rivers (adapted from Balatka, Štěpančíková 2006 and Balatka 2007). Stratigraphical correlation of accumulation terraces are demonstrated in Table 1.

molluscs and archaeological material.

The Vltava terrace sequence (Fig. 3) can be subdivided longitudinally into two reaches. Downstream of its confluence with the Sázava river the terraces are subparalled to each other and to the modern channel gradient of ca

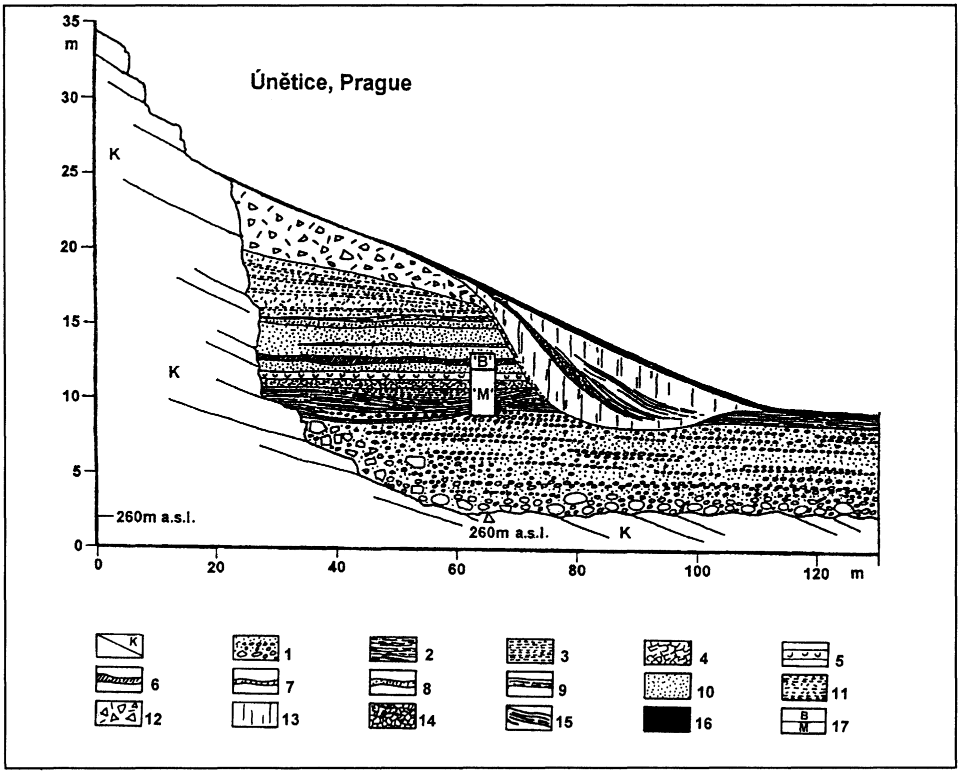

Fig. 4 – Cross-section through the Suchdol Terrace of the Vltava river (near Únětice) of the Pleistoce age (adapted from Záruba et al. 1977 and Tyráček et al. 2004). Explanations: K – Proterozoic lydite, 1 – gravel of the Suchdol Terrace, 2 – floodplain clay, 3 – calcareous channel deposits, 4 – brown decalcified floodplain soil, 5 – grey freshwater marl, 6 – dark humic gley soil intercalation, 7 – rusty brown gley soil intercalation, 8 – slopewash derived from Cretaceous sandy limestones, 9 – clayey slopewash, 10 – loose calcareous tufa, 11 – slopewash containing Cretaceous debris, 12 – debris of Proterozoic lydite, 13 – loess, 14 – parabraunerde soil, 15 – reworked older chernozem, 16 – post-glacial chernozem soil, 17 – possible magnetostratigraphical boundary of Matuyama and Brunhes chrons (after interpretation by Záruba et al. 1977).

0.4 m.km-1. Further upstream, the channel gradient is more variable, but typically steeper than the terraces, which thus converge towards the source of the river (Balatka, Sládek 1962a). An estimation of the values of the antecedent deepening of the Vltava river according to the position of relics of river accumulation terraces is influenced by a series of uncertainties such as terrace surfaces being irregularly lowered by erosion (comp. Fig. 4) and destruction of their base. However, the results of the estimation are an example of the dynamics of fluvial incision into bedrock and the transportation of weathered material in the region of central Bohemia during the Quaternary (Kalvoda, Balatka 2006): a) Middle Miocene to Pliocene: rate of deepening about 2–4 cm/1,000 years, b) Early Pleistocene: 6–12 cm/1,000 years, c) the younger part of the Middle Pleistocene: 6–8 cm/100 years, d) a part of the Late Pleistocene (40 to 20 ka): 2–4 cm/1,000 years, e) Holocene: mostly recycling of gravels, sands and slope accumulations in the valley bottom. The rate of downward erosion of the

Vltava probably reached its maximum of between 6 and 10 cm/100 years at some time during the Middle Pleistocene (Kalvoda, Balatka 2006; Kalvoda 2007a, b).

The deepening of the river network in the late Cenozoic is also indicated by landform evolution in the area of the regional base level of erosion of the Bohemian Massif (respectively of the Česká vysočina Highlands), i.e. in the Děčínská vrchovina Hilly Land. Between Děčín and Hřensko, erosion by the river Labe reached at least 50 m in the Pliocene and 180–200 m in the Quaternary (Balatka, Kalvoda 1995; Kalvoda, Balatka 1995; Kalvoda et al. 2004). Besides the system of river accumulation terraces, wind-blown sands, loess loams and loess (e.g. Demek et al. 1965, Czudek 1997) provide valuable sedimentary evidence of the evolution of landforms in the Quaternary (Figures 1 and 4). They have survived in a stratigraphically significant thickness in depressions or on lower plateaux of the Česká vysočina Highlands.

A very important secular process related to the dynamics of fluvial events in the Quaternary is the oscillation of the surface of oceans due to climatic changes. An example from the Late Pleistocene of the recent geodynamics of the European area may be the difference of levels of the world ocean between the Eemian interglacial stage and the Vistulan glacial. In the Eemian (130,000–116,000 years ago), the ocean flooded the English Channel and, on the contrary in the Vistula glacial (60,000–13,000 years ago), when the Scandinavian continental ice sheet moved to the Berlin region 28,000 years ago, the level of the world ocean was about 120 m lower than it is today.

Sázava valley evolution: an example of the interaction of neotectonics and climate changes during the late Cenozoic

The Sázava valley was formed by integration of several Miocene individual catchment areas with different drainage directions accomplished by captures. According to Novák (1932), these were the western part of the upper course orientated from Světlá nad Sázavou northwards in the direction of the today's Sázavka, Želivka and Blanice rivers directed as individual streams to the middle Labe region and to the lower course basin either northwards or westwards to Klínec and lower Berounka (Malkovský 1975).

The genesis and structure of the terrace system and valley evolution within the 225 km longitudinal profile of the stream was largely influenced by two marked steps (bends) of increased water surface incline (Figures 5 and 6): the upper one in the Melechov granite massif (between the river kilometres 139.5 and 135.4) and the lower one (river kilometres 18–5). While in these reaches the mean gradient is 5.7 ‰ and 3.9 ‰ respectively, the 108 km long reach between two steps shows a mean gradient of only 0.88 ‰ (Balatka 2007). The incline in the reach upstream of the Melechov step is also constant (between river km 168–135 in average 1.3 ‰). This upstream reach is situated in a hanging position (approximately 25 m) above the valley bottom of the middle course.

Daneš (1913) introduced the concept of a Central Bohemian Oligocene peneplain and suggested the possibility of drainage of the middle Sázava to the north, in the direction of Kouřim. The fundamental paper on terraces and both valley and catchment evolution is the monograph by Novák (1932),

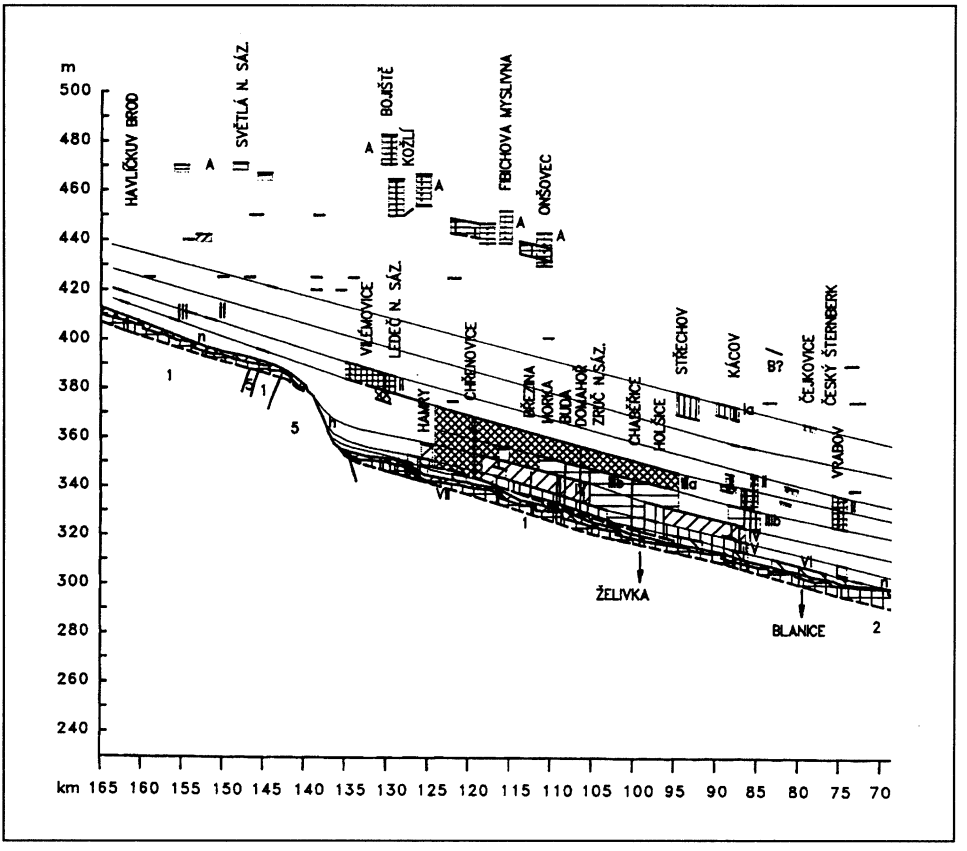

Fig. 5 – The longitudinal profile of the Sázava river terraces between Havlíčkův Brod and Český Šternberk (adapted from Balatka 2007). Explanations: Bedrock (1–6): 1 – Moldanubic paragneiss and migmatites, 2 – Moldanubic paragneiss with amphibolite body, 3 – metamorphosed volcanites of the Jílové Zone and metamorphosed Upper Proterozoic rocks, inclusive insular zone: rhyolites, dacites, andesites, bazaltes, amphibolite slates and hornstones, 4 – metamorphosed Upper Proterozoic rocks: siltstones, slates and greywackes, 5 – Upper Palaeozoic Plutone: granite, granodiorites, tonalites and diorites, 6 – Ordovician slates, greywackes and sandstones; A, B – Neogene sediments, I–VII – Quaternary terraces (– – surface, — base), = valley edges, n – surface of flood plain, h – river level, I – boreholes.

which was accepted by Záruba, Rybář (1961). These models proved the existence of relics of abandoned Pleistocene valley reaches filled by up to 25 m of terrace sediments in the larger neighbourhood of Zruč nad Sázavou. Today's Sázava valley was probably initiated in the Pliocene as a result of tectonic movements of anticlinal and synclinal character (Moschelesová 1930), which interrupted the original Tertiary drainage of the basin to the north (Novák 1932). If the Lower Miocene Sázava (with Želivka) flowed from the Melechov ridge already westwards, it captured the upper part of the valley to its course probably at the turn of the Miocene and Pliocene. Valley meanders and bends, characteristic for parts of the middle course of the Sázava river, were formed probably as bends on the bottom of the Pliocene wide valley. The present landforms appeared during a phase of Quaternary deepening of the valley, mainly by the development of larger bends with

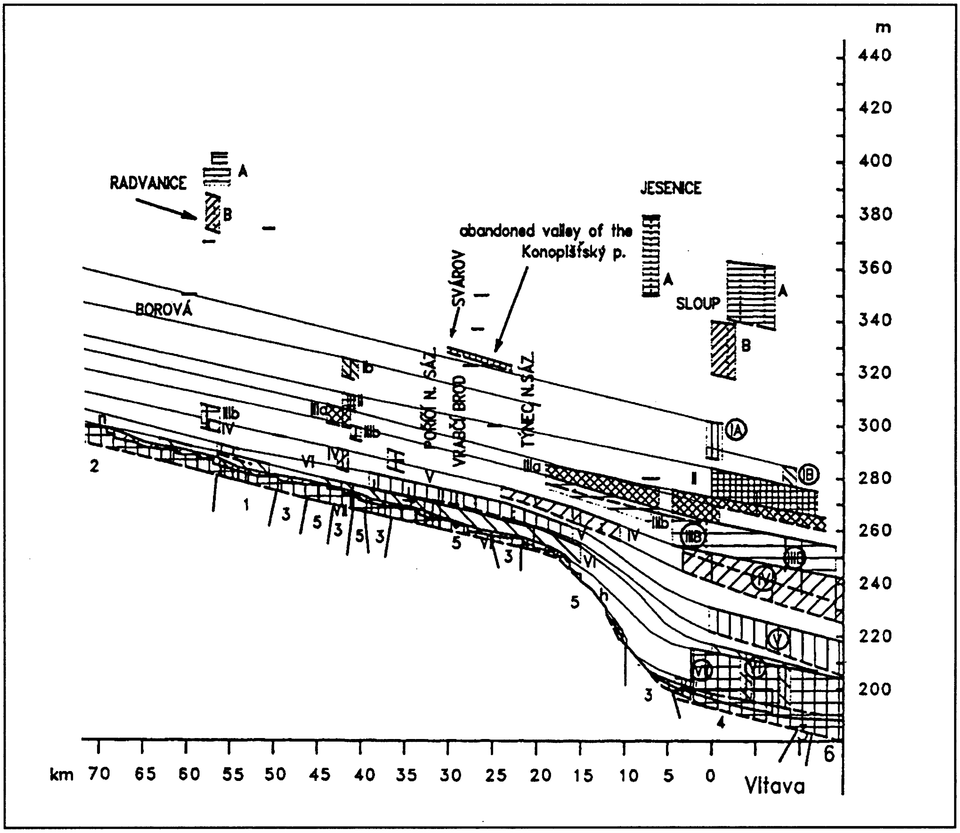

Fig. 6 – The longitudinal profile of the Sázava river terraces between Český Šternberk and the confluence with the Vltava river (adapted from Balatka 2007). For explanations see fig. 5.

terraces. The valley meanders with a narrow neck, indicate only small shape changes, with the exception of the most exposed extreme parts of concave scarps.

In the Sázava valley, seven main terrace surfaces with several secondary surface levels have been distinguished. The genesis and structure of the terrace system and the valley evolution were influenced by two pronounced incline steps of the river surface – the upper in the middle course and the lower in the lowermost course just before its junction with Vltava River (Balatka 2007). These incline steps caused huge fluvial accumulation in the lower reaches: the lower step mainly in the Vltava River valley, the upper step in the adjacent part of the middle course. Downstream the upper step (in the Melechov granite massif) a huge accumulation (aggradation) of sediments underlying the IIIrd (Chabeřice) terrace was formed (Fig. 5) which, because of its extraordinary thickness of about 25 m, levelled to this incline step.

The Sázava valley includes several remarkable geomorphological characteristics (Balatka, Sládek 1962a; Štěpančíková 2003; Balatka, Štěpančíková 2006; Balatka 2007): a) reaches with closed transverse profiles alternate with wider vales; b) the highest planation plateau surfaces of etchplain and pediplain type are situated mostly at 140–190 m above the river surface. Lower levels of denudational plateaux, generally of smaller dimensions, are situated at relative heights of mostly between 90 and 130 m, and that in two to three height levels situated in the largely open vale valley depression; c) upper edges of canyon-like valley reaches displaying the levels of Quaternary downcutting are situated mostly at 60–85 m (rarely at 40 m) above the present river surface.

Relics of Miocene sediments are found in two areas of the planation relief, i.e. in the morphostructural depressions of the Sázava – Želivka interfluve and the Sázava – Labe watershed. They represent relics of accumulation fills of old river channels as well as denudational relics of areal cover. They are fluvial to fluvial-lacustrine sediments, about 10 m thick, situated above the canyon-like valley cutting, with their surface at 110–135 m above the river (prevailing level A). Their present occurrences demonstrate either Sázava drainage from the Sázava town to the north (Novák 1932), or, according to Malkovský (1975, 1976; 1979; Ložek et al. 2004), Neogene drainage to the west, i.e. in the direction of the present course. Largely oscillating absolute heights of Neogene localities in the Sázava – Želivka interfluve could indicate their smaller tectonic disturbance reaching about 20 m.

Lower localities situated near the Sázava Town and upstream the confluence with the Blanice situated along the valley cutting belong undoubtedly already to the drainage in the present direction, i.e. to the west. Neogene sediments near Jesenice, southward from Prague, filling deep channels near the Sázava – Vltava watershed (Kovanda et al. 2001) indicate traces of drainage of the lower Sázava catchment to the north. It is indirectly proved also by the prevailing meridional orientations of Sázava tributaries in the larger neighbourhood. A great elevation above the distant Sázava level (over 185 m) can be most likely explained by a slight anticline vaulting of the area of the present watershed above the synclinal depression in the localities of the Sázava valley (Moschelesová 1930).

The oldest and highest, mostly Early Pleistocene terraces are maintained only very sporadically in small occurrences, and that above the edges of the valley incision. The relative height of the highest terrace Ia (60 to 105 m) indicates the approximate extent of the Quaternary erosion of the Sázava middle and lower course (Fig. 6). The IIIrd terrace group is the most significant set of fluvial landforms in the terrace system of the Sázava River both in occurrence and thickness of sediments. Under the Melechov incline step there occurred huge accumulation of sediments of the IIIrd terrace which, in an unparallel thickness of about 25 m, levelled out this incline step, so that the surface of this terrace was probably continuously aligned parallel to the valley bottom (floodplain) above this step. The erosional stage before the beginning of accumulation of sediments of the IIIrd terrace stopped near the level of the present water surface. It follows from this that the Sázava valley under the Melechov step was deepened already at that time nearly to its present level.

In the valley downstream the Melechov incline step there have formed in the middle course extraordinarily thick accumulations of sediments of the IIIa terrace (Chabeřice Terrace, up to 25 m), maintained in their total thickness in shorter abandoned valleys because of channel dislocation during the highest accumulation level (Fig. 5). In alluvia of this Chabeřice Terrace, there was formed a lower erosional terrace IIIb (Buda Terrace, comp. Tab. 1) with its surface about 8 m lower than the surface of the IIIa terrace and 30 m above the water level.

The predominantly sandy deposits of the Chabeřice Terrace indicate the generally constant incline conditions during the terrace sedimentation, with the exception of the beginning of the accumulation, when a higher incline of the channel at the terrace base-level resulted in accumulation of coarser gravels. In a 15 km long reach under the Melechov incline step, thicker deposits than those of the IIIa terrace were not found, as well as in the nearly 100 km long reach of the middle and lower course. It is suggested that the surface of the IIIa terrace is bound to the Vltava´s Kralupy Terrace (Ib, or IIIA) and its base-level could correspond to the bottom of the Vltava´s Karlovo náměstí Terrace – IIIb (Záruba, Rybář 1961). In comparison to the lower Vltava terraces, the sediments of the Chabeřice Terrace (IIIa) are more weathered and thus undoubtedly older.

In the lowermost part of the Sázava course, the IIIrd terrace is maintained above the valley cutting. The surface of the IIIa step is largely divergent downstream from approximately 30 m at the beginning of the incline step to 75 m in the Sázava – Vltava confluence area (Fig. 6). The surface of the terrace has a constant gentle inclination and its base-level in the lower course had probably an increased slope that was being progressively levelled out by accumulation progressing from the Vltava valley. Accumulation of sediments filled the furrow in the place of the present valley and during the following erosional stage these sediments were removed. The localities of the IIIrd terrace are represented by sediments from the final accumulation stage when the river widened its valley by lateral erosion to both sides. This is also indicated by minor thickness of sediments at these localities.

The slope steps have significantly influenced valley evolution, i.e. both in the intensity of erosion, depth and the extent of fluvial sedimentation – i.e. the course and position of main terrace elements in the longitudinal profile. While the highest terraces (Ia, Ib, II) represented in the long profile a constant course as incline steps still did not exist, the situation during the formation of the IIIrd terrace was more complex. The highest surface of the IIIrd terrace (IIIa) has also a constant and gentle slope, and the base-level of this terrace in incline steps shows a clear convergence upstream. Similarly, lower terraces, mainly in the lower incline step, show significant convergence upstream, and in the upper incline step the younger terraces are mostly progressively disappearing.

Incline steps of the water level as well as of the valley bottom of the Sázava represent fronts of waves of retrogressive erosion progressing upstream. The lower step was formed an in erosional period between the IVth and the VIIth terrace (Tab. 1), the upper step was essentially formed during the erosional stage between the surface

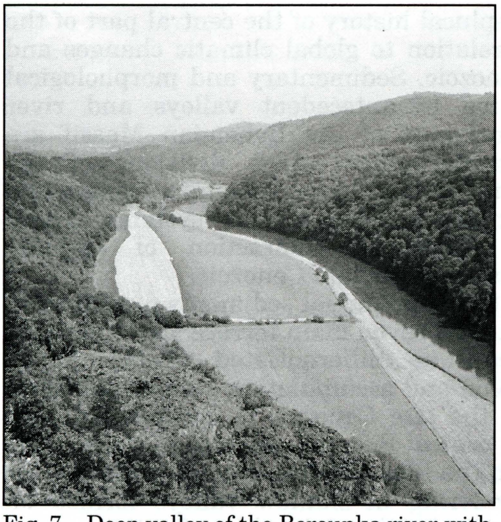

Fig. 7 – Deep valley of the Berounka river with a considerable fluvial plain originated in Cambrian volcanic rocks of the Křivoklátská vrchovina Highland at the beginning of the Neogene. Photo B. Balatka.

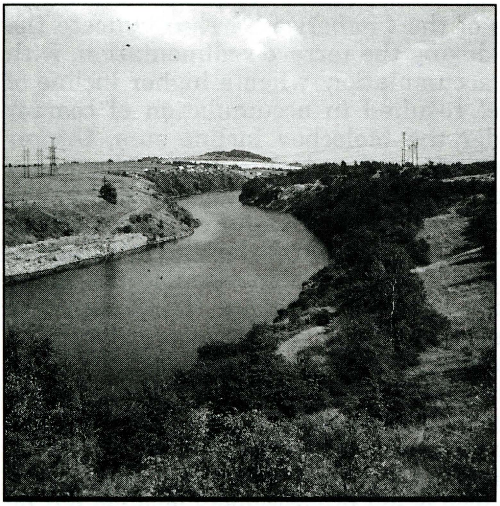

Fig. 8 – Canyon-like valley of the Ohře river in granulitic gneisses of a peripheral region of the Tertiary stratovolcano of the Doupovské hory Mountains is also cut through the complex of Pleistocene fluvial terraces. Photo B. Balatka.

of the IInd terrace and the base-level of the IIIrd terrace. Both steps are conditioned lithologically, i.e. by occurrences of more resistant rocks, the upper one probably also tectonically.

Reconstruction of the course of the IIIrd terrace in the longitudinal profile and the relation of this level to the Vltava terrace system (Fig. 3) has a crucial significance for the understanding of structural dependence of the Sázava terrace system, as well as for its stratigraphical correlation with Quaternary landforms and sediments in the Bohemian Massif (comp. Figures 7 and 8). Differently from Záruba, Rybář (1961) who equated the terrace with a high thickness of sediments near Zruč nad Sázavou probably with the lower Vltava terraces, it is supposed that the corresponding Chabeřice (IIIrd) Terrace is the stratigraphical equivalent to Vltava terraces IIIA (Kralupy) and IIIB (Vinohrady, comp. Tab. 1) which locally form also a uniform accumulation.

Conclusions

The main features of palaeogeographical history of the central part of the Bohemian Massif are presented in relation to global climatic changes and neotectonic processes during the Cenozoic. Sedimentary and morphological records of the Quaternary evolution of antecedent valleys and river accumulation terraces in the central part of the Bohemian Massif are correlated with regional chronostratigraphical stage divisions of the Quaternary (Table 1). Fluvial sediments in the Vltava, Berounka, Sázava and Labe valleys are preserved as extensive river terrace systems. These accumulation terraces originated from an interaction of climate-morphogenetic and neotectonic processes in the late Cenozoic.

Geomorphological analysis of late Cenozoic fluvial sediments preserved in the Bohemian Massif confirm that in total seven main terrace accumulations with several secondary levels can be differentiated (Table 1). A chronostratigraphical scheme of erosion and accumulation periods and their relations to variable uplift rates in the late Cenozoic is documented. The oldest river terrace accumulations in central Bohemia are situated above the margins of the canyon-like valleys. In the Early Pleistocene, the Vltava river and its affluents were freely meandering in shallow valleys formed on Neogene planation surfaces. The relative height of the oldest fluvial terraces above the present-day bottom of river valleys in the central part of the Bohemian Massif is more than 100 m which indicates the approximate depth of erosion in the Quaternary. An estimation of the values of the antecedent deepening of the Vltava in the late Cenozoic according to the position of relics of river accumulation terraces suggests that the rate of downward erosion of the Vltava probably reached its maximum of between 6 and 10 cm/100 years in part of the Middle Pleistocene.

Analysis of sediment transfers in the Quaternery environment was concentrated on fluvial transport and sedimentation in relation to neotectonics and climate changes in the Bohemian Massif. Important changes in the fluvial network occurred with significant manifestations of epigenetic and antecedent evolution of river valleys through deep, lateral and headward erosion. These processes were also connected with reconstruction of the large area of sedimentation of transported material. It is suggested to study the dynamics of fluvial processes together with records about weathering, denudation, erosion and mass movements.

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Shrnutí

VÝVOJ KVARTÉRNÍCH ŘÍČNÍCH AKUMULAČNÍCH TERAS VE VZTAHU KE ZDVIHU CENTRÁLNÍ ČÁSTI ČESKÉHO MASIVU

Paleogeografická historie centrální části Českého masivu je popsána zejména s ohledem na globální klimatické změny a neotektonické procesy v kenozoiku. Sedimentární a morfologický záznam vývoje antecedentních údolí a říčních akumulačních teras je porovnán se stratigrafickými stadii kvartéru v Evropě. Fluviální sedimenty v údolích Vltavy, Berounky, Sázavy a Labe jsou zachovány jako rozsáhlý systém říčních teras. Tyto akumulační terasy vznikaly interakcí klimato-morfogenetických a netektonických procesů v mladším kenozoiku.

Geomorfologická analýza fluviálních sedimentů mladšího kenozoika potvrdila, že lze rozlišovat sedm hlavních terasových akumulací s několika sekundárními úrovněmi (tab. 1). Je navrženo chronostratigrafické schema erozních a akumulačních období a jejich vztahů k variabilním hodnotám zdvihu v mladším kenozoiku.

Nejstarší říční akumulační terasy ve středních Čechách jsou umístěny nad okraji kaňonovitých údolí. V nejstarším pleistocénu Vltava a její přítoky volně meandrovaly v mělkých a širokých údolích na zarovnaném povrchu neogenního stáří. Relativní výška nejstarších říčních teras nad současným dnem říčních údolí centrální části Českého masivu je více než 100 m, což indikuje přibližný rozsah hloubkové eroze řek během kvartéru. Geomorfologická stanovení hodnot antecedentního zahlubování Vltavy v mladším kenozoiku, zejména podle polohy a sedimentární struktury reliktů říčních akumulačních teras, svědčí o tom, že hloubková eroze této řeky byla nejvyšší v části středního pleistocénu, a to mezi 6–10 cm za 100 let.

Analýza dynamiky přemísťování sedimentů v kvartérním přírodním prostředí byla zaměřena na fluviální transport a sedimentaci ve vztahu k neotektonice a klimatickým změnám v Českém masivu. Byly prokázány podstatné změny charakteru říční sítě s postupným epigenetickým a antecedentním vývojem údolí. Tyto kvartérní procesy jsou zároveň spojeny s rekonstrukcí rozsáhlých oblastí sedimentace řekami transportovaného materiálu. Je zdůrazněno, že komplexní výzkum dynamiky fluviálních procesů vyžaduje také studium procesů zvětrávání, denudace, eroze a svahových pohybů.

Obr. 1 – Neovulkanická kupa Říp (461 m) z vypreparované nefelinitové diatremy je obklopena kvartérním systémem říčních akumulačních teras širší oblasti soutoku Labe a Vltavy. Foto B. Balatka.

Obr. 2 – Antecedentní údolí Labe u Litoměřic vyhloubené do krystalinické hrásti vyzdviženého podloží neovulkanitů Českého středohoří. Foto B. Balatka.

Obr. 3 – Poloha říčních akumulačních teras v údolí Vltavy mezi jejími soutoky se Sázavou a Berounkou. Upraveno podle Balatky, Štěpančíkové (2006) a Balatky (2007).

Obr. 4 – Příčný profil pleistocenní suchdolskou říční akumulační terasou Vltavy u Únětic. Upraveno podle Záruby a kol. (1977) a Tyráčka a kol. (2004). Vysvětlivky: K – proterozoické lydity, 1 – štěrky suchdolské terasy, 2 – nivní jíly, 3 – vápnité říční sedimenty, 4 – hnědá odvápněná nivní půda, 5 – šedý sladkovodní slín, 6 – vrstva tmavé humózní glejové půdy, 7 – vrstva rezavě hnědé glejové půdy, 8 – proluviální sedimenty se zvětralých křídových písčitých vápenců, 9 – jílovité proluvium, 10 – zvětralé vápnité tufy, 11 – proluvium s drtěmi křídových hornin, 12 – svahové drtě z proterozoických lyditů, 13 – spraš, 14 – parahnědozemní půda, 15 – alterovaná černozem, 16 – postglaciální černozem, 17 – pravděpodobné magnetostratigrafické rozhraní mezi chrony Matuayama a Brunhes (podle interpretace Záruby et al. 1977).

Obr. 5 – Podélný profil říčními terasami Sázavy mezi Havlíčkovým Brodem a Českým Šternberkem. Upraveno podle Balatky (2007). Vysvětlivky: skalní podloží (1–6): moldanubické pararuly a migmatity, 2 – moldanubické pararuly s amfibolitovým tělesem, 3 – metamorfované vulkanity jílovského pásma a metamorfované svrchnoproterozoické horniny včetně ostrovní zóny: ryolity, dacity, andezity, amfibolické břidlice a rohovce, 4 – metamorfované svrchnoproterozoické horniny: prachovce, břidlice a droby, 5 – svrchnopaleozoický pluton: granity, granodiority, tonality a diority, 6 – ordovické břidlice, droby a pískovce; A, B – neogenní sedimenty, I–VII – kvartérní terasy (- - povrch, – báze), = erozní hrany údolí, n – povrch říční nivy, h – hladina řeky, | – vrty.

Obr. 6 – Podélný profil říčními terasami Sázavy mezi Českým Šternberkem a jejím ústím do Vltavy. Upraveno podle Balatky (2007). Vysvětlivky viz obr. 5.

Obr. 7 – Hluboké údolí Berounky s výraznou říční nivou, vytvořené v kambrických vulkanitech Křivoklátské vrchoviny, bylo založeno již na počátku neogénu. Foto B. Balatka.

Obr. 8 – Kaňonovité údolí Ohře v granulitových rulách periferní oblasti terciérního stratovulkánu Doupovských hor je vyhloubeno také do plošin staropleistocenních říčních teras. Foto B. Balatka.

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ASSESSMENT OF THE RIVER HABITAT QUALITY WITHIN EUROPEAN WATER FRAMEWORK DIRECTIVE: APPLICATION TO DIFFERENT CATCHMENTS IN CZECHIA

M. Matoušková: *Assessment of the river habitat quality within European Water Framework Directive: Application to different catchments in Czechia.* – Geografie–Sborník ČGS, 113, 3, pp. 223–236 (2008). – The paper presents the method of ecomorphological assessment of river habitat quality EcoRivHab, based on field mapping with possible usage of distance data. EcoRivHab is a tool used to assess the state of streams which lays an emphasis on hydromorphological characteristics of channel, ecohydrological state of the riparian belt and flood plain. Definition of the local reference state of the river habitat in the given physiographic region serves as a precondition. Overall ecohydrological state is evaluated by five degrees (ES I–V), characterizing the state of the watercourse in the context of the EC Water Framework Directive. The goal of this research was to assess the ecohydromorphological state of selected catchments in Czechia, representing varied relief types, and at the same, representing landscape with differing degrees of anthropogenic impact.
KEY WORDS: EcoRivHab – river habitat – ecohydrological principles – ecomorphological assessment – reference state – Czechia.

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Introduction

As part of the GAČR (Grant Agency of the Czech Republic) project „Assessment of Ecohydrological State of Streams in the Context of the Water Framework Directive 2000/60/EC“, the following method was formulated: “Ecomorphological Assessment of the River Habitat Quality” (EcoRivHab), stemming from the ecomorphological monitoring method of habitat quality of small streams in the hilly relief (Matoušková 2003, 2004). In order to arrive at broader application possibilities and due to the requirement to fulfil the Water Framework Directive (hereinafter WFD; EC, 2000) and ČSN EN 14614, 2005 criteria, its adaptation was performed.

The main goal of the research was to assess the ecohydromorphological state of streams, identify reaches which meet the so called good ecological state according to WFD, at the same time, to find watercourse reaches showing strong anthropogenic impact, as well as to find localities with natural or nearly natural habitat of water ecosystems. The objectivity and correctness of obtained results had to be tested by the application of different assessment methods. Important output of realized research is the comparative analysis of applied methods.

Applied Methods

The EcoRivHab method (Matoušková 2007) was used as the point of departure to assess the stream habitat quality. Within the framework of individual study river basins, foreign methods were tested, as well: Gewässerstrukturgütekartierung LAWA – Field Survey (LAWA 2000); LAWA – Overview Survey (Kern et al. 2000); Rapid Bioassessment Protocol – RBP (Barbour et al. 1999); Channel Assessment Procedure Guidebook – CAP (Ministry of Forest BC 1996); and comparative analysis of the outputs obtained was performed. HABSCORE and LAWA Field Survey (LAWA-FS) methods, as well as the EcoRivHab method, are based on field investigation with possible utilization of distance data, e. g. aerial or satellite images, specific layers of digital maps. The LAWA Overview Survey (LAWA OS) method is based on interpretation of distance information sources and other materials from river authorities. The field investigation is of supplementary nature only. The CAP method is part of the assessment block Watershed Assessment Procedure (WAP, B.C. Ministry of Forest and Ministry of Environment). It uses aerial images and field mapping in the assessment, focused on determining basic morphological types of riverbeds, not on assessing the habitat quality. It was used in connection with the study of fluvial-morphological processes of natural streams.

Within the framework of water bodies quality assessment in European Union countries, ecohydrological principles are of crucial importance. The so called ecological state is the basis in assessment of stream quality, defined based on hydromorphological, hydrochemical and hydrobiological parameters. Currently, monitoring of water formations habitat quality, of typology and definition of reference states of streams is being performed in individual membership countries. CEN EU formulated instructions to assess morphological situation of the riverbed, riparian belt and flood plain (CEN 2002) and created a directive to assess hydromorphological parameters of streams (EN 14614, 2004), implemented subsequently in the national legislation of EU membership countries (Weiss et al. 2007).

EcoRivHab Method Characteristics

The EcoRivHab method contains in a marked extent the assessment parameters pursuant to WFD. It includes analysis of hydromorphological characteristics of streams, analysis of the flow dynamics degree, of surface water quality, riparian belt vegetation, land use of flood plain, and other ecohydrological characteristics of the river basin. The method is based on definition of a local reference state. The assessment is performed in urban as well as rural areas. The water ecosystem is viewed as a broader area, formed by individual zones, integrated in the assessment (Matoušková, Mattas 2003). Thus the monitoring is not related to the riverbed only. Optimally, the spatial unit of the highest order should be represented by the whole river basin, as all processes occurring therein are reflected in qualitative and quantitative characteristics of the whole water ecosystem. The flood plain is a unit lower by one order, assessed in field investigation, and/or using distance data. Combination of both approaches is optimal. The field mapping concerns flood plain, the riparian belt and the channel.

The riverbed zone is formed by two components: water (pelagial) and the channel, formed by the so called interstitial and the amphibic part. The channel has an ecologically important function as it creates a mosaic of small biotopes for water organisms with varied flowing, bottom structure elements, various light differences etc. The bank vegetation is formed by watersides of the channel. Delimiting of the bank vegetation in small watercourses is quite difficult as it is relatively narrow, individual littoral zones thus cannot be always distinguished with sufficient clarity, thus distinguishing the bank vegetation and the riparian belt. Its width is variable depending on the cross profile shape.

The zone of riparian belt (includes a vegetation belt along the channel, and forms part of the terrestric area. From the geomorphological point of view, it is part of the flood plain; however, from the ecological viewpoint, it is suitable to delimit this zone separately. For the purpose of EcoRivHab, the borderline of riparian belt was not determined firmly. However, at the minimum, it should achieve the width of 10 m from left and right river bank. The width dimension of the bed, the river valley type and the whole flood plain type are determinant for an optimum choice of the size.

The flood plain zone is linked to the riparian belt. Its outer borderline can be delimited based on geomorphological characteristics. In areas of great human impact where the borderline cannot be delimited in a simple way, the minimum width of 100 m from the channel is recommended.

The river basin as the highest spatial ecohydrological zone includes all processes occurring in the given area, which have a direct or indirect impact on ecohydrological characteristics of the watercourse (e.g. surface water quality, erosion susceptibility of the land, outflow and stream bed load regime). The river basin boundary is delimited by the orographic watershed divide, and/or specified closer in small river basins by the hydrogeological watershed divide.

Delimiting of borderlines of individual zones is not of crucial importance; however, understanding of the watercourse as an integrated water ecosystem is important, showing a close interconnection between the aquatic and terrestrial part. The meaning of borderline areas between individual biotopes should be thus emphasized, as well as the importance of interconnection of the surface and underground outflow, together with the flow of substances.

Data Sources

The landscape where mapping is performed represents the basic source of information. This cannot do without available mapping resources, of course, which are as follows: Basic topographic map of Czechia 1:10,000; basic water management map 1:50,000; specific layers of the DiBaVod database 1:50,000 and 1:10,000 (Water Research Institute, Prague), and/or the digital terrain model DMÚ-25 (Czech Geodesic and Cadastral Office, Prague). Utilization of available information from watercourse authorities is suitable, as well, e.g. concerning the riverbed modifications performed. Within the research, aerial orthophotometric images in the digital form were used, as well, with the resolution of 50 cm (GEODIS), and the possibility of application of panchromatic and multispectral satellite images QuickBird (ArcData) was tested, having the resolution of 0.6 m in panchromatic and 2.4 m in multispectral images. The complex ecohydrological assessment should also include an analysis of the rainfall-runoff regime data, assessment of surface water quality, contamination of sediments, and/or other indicators.

Field Mapping

Mapping is performed along the entire length of the watercourse, as a rule from the spring to the mouth. Partial reaches are monitored, the lengths of which are determined firmly, and the beginning and end of the given reaches is laid down clearly in the map and determined using GPS. Their mutual overlapping may not occur. It is recommended to perform mapping in length-heterogeneous reaches, while laying an emphasis on their qualitative homogeneity. The length of individual reach should be in the range of 100–1,000 m in an optimum case. Every reach of the watercourse is marked using a three-character code in the map, and numbered using a three-digit number in the direction from the mouth to the spring (e.g. reach1 in the Rolava River is ROL001; reach 2 in the Rolava River is ROL002). If the watercourse branches out, each branch is assessed as well as marked separately.

Field investigation of hydromorphological structures of the riverbed should be performed during low water conditions, and before the maximum vegetation growth, in the optimum case. Mapping of riparian belt and the flood plain should be performed during the vegetation period. The mapper can use the mapping form where individual parameters are specified. The mapping results are recorded continuously in the digital working form and drawn in the graphical form in the maps. Assessment using a spreadsheet calculator follows, as well as conversion into thematic GIS layers by means of identifiers.

Chosen parameters jointly characterize the so called ecomorphological state of the watercourse. Within the framework of this methodology, monitoring of 31 parameters was proposed, associated in the group of 17 main parameters. 3 group parameters are derived from them, characterizing individual zones, and subsequently 1 resulting, the so called ecomorphological state (Table 1). The number of parameters can be optimized, i.e. an optimum number in respect of the monitoring type and purpose of assessment can be chosen.

The majority of parameters are assessed using five score-based classification (S: 1, 2, 3, 4, 5). Numeric measurement of characteristics of some parameters is difficult or their quantitative characteristics are relative. Such parameters are assessed using e.g. frequency assessment (F), expressing their relevant occurrence (1 – high, 3 – intermediate, 5 – low). Some parameters are of documentation nature, i.e. they are not assessed using scores (verbal assessment – V) See Table 2. All parameters have the same weight in the resulting determination of the so called ecomorphological state because the evaluation is done on the basis of additive principle. Final ecomorphological state is calculated as the arithmetical average of the evaluated three zones. The ecomorphological state is then classified on the basis of assignment of numerical result into one of the defined ecomorphological classes (see Table 3). The numeric result obtained is assigned verbal assessment in the conclusion, according to classification in

Tab. 1 – Overview of mapped parameters using the EcoRivHab method

Ecomorphological zones	Group of parameters	Parameters	Assessment type
Channel	Morphology and channel geometry	River valley, gradient	V
		Curvature	S (1,3,5)
		Channel character and shape	S (1,2,3,4,5)
		Deepening of the channel	S (1,2,3,4,5)
		Connectivity to ground water	S (1,3,5)
	Longitudinal profile	Steps	S (1,2,3,4,5)
		Erosion and accumulation forms	F (1,3,5)
		Flow patterns	F (1,3,5)
		Variation of depth (riffles a pools)	S (1,2,3,4,5)
		Modification of outflow	S (1,3,5)
	Cross profile	Type and stability	S (1,2,3,4,5)
		Middle profile depth	V
		Variation of width	F (1,3,5)
		Profile capacity	S (1,3,5)
	Bottom structures	Substrate type	V
		Bottom modification	S (1,2,3,4,5)
		Diversity of microhabitats	F (1,3,5)
	Bank structures	Character of bank vegetation	S (1,2,3,4,5)
		Structure of bank vegetation	S (1,2,3,4,5)
		Bank modification	S (1,2,3,4,5)
		Stability of banks	S (1,2,3,4,5)
	Surface water quality	Hydrochemical features	S (1,2,3,4,5)
		Hydrobiological features	S (1,2,3,4,5)
		Occurrence of sewage outlets	V
		Channel vegetation	V
Riparian belt		Existence	F (1,3,5)
		Character and structure of vegetation	S (1,2,3,4,5)
		Land use	S (1,2,3,4,5)
Flodd plain		Prevailing land use	S (1,2,3,4,5)
		Occurrence of flood protection measures	S (1,3,5)
		Retention capacity	F (1,3,5)

Note: F – frequency assessment, S – score based assessment, V – verbal assessment, S – verbal assessment

Tab. 2 – Example of verbal and point assessment – parameter curvature

Type	Symbol	Point assessment
Meandering	M	Natural origin
Sinuous with branches	SB	1
Sinuous without branches	S	Slightly modified
		3
Braided	B	Modified, new river course and riverbed
Straight	ST	5

Note: Degree of sinuosity could be determined using Klimazewski Index (*Km*)

$$Km = \frac{Lr[m]}{Lv[m]}$$

Lr length of the river bed, *Lv* length of the valley, $Km>1.5$ meandering channel course, $Km<1.5$ sinuous channel course, $Km=1$ straight channel course.

fixed delimited and defined intervals. The graphical output is represented by thematic maps of individual group parameters and the map of an overall ecohydromorphological state of the watercourse.

Tab. 3 – Final classification of the ecomorphological state, comparison to WFD quality classes

EcoRivHab quality class (ES)	I	II	III	IV	V
Point assessment Description Color WFD quality class	<1–1.5> Natural, near natural (unchanged) blue 1	(1.5–2.5> Slightly changed green 2	(2.5–3.5> Moderately changed yellow 3	(3.5–4.5> Strongly changed orange 4	(4.5–5> Completely changed red 5

The summary ecomorphological state is characterized by five ecomorphological classes, hereinafter ES (ES I – natural or near natural state (reference condition); ES II – slightly changed; ES III – moderately changed; ES IV – strongly changed; ES V – completely changed). The resulting ecomorphological state documents the level of anthropogenic impact of the water ecosystem.

Study Areas

The following river basins were chosen as study areas to assess the river habitat quality: Upper Blanice River, Rolava River, Křemelná River, Liběchovka River, Košínský Brook, Rakovnický Brook, Klíčava River and Bílina River (Fig. 1). By their nature, the river basins chosen represent well the geographic diversity of the relief of Czechia, and they differ in the level of anthropogenic impact. A condition used in their selection was also represented by existence of natural or near natural localities due to the need of defining the reaches with reference condition. On the contrary, the Bílina River basin was chosen as an example of a river basin with very strong anthropogenic impact. Overall, approximately 450 km of streams were mapped, while in the majority of the study catchments, at least two different methods were applied. In linkage to the GAČR project, areal field investigation of streams in the Berounka River basin is still being performed in the Křivoklát Protected Landscape Area, the administration of which showed an interested in areal mapping of the watercourse habitat quality using the EcoRivHab method. Possibilities of distance investigation are furthermore being tested in the main watercourse of the Berounka and Upper Blanice Rivers.

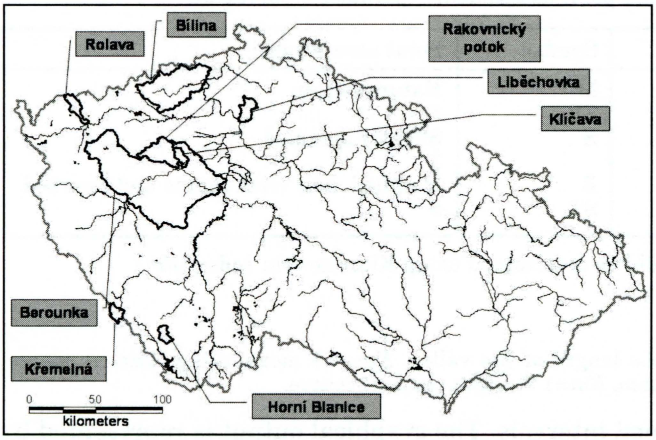

Fig. 1 – Location of study river basins of ecomorphological monitoring

Determination of Reference Condition

Determination of ecological quality of the so called reference state is problematic, which can be derived from localities not affected by human activities, representing not an easy task in the today's prevailing cultural landscape of Central Europe. Based on the research performed, definition of the local reference state can be recommended, which can be suitably derived from natural or nearly natural localities found in the given or near river basin, showing identical physically geographic characteristics. To define the reference state, the following parameters are crucial: river valley type and the gradient; curvature degree; communication with ground water; erosion and accumulation forms; stability of the cross profile; width and depth profile variability; microhabitat diversity; character and structure of the bank vegetation; character and land use of riparian belt; land use and retention potential of flood plain; surface water quality (quality class I – II in the optimum case). No artificial steps (weirs and other migration barriers) and no technical flood protection measures should exist in the reference reaches. Analysis of maps and field mapping was realized for the delimitation of reaches in reference condition, which was based on above mentioned parameters. The final ecomorphological state of reaches in reference condition should not be higher than 2.

Mapping Results Using the EcoRivHab Method

It follows from the mapping performed in all river basins of interest that the best ecohydrological state is shown by the river basins of Upper Blanice, Klíčava and Liběchovka Rivers. Approximately 80 % are represented by ES I and II reaches, see Figure 2, conditioned by their geographic position, considerable extent of protected areas and low proportion of anthropogenic

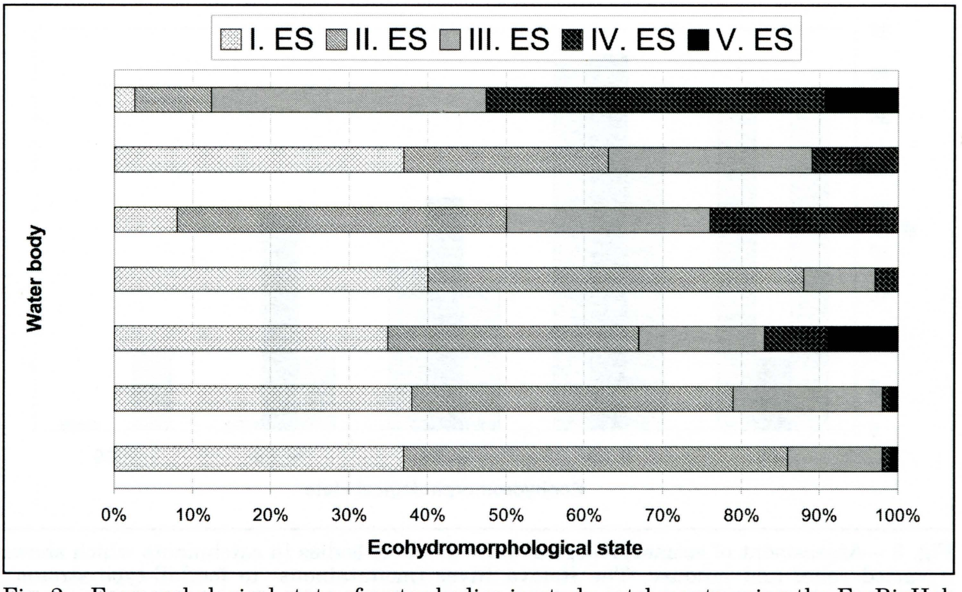

Fig. 2 – Ecomorphological state of water bodies in study catchments using the EcoRivHab method. Field mapping&assessment: Bicanová (2005), Dvořák (2008), Lelut (2007), Matoušková (2003), Šilhánová (2007), Šípek (2006) and Vondra (2006)

activities. River basins of the Rolava River, Košínský Brook and Rakovnický Brook show a higher degree of anthropogenic modification. 10–25 % of the total length of the reaches mapped show a not very good ecohydromorphological state (ES IV and V). These are clearly reaches bound to anthropogenic activities in the river basin, no matter if built-up areas are concerned or rural landscape, used for intensive agricultural activities.

Exceptional position in ecohydromorphological monitoring is occupied by the Bílina River basin. This river basin was chosen intentionally as an example of an area with very strong human impact where the possibility of the EcoRivHab method application was tested on artificial watercourses. Numerous channel reaches are modified or displaced. Only 12 % of the total length of the main Bílina River can be designated as natural or nearly natural. Except for rare cases, these reaches are situated in the mountain areas and foothills of Krušné hory (Krušné Mountains). Reaches found predominantly in České středohoří (Czech Low Mountain Range) were classified reaches with moderate human impact (ES III; 34 %). In reaches showing a quite unsatisfactory state, i.e. ES IV and V, are situated in the middle course (Jirkov – Obrnice area; Ervěnický koridor – Ervěnický Corridor) and in urban areas of cities where the channel has been modified in the greatest extent. It is alarming that the whole length of these reaches represents 51 % of the total main stream length (Dvořák 2008).

The Rolava River basin can be provided as an example of the mountainous- up to foothill-type river basin. Major modifications of the riverbed were performed in the middle and lower course of Rolava River, especially in order to provide flood protection measures and energy utilization by small water power plants, having a negative impact, too, on the habitat character. The

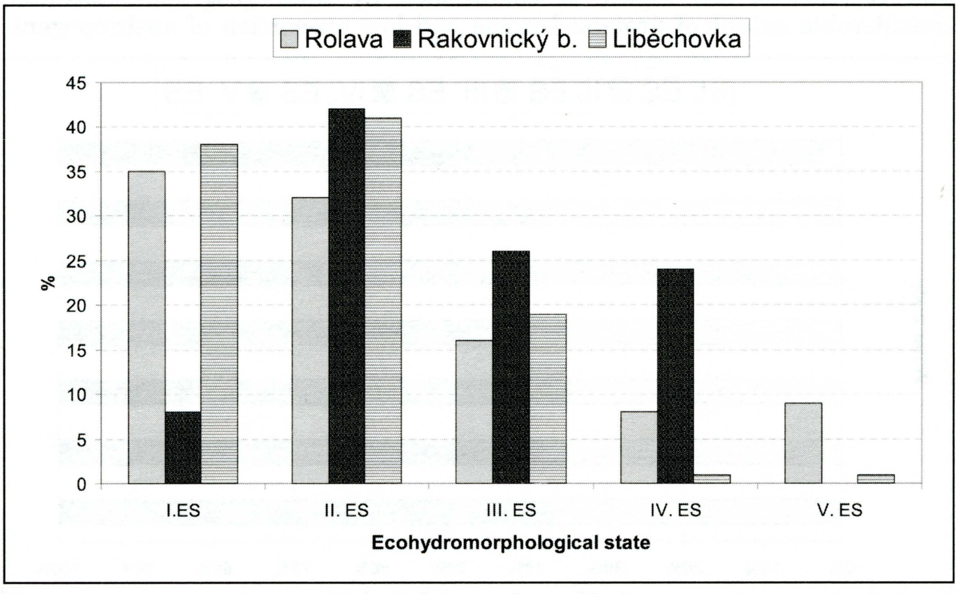

Fig. 3 – Assessment of ecomorphological state of water bodies in catchments which shows a varied relief and landuse: The Rolava River (mountainous- to foothill-type stream), Rakovnický Brook (hilly-type stream), Liběchovka River (lowland-type stream) using the EcoRivHab method. Field mapping & assessment: Lelut (2007), Matoušková (2003), Šípek (2006)

overall ecomorphological state in the Rolava River basin can be characterized as good. Significant differences exist between the state in upper courses, which run through mountainous and rarely settled landscape, where ES I and II prevail. The situation is unsatisfactory in the middle and lower course where the Rolava River flows through urban areas of the communities of Nejdek, Nová Role and Karlovy Vary. Here ES IV and V prevail, while these parts represent 12 % of the total main watercourse length. The situation is also adverse in the Nejdecký Brook as 40 % of its total length is assessed as areas with moderate up to strong anthropogenic impact (ES III and IV; Lelut 2007).

The river basin of the Rakovnický Brook can be mentioned as an example of hilly area. Overall ecomorphological state of the catchment can be characterized as not very satisfactory as almost 25 % of the mapped length of the main watercourse is represented by reaches which show strong anthropogenic impact (ES IV), see Figure 3. Reaches found in the Křivoklát Protected Landscape Area show a relatively sharp contrast, where, with the exception of urban areas of small communities, ES I and II prevail. On the contrary, the situation is alarming in the upper stream area of the Rakovnický Brook where intensive agricultural activities prevail. Reaches in the middle course, in the predominantly agricultural landscape, show strong anthropogenic impact, as well. Reaches found in the Rakovník city urban area and in the Křivoklát community are classified as ES IV, both due to channel modification, only partial existence of the riparian belt, and due to considerable transformation of flood plain because of continuous built-up area and roads (Matoušková 2003).

The Liběchovka River basin presents a geomorphologically varied relief of Polomené hory (Polomené Mountains). Slowly changing reaches of lowland nature prevail; nevertheless, reaches showing marked gradients are found in this river basin, as well. At present, the flood plain is free of significant anthropogenic activities; however, as few as 50 years ago, it was used for agricultural activities. The river basin is thus interesting from the viewpoint of monitoring possible development of river habitats upon withdrawal of agricultural activities. Ecomorphological state in the Liběchovka River basin can be classified as favourable, as 77 % of the total length of the reaches mapped was assessed as ES I and II. Upper stream reaches are concerned, as well as almost the whole middle course of the Liběchovka River. Reaches classified as ES III are bound to areas used for agricultural activities. Riparian belts exist, however, their composition as well as structure is modified. ES IV is found especially in areas where dispersed built-up areas prevail in the flood plain. Riparian belt is not developed as a rule. ES V differs from ES IV especially in land use in the flood plain where unlike dispersed built-up areas, continuous built-up zones prevail, as well as industrial objects or roads (Šípek 2006).

Comparative Analysis of the Methods Applied

All the methods applied showed the capacity to identify natural reaches and moderate to completely change reaches and provided precious information on the river habitat state. However, they are varied from the viewpoint of the number of parameters, number of monitored zones, time and knowledge demands on the assessment performed (see Table 2).

Tab. 4 – Features of applied assessment methods

Method	EcoRivHab	RBP	LAWA-Field Survey	LAWA-Overview Survey
Number of parameters	31	10	25	17
Monitored zones	channel, riparian belt, flood plain	channel, riparian belt	channel, river banks, riparian belt	channel, river banks, riparian belt
Length of reaches	heterogeneous	heterogeneous	homogeneous	homogeneous
Point assessment	5	20	7	5
Number of classes	5	4	7	5
Accent on hydromorphology	yes	no	yes	yes
Slope condition	yes	yes	no	no
Water quality	yes	yes	no	no

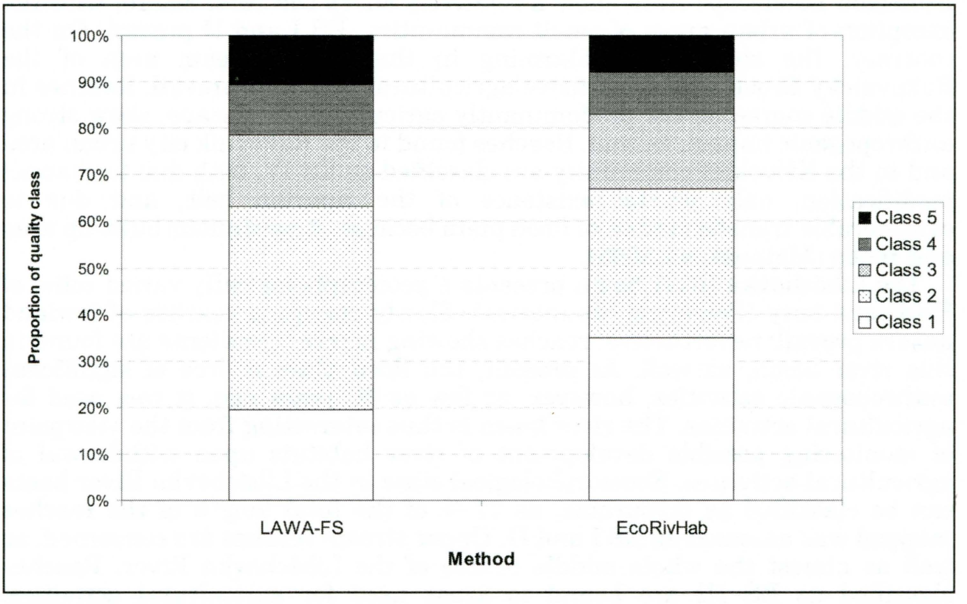

Fig. 4 – Assessment of the habitat quality of the Rolava main stream using the methods EcoRivHab and LAWA-FS (comparative analysis), mapping Lelut, analysis Matoušková

Qualitatively identical results were brought especially by the methods EcoRivHab and RBP. Both methods are similar. The method RBP is less time demanding as it assesses the watercourse habitat based on 10 hydromorphological parameters. Greater differences were found between LAWA-Field Survey (FS) and the methods EcoRivHab & RBP, which is given by certain preference of the negative anthropogenic impact on the modification rate of the channel in the case of the method LAWA-FS. As for EcoRivHab, every one of the zones assessed participates in the same level in the total assessment of the watercourse habitat quality, i.e. by one third. In the case of LAWA-FS, the riverbed and the bank are assessed separately. On the contrary, the riparian belt and flood plain are assessed jointly. Certain differences in the resulting assessment can also occur due to different delimiting of the mapped reaches. The method LAWA-FS is more time demanding due to mapping in 100 m reaches, however, it cannot be stated clearly that it provides greater precision as in the relatively short length of the reaches assessed; merging of two markedly different habitats may occur. However, upon conversion of the 7 resulting ecomorphological classes of LAWA to 5 as required by WFD, similar results were obtained as in other assessments, see Figure 4. The method LAWA-Overview Survey (Kern et al. 2002) is based on processing of distance data and information available from watercourse administrators. Its outputs seem to be least precise from the viewpoint of application to small streams. It is suitable especially for large-scale monitoring of watercourse habitats (Table 4). During our application occurred problems with insufficient evidence of necessary data and additional field mapping were done.

Comparison of the assessment system of individual methods and WFD requirements was performed, as well. As for the method EcoRivHab, the classification scale, i.e. 5 ecomorphological classes, shows full compatibility with the WFD assessment system, i.e. 5 quality classes: ES I – 1 class unchanged (reference condition); ES II – 2 class slightly changed; ES III – 3 class moderately changed; ES IV – 4 class strongly changed; ES V – 5 class completely changed. Nevertheless, unlike WFD requirements the method EcoRivHab does not include quantitative assessment of the hydrological regime directly; however, this assessment is recommended to be performed in the initial phase of investigation. On the contrary, it includes the following parameters: river valley type; waste water outlets; and surface water quality state.

Conclusions

An advantage of the formulated method EcoRivHab is a complex view of the river habitat quality from the viewpoint of the parameters assessed, but also from the viewpoint of the space, i.e. taking account of a broader background of the stream. Furthermore, relatively simple and clear quantification of outputs can be presented, as well as the possibility of mutual comparative analysis of the outputs obtained. A certain disadvantage is formed by the necessary generalization of the water ecosystem characteristics within the framework of the parameters defined. The demanding nature of field investigation should be mentioned, as well, compared to methods based only on distance data utilization. Nevertheless, the time demands are manifested in higher quality and topicality of the outputs obtained. Negative characteristics also include a certain level of subjective assessment of the mapper in the field monitoring phase. The subjectivity can be eliminated by sufficient training of the mappers, necessary photodocumentation of the field investigation phase, and subsequent checking of the field outputs obtained.

Out of the outputs of the field mapping of watercourses performed it follows that the definition of references states is optimal based on local situation, i.e. if the given watercourse or its near equivalent in the given relief type flows, for example, through protected landscape. The drainage measures taken in the agricultural land and modifications of channel related thereto have a negative impact on the nature of watercourse habitats; ES III and IV was recorded predominantly. Achievement of a good ecological state is realistic provided that the necessary minimum space for riparian belt is provided, and that revitalization measures are taken according to the locality type. River habitats in urban areas of communities are usually modified in a significant extent (ES IV and V prevail). Improvement of the ecohydrological state is problematic here as the modifications performed are connected with continuous built-up area in the riparian belt and flood plain, with existence of flood protection measures and artificial grounds. Certain improvement of the hydromorphological state of the channel can be achieved, for example, by application of biotechnical modifications. However, qualitative parameters of surface water quality can certainly be improved.

Methods based on field investigation can be suitably applied in assessment of the ecohydrological state of small watercourses, especially due to the quality and informative value of the results obtained. In the case of areal monitoring of significant watercourses, distance data available can be utilized. However, quality of the outputs obtained should be retested using field investigation. A powerful and efficient monitoring programme has to be created, to be used to assess watercourse habitat quality in Czechia. Cooperation with neighbouring EU countries in its creation is advisable, on the level of integrated river basins at best. The outputs obtained shall serve not only to fulfil WFD requirements but they will also provide an outstanding source of information for integrated checking, monitoring, planning, protection and possible revitalization of streams.

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Shrnutí

HODNOCENÍ KVALITY HABITATU VODNÍCH TOKŮ V KONTEXTU EVROPSKÉ RÁMCOVÉ SMĚRNICE O VODNÍ POLITICE: APLIKACE V ROZMANITÝCH POVODÍ V ČESKU

Příspěvek představuje metodu ekomorfologického hodnocení kvality habitatu vodních toků EcoRivHab založenou na terénním průzkumu s možným využitím distačních dat, která je nástrojem pro hodnocení stavu vodních toků s důrazem na hydromorfologické charakteristiky koryt vodních toků, ekohydrologický stav příbřežní zóny a údolní nivy. Předpokladem je definice lokálního referenčního stavu habitatu vodního toku v daném fyziografickém regionu. Hlavním cílem výzkumu bylo objektivní vyhodnocení ekohydromorfologického stavu vodních toků, identifikace úseků, které splňují tzv. dobrý ekologický stav, zároveň nalezení silně antropogenně ovlivněných úseků vodních toků, stejně tak jako nalezení lokalit s přírodním, či přírodě blízkým habitatem vodních ekosystémů. Souhrnný ekohydrologický stav vodních toků byl charakterizován pěti stupni (I.–V. ES), což je plně kompatibilní s hodnocením kvality vodních útvarů v kontextu s Rámcovou směrnicí o vodní politice EU.

Pro zajištění objektivity byly v jednotlivých modelových povodí rovněž testovány zahraniční metody: Gewässerstrukturgütekartierung LAWA – Field Survey (LAWA, 2000), LAWA- Overview Survey (Kern a kol., 2002), Rapid Bioassessment Protocol – RBP (Barbour a kol., 1999), Channel Assessment Prodcedure Guidebook – CAP (Ministery of Forest BC, 1996) a byla provedena srovnávací analýza získaných výstupů.

Jako modelová povodí pro hodnocení kvality habitatu vodních toků byla vybrána povodí: horní Blanice, Rolava, Křemelná, Liběchovka, Košínský potok, Rakovnický potok, Klíčava a Bílina. Zvolená povodí svým charakterem dobře reprezentují geografickou rozmanitost reliéfu Česka a jsou odlišná mírou ovlivnění člověkem. Celkově bylo zmapováno přibližně 450 km vodních toků.

Z provedeného mapování ve všech zájmových povodí vyplývá, že nejlepší ekohydrologický stav vykazují povodí horní Blanice, Klíčavy a Liběchovky. Přibližně 80 % představují úseky v I. a II. ES, což podmíněno jejich geografickou polohou, značnou rozlohou chráněných území a nízkým podílem antropogenních aktivit. Povodí Rolavy, Košínského potoka a Rakovnického potoka vykazují vyšší stupeň antropogenní modifikace. V nedobrém ekohydrologickém stavu se nachází 10–25 % z celkové délky mapovaných úseků (IV. a V. ES). Jedná se jednoznačně o úseky, které jsou vázány na antropogenní aktivity v povodí. Výjimečné postavení zaujímá povodí Bíliny, úseky se zcela nevyhovujícím stavem, tj. IV. a V. ES představují 51 % celkové délky toku.

Pro hodnocení ekohydrologického stavu drobných vodních toků je vhodné využít metody založené na terénním průzkumu, především z důvodu kvality a vypovídající schopnosti získaných výsledků. V případě plošného monitoringu významných vodních toků je možné vy-

užít dostupných distančních podkladů. Měla by však být zpětně ověřena kvalita získaných výstupů pomocí terénního průzkumu.

Obr. 1 – Lokalizace zájmových území ekomorfologického monitoringu.
Obr. 2 – Ekomorfologický stav vodních útvarů v zájmových povodí s využitím metody EcoRivHab. Terénní mapování a analýza: Bicanová (2005), Dvořák (2008), Lelut (2007), Matoušková (2003), Šilhánová (2007), Šípek (2006) a Vondra (2006).
Obr. 3 – Hodnocení ekomorfologického stavu vodních útvarů pomocí metody EcoRivHab v povodích s rozmanitým reliéfem a odlišným využitím krajiny: povodí Rolavy (horský až podhorský typ vodního toku, Rakovnický potok (pahorkatinný tok), Liběchovka (nížinný tok). Terénní mapování a vyhodnocení: Lelut (2007), Matoušková (2003), Šípek (2006).
Obr. 4 – Hodnocení kvality habitatu hlavního toku Rolavy s využitím metod EcoRivHab a LAWA-FS (srovnávací analýza), mapování Lelut, analýza Matoušková.

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JAKUB LANGHAMMER, JAN SITAŘ

MODELLING THE IMPACT OF ANTHROPOGENIC MODIFICATIONS TO RIVER CHANNELS ON THE COURSE OF EXTREME FLOODS. CASE STUDY: AUGUST 2002 FLOOD, BLANICE RIVER BASIN, CZECHIA.

J. Langhammer, J. Sitař: *Modelling the impact of anthropogenic modifications to river channels on the course of extreme floods. Case study: August 2002 flood, Blanice River basin, Czechia.* – Geografie–Sborník ČGS, 113, 3, pp. 237–252 (2008). – This paper presents the results of analysis of the impact of anthropogenic modifications to river channels on the course of floods by means of hydraulic modelling. The study is focused on the quantitative analysis of changes of the flow dynamics in the river bed and in the inundation zone due to river network modifications. The one-dimensional hydraulic model HEC-RAS coupled with GIS is used to simulate the effect of the river channel changes on the course of extreme flood. The analysis is made on the example of the extreme flood in August 2002 on the down course of Blanice River in Czechia. The results of the simulations proved that the common anthropogenic modifications of river channel have only a minimum impact on the overall course of extreme floods. At the local level, weirs and unsuitably dimensioned bridges have a negative impact on the course of floods. The simulations also showed a negative impact of extensive complex modifications of the river bed, performed in the lower course of Blanice River in the first half of the 20th century. However, the overall impact of common types of river channel modifications on peak flows and water levels in the culmination is negligible.
KEY WORDS: floods – modelling – hydrological extremes – floodplain – stream modifications.

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1. Introduction

Anthropogenic modifications of river networks and river basins may, according to geographical and hydrometeorological conditions, have significant impacts on the course and consequences of floods. The effects are apparent at the local scale as well as at the river basin scale, and may affect the course as well as magnitude of the event (Gilvear 1999). Anthropogenic modifications which may have the most marked impacts on the passing of the flood wave through the inundation zone include changes of the river bed route, modifications of the watercourse longitudinal profile, changes of transversal profiles, and changes in the nature of land use of the floodplain and the riparian zone (De Roo et al. 2001, Langhammer 2006).

Intensive changes in the landscape and floodplain, and modifications of streams are manifested by accelerated runoff from the landscape, increases of flow speed in the riverbed, higher steepness of the flood wave, and changes in timing of flood waves from parts of the river basin by decreased transformation and retention capacity of the landscape and alluvial plain, or by resulting increases of peak flow and peak water level values. The manifestations of changes in the landscape mentioned above differ in their effects with varied levels of the flood extremity; moreover, individual factors have a different impact on various spatial levels of assessment as well as depending on the flood event extremity.

Suitable tools to study the impact of such modifications of river bed environments on the course of floods are represented by mathematical models that make it possible to simulate the effect of individual modification types of the river bed on the course of the flood, and to simulate the effects of flood-protection measures. One-dimensional or two-dimensional hydrodynamic models can be used to simulate the hydrological course of the flood depending on the change of external conditions (Bates, de Roo 2000; Horrit, Bates, 2002). One-dimensional models (for example, MIKE 11 and HEC-RAS) make it possible to calculate basic characteristics of the flow and inundation in a given time step. Outputs of these models provide information on the flows, water level heights, and extent of the flood spill. On the contrary, two-dimensional models (for example, MIKE 21 and FLO-2D) make it possible to express in substantially greater detail the dynamics of flow within the entire flood range, and thus to express the distribution of flow depths and speeds in individual grid fields into which the flood area is decomposed (Beffa, Connell 2001; Beven 2001; Verwey 2001).

The issue of impact of anthropogenic changes in the river bed on the flood course is evaluated using the model example of the Blanice River basin in Czechia (Fig. 1) for the case corresponding to the extreme flood in August 2002. The intensity of straightening of the Blanice River course in this area is extraordinary – during the past 150 years, the river has been shortened by 38 % between Bavorov and the confluence with the Otava River (Langhammer, Vajskebr 2003). Complex, historic modification of the river bed, including flood protection barriers, does not allow full utilization of the natural retention and transformation potential offered by the flat and up to 2 km wide floodplain in the area. The riverbed itself is moreover affected by numerous interventions in the longitudinal profile and crossed by numerous communication lines. Some bridges, roads, and railways are not dimensioned sufficiently and this, according to consequence analyses results of the 2002 flood, leads to the increased intensity and frequency of erosion-accumulation as well as destruction manifestations of floods (Hartvich et al. 2007).

This paper presents analysis results of the impacts of basic water management modification types of watercourse beds on the course of extreme floods as calculated using a mathematical hydraulic model. The impacts of weirs, bridges, railway embankments crossing the floodplain, and flood protection dikes are studied by means of hydraulic modelling. The one-dimensional hydraulic model HEC-RAS was used for quantitative assessment of the impact of the interventions in the bed and floodplain geometry.

2. Materials and Methods

2.1 Study Area

The watercourse of the Blanice River in South Bohemia, Czechia, was chosen as the model basin. The specific area used for modelling was the lower part of the stream between Bavorov and the mouth profile at the confluence point with the Otava River (Fig. 1).

The Blanice River basin is situated in the foothills of the Šumava Mountains, and its relief and natural conditions, as well as the intensity of anthropogenic utilization, are variable. The spring area of the river basin

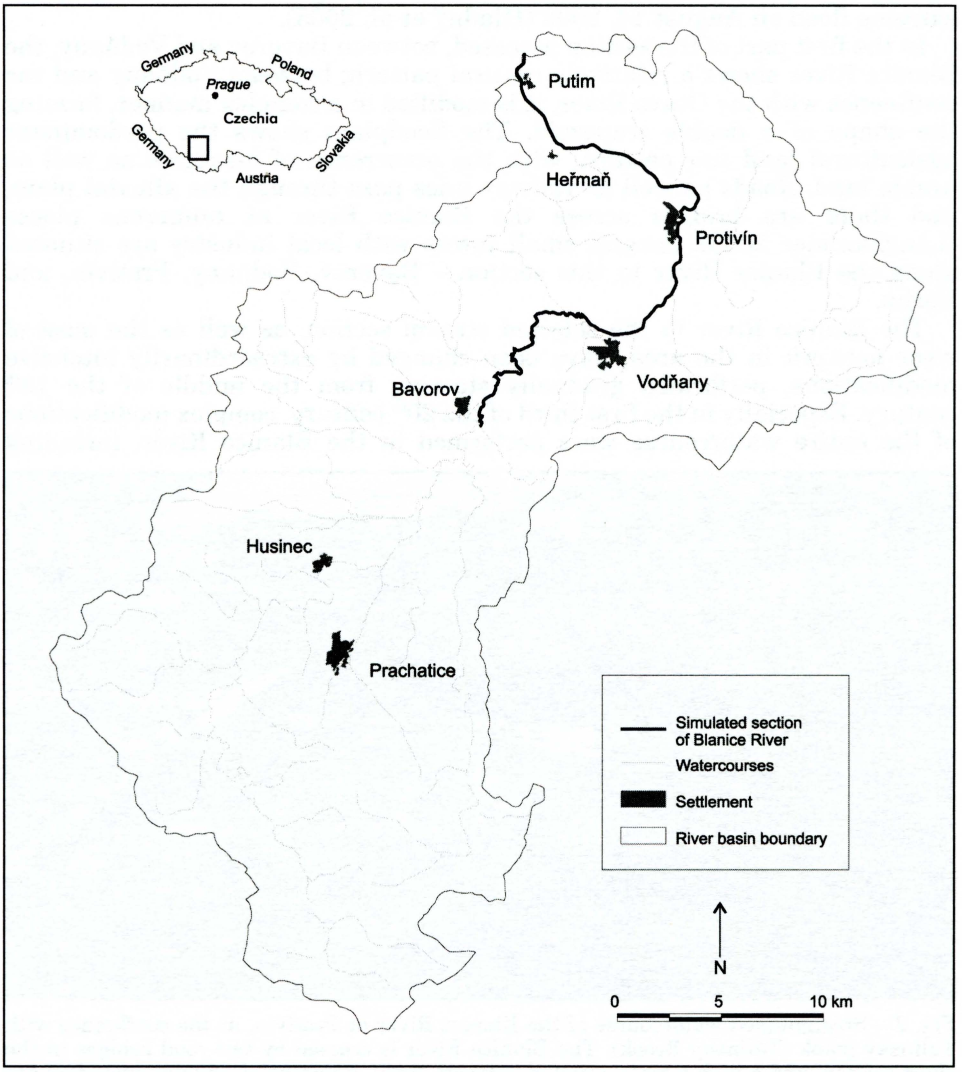

Fig. 1 – Blanice River with the simulated section of stream between Bavorov and the confluence with the Otava River highlighted

reaches into the highest parts of Šumava in the Šumava National Park. The passage to the lowland part, in the area of Prachatice, is steep, and the watercourses achieve a high slope and energy in this area. The lowland part of the river basin on the lower watercourse of the Blanice River from Bavorov features a flat and wide alluvial plain. The plain width varies from 1-2 km in this area.

In the study, the section of the Blanice River and floodplain between Bavorov and the confluence with the Otava River is assessed. The length of this section is 40.5 km; the average long-term flow of the Blanice River in the profile of Heřmaň before the mouth point amounts to 4.65 m^3s^{-1}; Q2=47 m^3s^{-1}; Q100=300 m^3s^{-1}. The highest flow recorded during the period observed corresponds to 443 m^3s^{-1} and was achieved during the second wave of the extreme flood on August 14, 2002 (Hladný et al. 2005).

In the first part of the section assessed, between Bavorov and Vodňany, the Blanice River shows a relatively natural pattern; between Vodňany and the confluence with the Otava River, it is modified in a complex manner, forming the shape of a double trapezoid. The floodplain shows the predominant agricultural land use pattern, with the occurrence of meadows as well as arable land. Roads as well as railway lines pass through the alluvial plain, and there are bridges across the Blanice River at numerous places (Langhammer 2003). Several small towns with local industry are situated along the Blanice River in this section – Bavorov, Vodňany, Protivín, and Putim.

The Blanice River in the selected stream section, as well as the most of river network in the area, have been changed by extraordinarily intensive modifications, performed gradually starting from the middle of the 19^{th} century. Especially in the first third of the 20^{th} century, complex modifications of the entire watercourse were performed in the Blanice River, including

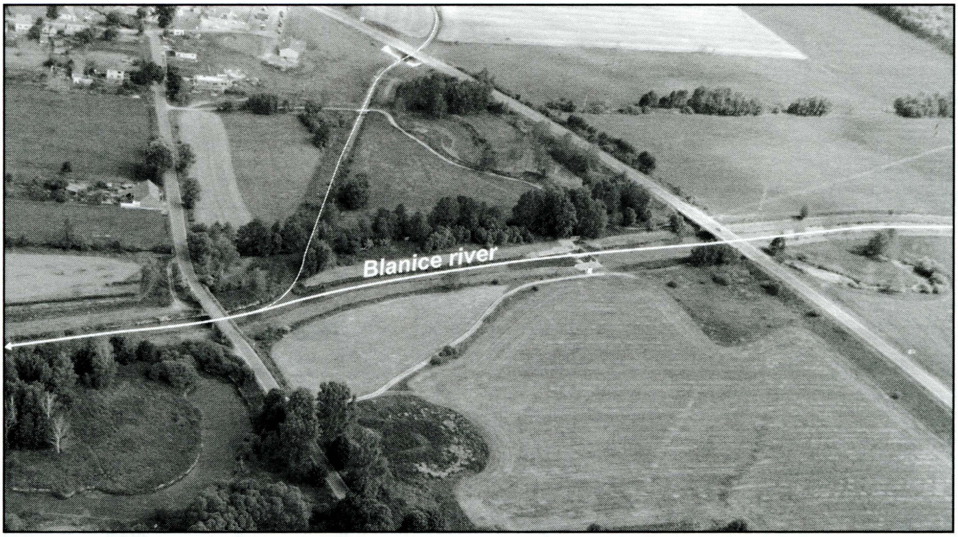

Fig. 2 – Straightened watercourse of the Blanice River at Protivín, at the confluence with Tálínský potok (Tálínský Brook). The Blanice River is crossed by two road bridges in the short section, and a high weir is situated between them. Remains of original meanders are apparent on the left bank, cut off upon straightening the watercourse bed. Photograph by Langhammer 2005

straightening of the stream route, geometric modification of the riverbed, and the building of flood protection dikes in long and compact sections of the watercourse. These modifications prevent efficient usage of the retention and transformation potential offered by the wide and extensively used floodplain (Fig. 2).

2.2 The Model and Its Application to the Blanice River

The one-dimensional hydraulic model HEC-RAS was used to assess the impact of anthropogenic modifications of the Blanice River bed. This model currently represents one of standard tools used in research, as well as application practice, to calculate the flow dynamics in open channels and river beds.

The model HEC-RAS includes a 1D model of non-uniform flow in open beds, HEC2, and a 1D model of variable flow in river beds, UNET. The mathematical basis of the model stems from equations which describe the one-dimensional movement of water in the bed (HEC 2002a). The computational methods used make it possible to take into account flow obstructions, such as bridges, culverts and weirs (HEC 2002a, 2002b).

The model to simulate water flowing through the river bed stems from three groups of input data:

- Transverse profiles of the river bed and adjacent inundation zone
- River bed roughness coefficients
- Boundary conditions.

The definition of the stream channel model by a set of cross-sections was set up by the T.G.M. Water Research Institute in Prague (Havlík et al. 2003, Sitař 2007). The channel geometry was set up based on geodetically surveyed transverse profiles through the floodplain and the river bed, and a digital terrain model. Cross-sections were placed with irregular spacing in an interval of ca. 70-500 m, according to the nature of the floodplain relief and the watercourse bed. The transverse profiles ran across the entire inundation zone; the spacing was chosen in such a manner so that important elements of the plain morphology are captured. In places with rather complex flowing conditions and marked terrain changes, the profile intervals are shorter than 100 m; in the case of uncomplicated sections, they may exceed 400 m (Fig. 3).

The model was calibrated for the flood situation of August 2002. The hydrogram of the flood second wave course from August 2002 was therefore used as a boundary condition; side tributaries and tributaries from the intermediate river basin were not taken into account.

3. Results

Four scenarios of river network changes were simulated. The basic simulation scenario represented the course of the flood in August 2002 on the original model. In the other scenarios of the model, the geometric parameters of the river bed and of the adjacent inundation zone were modified, and the simulation results were compared to the original model results. The following three scenarios of river network modifications were evaluated in regard to their impact on the course of the flood in August 2002:

- Impact of weirs on the flood course

– impact of bridges and road embankments on the flood course
– impact of complex river bed modifications on the flood course.

3.1 The Impact of Weirs on the Flood Course

In the simulated segment of the Blanice River, the stream is marked by 17 weirs. The simulation results showed that their potential removal has a marginal impact on the flood course hydrograms. Comparison of the

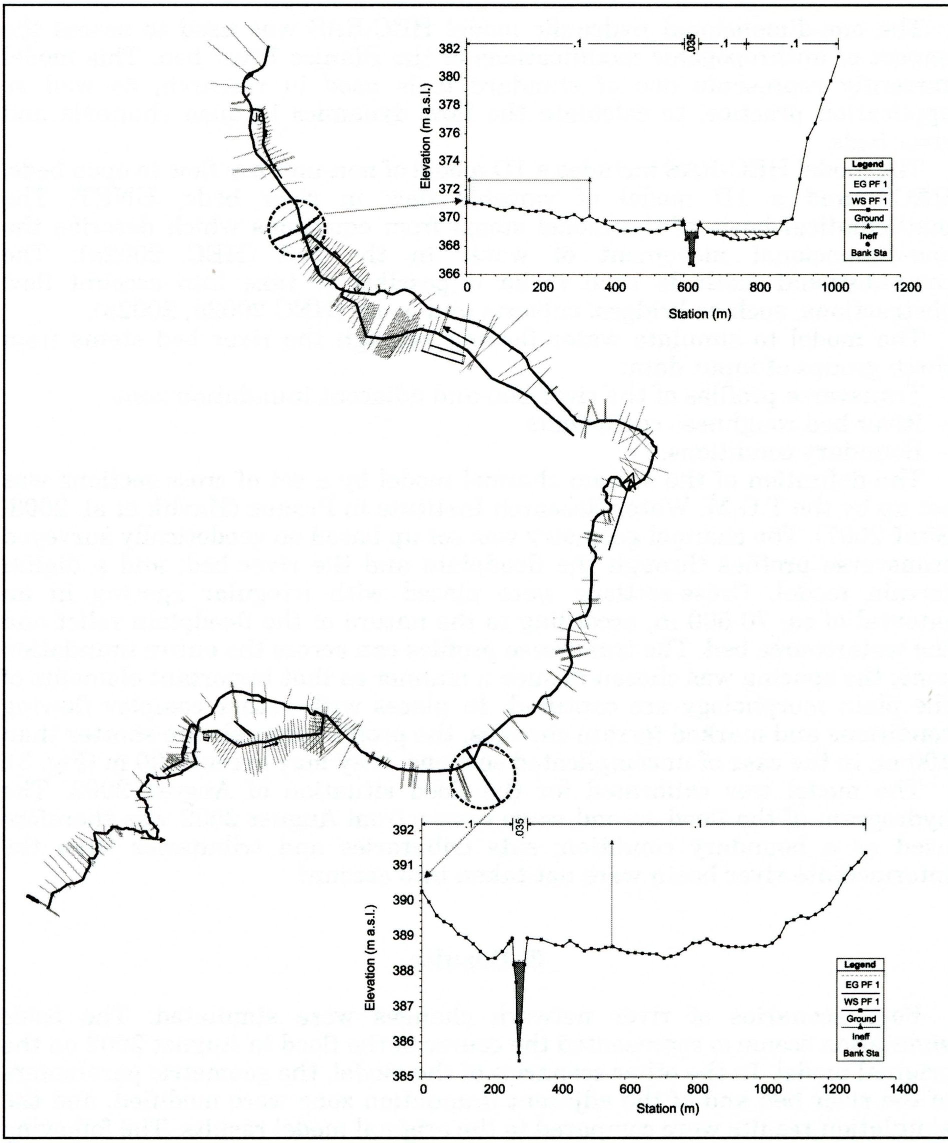

Fig. 3 – Scheme of the Blanice River channel representation in the HEC-RAS model. The scheme shows the frequency of cross-sections and the level of detail used for its construction. Data: VÚV T.G.M. 2002

Tab. 1 – Comparison of the culmination time, flows, and water levels in selected profiles on the Blanice River using the model with and without weirs

Profile	Km	Scenario	Culmination time	Flow ($m^3.s^{-1}$)	Water level (m above sea level)
Bavorov	36.165	With weirs	12.8. 12:45	476.23	419.43
		Without weirs	12.8. 12:45	476.23	419.43
Vodňany	23.400	With weirs	12.8. 20:16	418.87	394.25
		Without weirs	12.8. 20:33	417.06	394.24
Protivín	15.450	With weirs	13.8. 02:17	383.11	383.11
		Without weirs	13.8. 02:45	380.75	383.10
Heřmaň	4.249	With weirs	13.8. 17:08	308.23	371.17
		Without weirs	13.8. 17:53	307.02	371.16

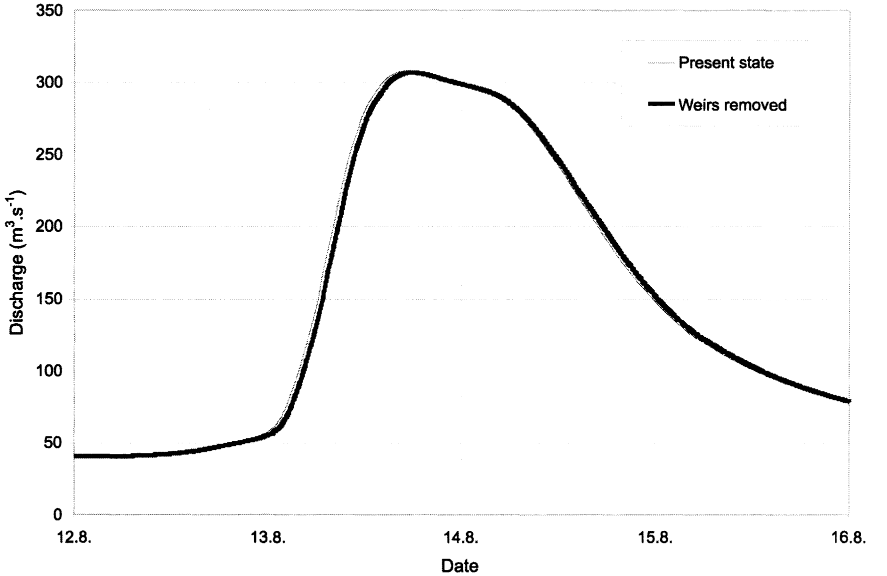

Fig. 4 – Comparison of the course of simulated hydrograms at the Heřmaň profile for the river bed with and without weirs

simulated culmination flows and water levels in Bavorov, Vodňany, Protivín, and Heřmaň is shown in Table 1. In the case of the weir-free model, slightly lower peak flows and water levels were achieved in Vodňany, Protivín, and Heřmaň. The culmination flows differ by 1.81 $m^3.s^{-1}$ in Vodňany, by 2.36 $m^3.s^{-1}$ in Protivín, and by 1.21 $m^3.s^{-1}$ in Heřmaň, representing a difference of 0.43, 0.62, and 0.39 %. The water levels achieved a level lower by only 1 cm.

It follows from the comparison of the culmination times that the time difference of the peak flow time increases downstream. While in Vodňany, this difference is only 17 minutes, in Protivín it reaches 28 minutes, and reaches 45 minutes in Heřmaň. In the case of the model without weirs, partial transformation of the flood wave occurs; however, the differences and their importance for the overall course of the flood are minor.

The impact of weirs on the flood wave shape in Heřmaň is shown in Figure 3. Upon removal of weirs from the river bed model, the culmination time of 5:53pm on August 13 was obtained, with the flow equal to 307.02 $m^3.s^{-1}$ The maximum water level reached 371.16 m above sea level. Compared to the original model, in the case of the weir-free river bed the flood would have culminated 45 minutes later and the flow would have been lower by 1.21 $m^3.s^{-1}$ (Table 1).

In lower water levels, water flowing in the river bed above the weirs slows down. The difference in speed can be observed almost in all weirs, while the differences achieve values up to 0.5 $m.s^{-1}$ (Fig. 4).

The maximum water levels reached are especially decisive for assessment of the flood consequences and of the damage caused as the water level in the culmination has a direct impact on the flooded area. In most profiles, water levels upon removal of the weirs differ only by several centimetres. In 56 % of the profiles, culmination water levels of the model without weirs reach lower values (Tab. 2; Fig. 3). Of these, in 59 % the water level was lower by only 1 cm, representing almost 33 % of the total number of profiles. In 22 % of the profiles, there is no difference. Higher water levels were thus reached in the remaining 22 % profiles. In 96 % of the profiles, the difference of the water levels amounts to a maximum of 10 cm.

3.2 The Impact of Bridges on the Course of the Flood

In second scenario, the bridges were removed from the Blanice River bed model. The course of simulated hydrograms at the Heřmaň profile was compared to the situation corresponding to the actual state of the riverbed under conditions of the August 2002 flood. In the section observed, the model includes a total of 11 bridges. Upon removal of all bridges from the Blanice River bed model, peak flow at the Heřmaň station was reached at 3:37pm on August 13, with the flow equal to 308.70 $m^3.s^{-1}$ (Table 3). The maximum water level reached 371.17 m above sea level. Compared to the original model, the flood culminated 1 hour and 31 minutes earlier, representing an advancement time shortening by 5.3 %. The culmination flow was higher by 0.47 $m^3.s^{-1}$ or by 0.15 %. The water level did not change and reached the same level, i.e., 371.17 m above sea level.

In Vodňany, the flood culminated at almost the same time as in the case of the original model, while further down along the watercourse a marked shift of the culmination time can be observed. In Protivín, the shift reached 1 hour and 6 minutes, and in Heřmaň the culmination time occurred 1 hour and 31 minutes earlier. In Vodňany and Protivín, the flow reached values higher by 2.78 and 14.44 $m^3.s^{-1}$, respectively, a difference of 0.7 and 3.8 %, respectively. The water level did not differ in Vodňany, and in Protivín it was higher by 4 cm. Comparison of the simulated hydrogram shapes in Heřmaň is shown in Fig. 4.

Furthermore, differences of simulated values of the watercourse flowing speeds and water levels in the original model and in the model without bridges were compared in individual profiles of the river bed model. At the beginning of the simulation, the simulated values did not differ; thus the bridges have no crucial impact on water flowing through the river bed when the water levels are lower. At culmination, the bridges do affect flowing of water. Upon removal of the bridges, water flows through the river bed slightly

Tab. 2 – Comparison of the culmination time, flows, and water levels at selected profiles on the Blanice River with various modifications of the river bed geometry and of the inundation zone

Profile	Km	Scenario	Culmination time	Flow ($m^3.s^{-1}$)	Water level (m above sea level)
Bavorov	36.165	Original model	12.8. 12:45	476.23	419.43
		Without bridges	12.8. 12:45	476.23	419.43
		Without bridges and embankments	12.8. 12:45	476.23	419.43
Vodňany	23.400	Original model	12.8. 20:16	418.87	394.25
		Without bridges	12.8. 20:18	421.65	394.25
		Without bridges and embankments	12.8. 20:18	421.61	394.23
Protivín	15.450	Original model	13.8. 02:17	383.11	383.11
		Without bridges	13.8. 01:11	397.55	383:15
		Without bridges and embankments	13.8. 00:35	400.54	383.09
Heřmaň	4.249	Original model	13.8. 17:08	308.23	371.17
		Without bridges	13.8. 15:37	308.70	371.17
		Without bridges and embankments	13.8. 14:51	310.92	371.17

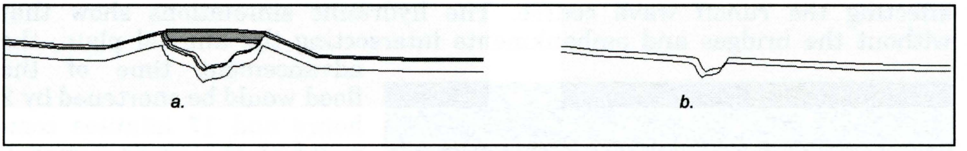

Fig. 5 – Scheme of modification of bridge and embankments in the simulated scenario – before modification (a) and upon modification (b)

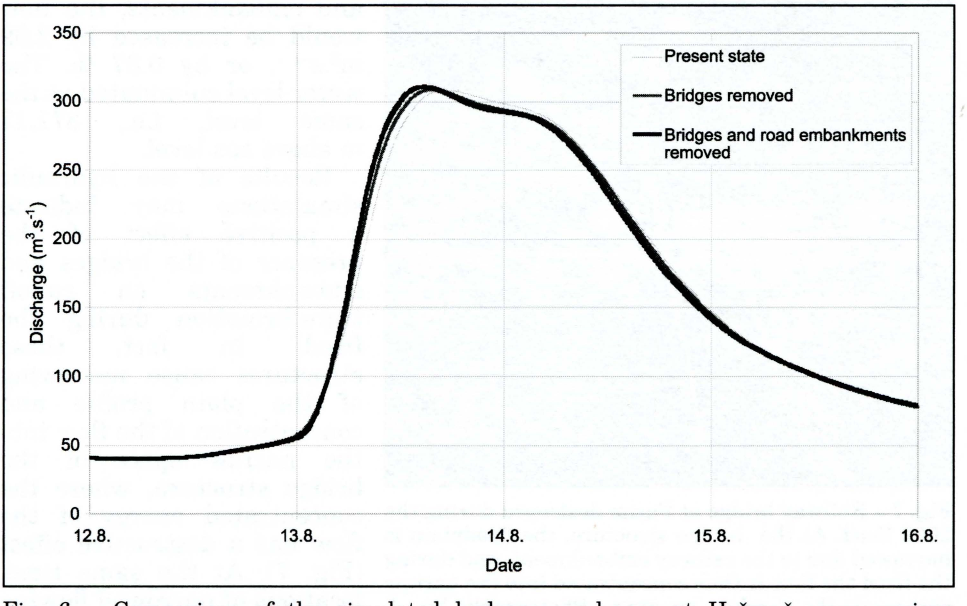

Fig. 6 – Comparison of the simulated hydrogram shapes at Heřmaň upon various modifications of the river bed geometry and of the inundation zone

faster. The most marked difference can be observed above the bridge located at km 27.5; upon removal of this bridge, water flowing would be faster by 0.91 $m.s^{-1}$. In other bridges, the differences are not as distinct and differ in the range of 0.1 to 0.2 $m.s^{-1}$. Together with accelerated water flow, the flow values increased as well. Maximum differences reached up to 14.5 $m^3.s^{-1}$ in places.

In places where the bridges are found, the river bed shape and the adjacent inundation zone are often modified as well. In these places, the river bed is deepened, and road embankments are found in the inundation zone, representing obstructions to water flow.

A subscenario was tested to simulate the effect of removal of the bridges plus modification of the respective stream cross-sections by removing the road embankments while the terrain level of the floodplain and the riverbed was preserved (Figure 5).

By modifying the inundation zone geometry so that the road embankments would not form an obstruction to the flow, further acceleration of the flood advancement was achieved as expected, as well as an increase of the flow culmination values at selected profiles (Tab. 2). Culmination of the flood wave in Heřmaň thus occurred on August 13, 2002 at 2:51pm, with the flow equal to 310.92 $m^3.s^{-1}$.

From comparison of the simulated hydrogram shapes at the Heřmaň profile (Fig. 6), it follows that the bridges and road embankments take part in affecting the runoff wave course. The hydraulic simulations show that without the bridges and embankments intersecting the alluvial plain, the advancement time of the flood would be shortened by 2 hours and 17 minutes compared to the original model, i.e., approximately by 8 %. In the scenario without bridges and embankments, the flow would be increased by 2.69 $m^3.s^{-1}$, or by 0.87 %. The water level culminated at the same level, i.e., 371.17 m above sea level.

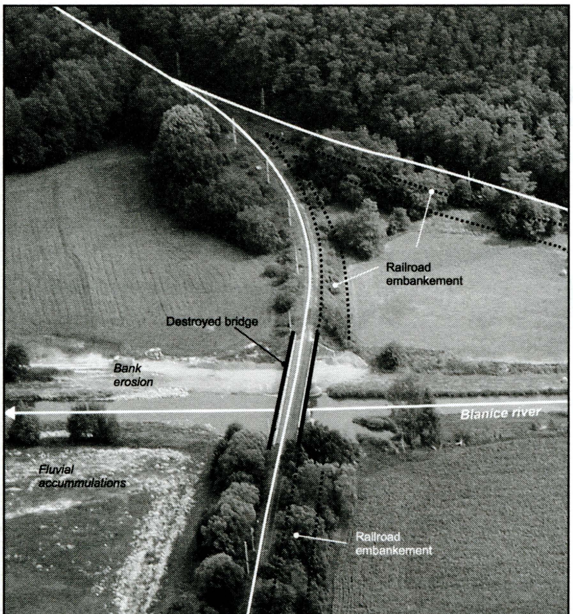

Fig. 7 – Railway bridge at Putim destroyed during the 2002 flood. At the bridge structure, the floodplain is narrowed due to the railway embankment, and during the flood the flow is thus concentrated into the narrow space of the bridge opening. Photograph by J. Langhammer, 2003

Results of the hydraulic simulations may indicate a positive effect of the presence of the bridges and embankments on runoff transformation during the flood. In fact, these structures cause narrowing of the plain profile and concentration of the flow into the narrow space of the bridge structure, where the concentrated energy of the flow has a destructive effect (Fig. 7). At the same time, locations of narrowed flowing often tend to become blocked

Tab. 3 – Comparison of the culmination times and flow values and water levels achieved in the case of the original model and the model with modified transversal profiles at selected profiles of the Blanice River

Profile	Km	Scenario	Culmination time	Flow ($m^3.s^{-1}$)	Water level (m above sea level)
Bavorov	36.165	Original	12.8. 12:45	476.23	419.43
		Without dikes	12.8. 12:45	476.23	419.43
Vodňany	23.400	Original	12.8. 20:18	418.76	394.25
		Without dikes	12.8. 20:33	417.06	394.24
Protivín	15.450	Original	13.8. 02:42	377.07	383.10
		Without dikes	13.8. 02:45	380.75	383.10
Heřmaň	4.249	Original	13.8. 17:08	308.23	371.17
		Without dikes	13.8. 17:46	306.62	371.02

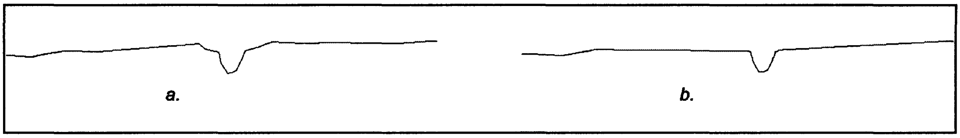

Fig. 8 – Cross-section of the innundation zone at km 8.385 before modification of the profile (a) and after modification (b)

by materials carried by the flood, causing subsequent acceleration of erosion processes in the surroundings of the artificial obstruction, and upon its rupture, a massive accumulation of the carried materials occurs, and a secondary flood wave is often caused.

3.3 The Impact of Complex River Bed Modifications on the Course of the Flood

In the lower part of the Blanice River, from Vodňany to its confluence with the Otava River, a complex modification of the river bed can be seen. In this section, the river bed shows a trapezoidal shape with flood protection dikes on the banks. The modification was performed in the 1920s when the Blanice River was straightened considerably. This is a marked anthropogenic intervention in the river bed shape, leading to its increased capacity. The modification should be dimensioned for design flow of up to 90 $m^3.s^{-1}$ (Šobr 2005).

For this simulation scenario, the cross-sections of the river bed and inundation zone were modified so the elevations representing the dikes were removed from both banks of the river bed (Fig. 8).

The simulation results were compared again to the values achieved in the original model (Table 3). Upon modification of the shapes of transversal profiles, the flood culminated at Heřmaň at 5:46 pm, with a flow equal to 306.62 $m^3.s^{-1}$ and with a water level of 371.02 m above sea level. The advancement time of the flood was extended by 38 minutes, the peak flow was reduced by 1.61 $m^3.s^{-1}$, and the water level was reduced by 15 cm.

Upon removal of barriers from the river channel, flows and water levels decreased at the beginning of the simulation at most of the assessed profiles. The decrease of peak discharge was 0.78 $m^3.s^{-1}$ at the maximum (Fig. 9); the water level differences varied from 1 to 22 cm.

By means of modifying the river bed and the inundation zone geometry, flow conditions changed. This was manifested in decelerated advancement of

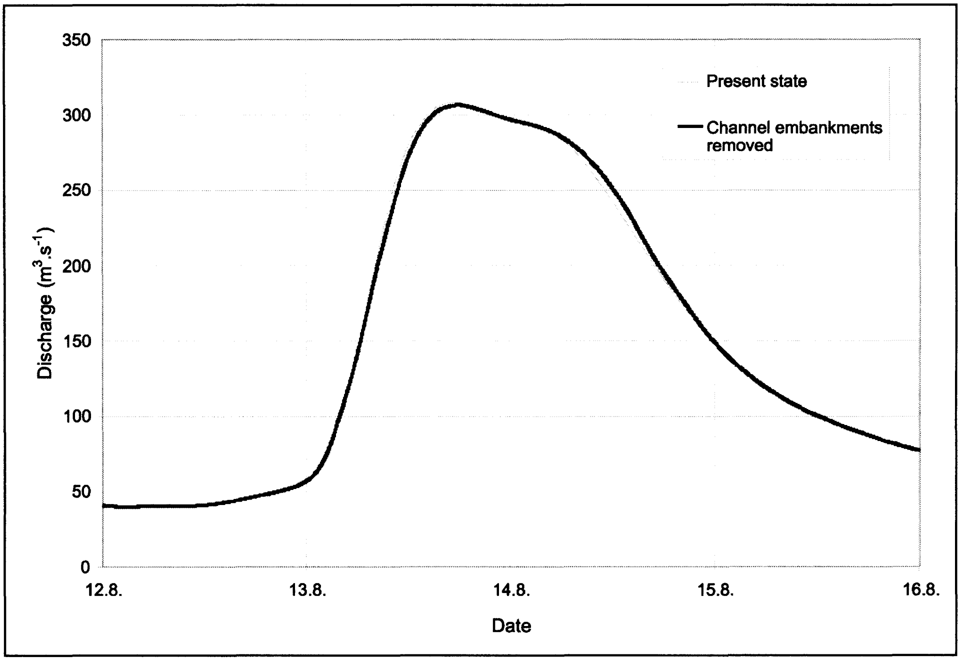

Fig. 9 – Comparison of the simulated hydrogram shapes at Heřmaň in the case of the original model and the model with the modified transversal profile shape

the flood and in a decrease of culmination water levels in most of the modified profiles.

4. Discussion and Conclusions

Results of the model helped to quantify the outcomes and assumptions of preceding studies dealing with the impact of river bed modifications on the course of floods in extreme events (Bryant, Gilvear 1999; Havlík 2002; De Roo et al. 2001). Scenario-based modelling of the course of the 2002 flood in the Blanice River confirmed that in extreme events, the impact of modifications which affect the river bed roughness and flow conditions was minimum, and that such modifications of the watercourse and riparian zone had no essential impact on the time course and the flood wave transformation (Langhammer, Vilímek 2007).

On the contrary, an important role is played by modifications acting as potential flow obstructions, which include bridges and road embankments crossing the inundation zone (Havlík et al. 2002). The impact of unsuitably localised or insufficiently dimensioned constructions of bridges and culverts leads to local increases of the flow dynamics, and moreover, extreme manifestations of destruction can be seen regularly in such localities, as well as erosion and accumulation of materials carried by the flood.

Out of the river bed modifications and floodplain modifications assessed, the effect of complex river bed modifications were the most important; however, overall results in all scenarios show that the impact of the modifications assessed on the course of the 2002 flood was negligible.

Simulations of the impact of weirs on flow during the flood showed that under extreme runoff conditions when maximum water level is up to several metres higher than normal values, the effect of weirs on the flow dynamics is minimal. The impact of theoretical removal of the weirs on the achieved peak flows is marginal – the decrease of peak flow reaches slightly less than one per cent of the flow, while the flood duration time can be extended by up to 45 minutes.

However, the impact of weirs on the course and consequences of the flood consists especially of affecting the dynamics of fluviomorphological processes in which the weirs act as centres of intensive erosion, accumulation, and destruction in the river bed and in the floodplain (Křížek, Engel 2004). However, hydraulic models cannot capture these aspects of the flood activity.

Simulations of the effect of bridges and road embankments intersecting the floodplain had similar outcomes. The model results indicated the seemingly positive effect of these constructions on the runoff transformation. Upon their removal, the flood advancement was accelerated by more than 2 hours, and observable lowering of the water level occurred. This result should be interpreted in relation to the fluvial processes occurring in the riverbed and floodplain during the floods. Deceleration of flow beyond the embankment and bridge bodies does not represent a positive effect which could be indicated by mechanistic interpretation of model results. It is rather the opposite, as in floods these objects represent one of the most critical elements of the river network (Langhammer 2003). Construction of bridges and culverts causes temporary blockage by materials carried by the flood and formation of temporary flow barriers. Upon their rupture, the bridge or culvert structure is usually damaged, and extensive erosion and accumulation occurs in the immediate surroundings. Moreover, a sharp increase of the flow upon destruction of these artificial obstructions can complicate the course of the flood within the lower sections of the watercourse.

The most valuable results from the viewpoint of their practical applicability were the simulation of complex river bed modifications, including the impact of flood protection dikes. The issue of the impact of intensive watercourse modifications on the extremity of extraordinary floods was intensively discussed in connection with extreme floods in 1997 in Moravia and in 2002 in Bohemia, and has also been systematically studied in different geographical regions (Langhammer, Vilímek 2007). The findings based on the modelling results in the Blanice River confirm the general assumptions formulated in the different physiogeographical conditions.

The impact of complex modifications of the river bed on the flood course is of crucial importance. However, under extraordinary levels of flood magnitude, as was the case of the August 2002 flood, these modifications did not have essential impact on the course and magnitude of the entire event. Extension of the flood duration time upon removal of the barriers amounts to 38 minutes, which represents a change of 2.2 %. Reduction of the culmination flow amounts to 0.52 % of the maximum value achieved; the water level decreased by 15 cm, corresponding to 3.2 %; and the overall range of the flood decreased by 4.4 %.

The reason for such small impacts of individual river beds and floodplain modification types and their simulated removal on transformation of the flood wave in 2002 can be seen in unprecedented extremity of the flood event. In the situation when the entire area of the floodplain is engaged in the runoff, and when even overflowing of the flood protection barriers occurs, watercourse modifications assessed have only marginal influence on the flow dynamics within the inundation zone. However, the effects of such types of river bed modifications will be substantially higher in cases of events with a lower magnitude.

Moreover, the study also indicated also the limits of a purely hydraulic assessment of the flood course. Modifications of the river bed, which from hydrodynamic viewpoint have a positive impact on transformation of the runoff, represent in fact a source of a considerable risk. Detailed analyses of the consequences of recent extreme flood events pointed out this fact (Langhammer, Vilímek 2007; Sear, Newson 2003; Vilímek, Kalvoda 1998). However, these processes cannot be assessed using hydrodynamic models, which can simulate only water movement in an open channel. In order to interpret the results, it is always necessary to take into account the complex nature of the processes taking place within the floodplain during the flood.

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Shrnutí

MODELOVÁNÍ VLIVU ANTROPOGENNÍCH ÚPRAV KORYTA TOKU NA PROUDĚNÍ PŘI EXTRÉMNÍ POVODNI

Příspěvek ukazuje možnosti hodnocení vlivu antropogenních úprav koryta a inundačního území na průběh povodní pomocí metod hydraulického modelování. Antropogenními zásahy do koryt toků mohou v závislosti na podmínkách prostředí a extremity povodně významně ovlivňovat průběh a následky povodní v lokálním měřítku i v měřítku povodí jako celku. Mezi úpravy, které mohou nejvýrazněji ovlivnit průchod povodňové vlny inundačním územím patří změny vedení trasy koryta, úpravy podélného profilu toku, změny příčných profilů a změny v charakteru využití území údolní nivy a příbřežní zóny. Vhodný nástroj pro podrobnou kvantitativní analýzu dynamiky proudění v korytě a inundační zóně a její změny v důsledku úprav říční sítě představují v současné době hydraulické modely, propojené s GIS.

Studie představuje výsledky analýzy vlivu základních typů vodohospodářských úprav koryt toků na průběh extrémní povodně, zpracované pomocí matematického hydraulického modelu. Z typů úprav je zkoumán vliv jezů, mostů, náspů vedených napříč údolní nivou a povodňových hrází.

V příspěvku je použit použit hydraulický jednorozměrný model pro simulaci proudění vody v otevřených korytech HEC-RAS. Otázka vlivu antropogenních změn koryta toku na průběh povodně je hodnocena na příkladu povodí jihočeské Blanice pro situaci odpovídající extrémní povodni ze srpna 2002.

Výsledky simulací potvrdily předpoklad, že antropogenní úpravy koryt vodních toků a přilehlého inundačního území ovlivňují celkový průběh extrémních povodní jen minimálně. Na průběh povodně mají na lokální úrovni negativní vliv jezy a nevhodně dimenzované mosty, simulace rovněž prokázaly negativní vliv rozsáhlých komplexních úprav koryta, které byly provedeny na dolním toku Blanice v 1. polovině 20. století, celkový vliv na průtok či vodní stav při kulminaci a na dobu doběhu povodně je zanedbatelný.

Výsledky navíc ukazují i na limity ve využití výsledků hydraulického modelování pro hodnocení povodnňového rizika. Některé typy úpravy koryta, jmenovitě jezy totiž z čistě hydrodynamického pohledu indikují pozitivní vliv na transformaci odtoku, při povodňové situaci však naopak představují výrazný zdroj rizika vzhledem k akceleraci fluviálně morfologických procesů v korytě toku a údolní nivě. Tyto procesy však běžnými hydrodynamickými modely, které se soustředí pouze na simulaci pohybu vody v otevřeném korytě, není možné simulovat. Intepretaci výsledků modelování je zapotřebí vždy provádět v kontextu komplexního charakteru rizikových procesů, probíhajících v údolní nivě při povodni.

Obr. 1 – Modelovaný úsek toku Blanice mezi Bavorovem a soutokem s Otavou.
Obr. 2 – Napřímený tok Blanice u Protivína v místě soutoku s Tálínským potokem. Tok Blanice protínají na krátkém úseku dva silniční mosty, mezi kterými je situován vysoký jez. Na levém břehu jsou zřejmé pozůstatky původních meandrů, odříznutých při napřímení koryta toku. Foto Langhammer 2005.
Obr. 3 – Ukázka definice korytového modelu Blanice v modelu HEC-RAS. Schéma zobrazuje proměnlivou četnost příčných profilů a jejich podrobnost. Data: VÚV T.G.M. 2002.

Obr. 4 – Srovnání průběhu simulovaných hydrogramů v profilu Heřmaň v případě koryta s jezy a bez jezů.
Obr. 5 – Schéma úpravy mostu a hrází ve varianě modelu před úpravou profilu (a) a po úpravě (b).
Obr. 6 – Srovnání tvaru simulovaných hydrogramů v Heřmani při různých úpravách geometrie koryta a inundačního území.
Obr. 7 – Železniční most u Putimi, stržený při povodni 2002. V místě mostní konstrukce je díky náspu železnice zúžená niva a proud při povodni je tak koncentrován do úzkého prostoru mostního otvoru. Foto Langhammer 2003.
Obr. 8 – Profil 8,385 před úpravou (a) a po úpravě (b).
Obr. 9 – Srovnání tvaru simulovaných hydrogramů v Heřmani v případě původního modelu a modelu s upraveným tvarem příčných profilů.

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LUDĚK ŠEFRNA, FRANCO PREVITALI, ROBERTO COMOLLI, DAVIDE CANTELLI, MIRJANA ZDRAVKOVIČ

TRACE ELEMENTS IN SOILS IN THE NORTHERN AND THE CENTRAL TIAN-SHAN (KAZAKHSTAN - KYRGYZSTAN)

L. Šefrna, F. Previtali, R. Comolli, D. Cantelli, M. Zdravkovič: *Trace elements in soils in the northern and the central Tian-shan (Kazakhstan – Kyrgyzstan).* – Geografie–Sborník ČGS, 113, 3, pp. 253–268 (2008). – The present paper examines and compares heavy metal contents in soils from two altitudinal sequences in the northern and the central Tian-Shan mountains. The soil horizons of 11 sites were described, sampled, analysed, interpreted and classified. Results show that pedological processes similar to those responsible for the development of steppe chernozems are active even at very high elevations. This is probably in part due to the presence of blankets of aeolian silt deposited recently and in the past.
In order to verify the degree of accumulation and possible ecotoxicity, the distribution and mobility of Cd, Cr, Cu, Zn, Pb, and Ni within soil profiles were checked. Relationships among elements and other pedological parameters, such as organic carbon content, pH, texture, etc., were investigated. Lastly, the possible risk of contamination was assessed.
KEY WORDS: trace elements – soils – Tian-Shan – taxonomy.

1. Introduction

Soil profiles situated northwest and east-southeast of Lake Issyk-Kul (Fig. 1) in the central Tian-Shan mountains (Kazakhstan and Kyrgyzstan) were investigated. Two previous works (Comolli et al. 2003, Previtali et al. 1997) discussed findings on relationships among soils, climatic conditions, vegetation cover and landforms.

This work examines the soil content of trace elements considered to be good indicators of possible soil contamination at high altitudes (2,000–3,000 m a. s. l.), which is often due to atmospheric contributions. Trace element contents in high altitude glaciers and soils from various parts of the world are often higher than expected. This is due to the fact that atmospheric transport and fallout bring human-induced pollution to regions even very distant from the source.

2. Geography, Geology and Geomorphology

The Tian-Shan mountain belt extends for about 2,500 km from the Syrdarja River basin in the west to the Gobi Desert in the east. The belt is characterised by several parallel E-W-trending mountain systems, with elevations frequently exceeding 5,000 m. The mountain system is about 600

Fig. 1 – Geographic location of the study area

km wide from the northern Kazakh shield to the southern Tarim block. Between 2,000 and 3,000 m a. s. l., ridges are separated by depressions either partially filled with glacial, fluvioglacial and alluvial deposits or occupied by lakes (e.g., Alma-Atijnskoe Ozero). The major rivers in this region, the Čylyk and Čon-Kemin, flow respectively to the east and west and have their sources in the area between the Zailijskij Alatau and the Kjungej Ala-Too ranges.

Soils, their forming factors and geochemical load along two transects were investigated between latitudes 42°10'N and 43°10'N and longitudes 76°45'E and 78°32'E. Soil sites are situated at altitudes ranging between m 2,000 and m 3,500 a. s. l.

Two different physiographic districts, located respectively south of the town of Alma-Ata and south of Prževal'sk, were identified (Figures 2 and 3):

– the Northern District (north of Lake Issyk-Kul)
– the Eastern District (east of the lake).

In the Northern District, to the south of Alma-Ata, the Quaternary loess cover and glaciofluvial deposits extend over large areas. The loess mantle is in places up to 20–30 m thick. Devonian granites and granodiorites constitute the near mountain chains (Ministry of Geology of SSSR 1983, Abdulin et al. 1984). Around Lake Alma-Atijnskoe, Ordovician gabbros and norites are associated with granites (Tibaldi et al. 1997).

Further south, having crossed the watershed, in the Kyrgyz Republic, several large faults mark a sharp lithological change from igneous formations

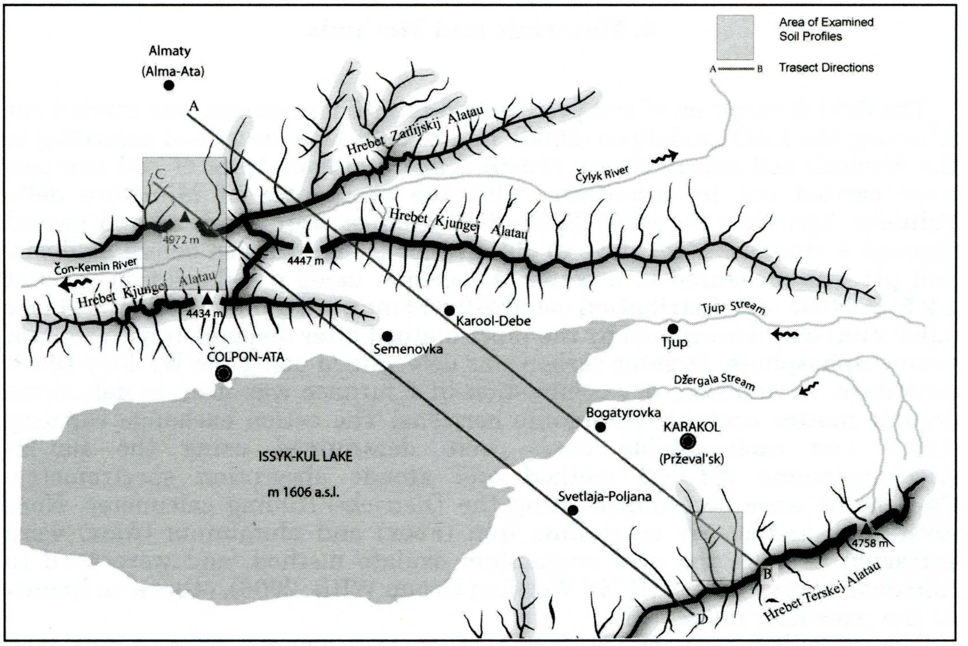

Fig. 2 – Major mountain ranges and rivers in the investigated area. A–B and C–D are the transect directions

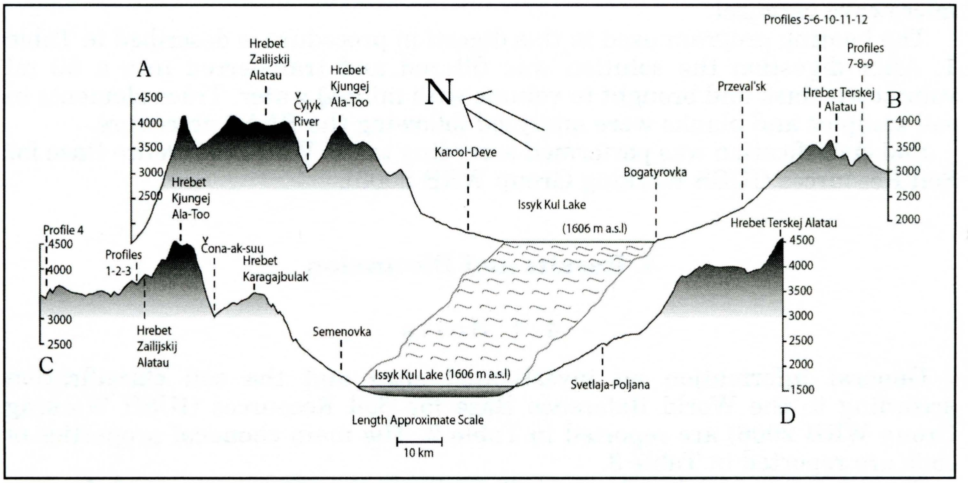

Fig. 3 – Cross sections A–B and C–D showing the location of soil profiles

to sedimentary (mainly sandstones and conglomerates) and metamorphic (phyllites, slates, greenschists, amphibolites) ones.

In the Eastern District, near Prževal'sk, the Tertiary sedimentary formations dominate, while further south deep faults place them in spatial continuity with Precambrian and Palaeozoic igneous masses (granodiorites, granites, and gabbros) locally alternating with metamorphic, extrusive igneous and carbonate rocks.

3. Materials and Methods

The field description of soil profiles and their environment was carried out following the FAO guidelines (2006). Soil colours were described according to the Munsell soil colour charts (2000). Laboratory analyses of soil samples were carried out in accordance with the procedures of Ministero delle Politiche Agricole e Forestali (2000). Soil samples were air-dried and passed through a stainless steel sieve to obtain the <2 mm fraction before analysis. Soil pH was measured in a water suspension using a soil:solution ratio of 1:2.5. Particle size distribution (sand 2-0.050 mm, silt 0.050-0.002 mm, clay < 0.002 mm) was determined by the pipet method after dispersion with sodium exametaphosphate. Organic carbon was determined using the Walkley-Black procedure. In addition, dry combustion in a furnace was used to determine organic matter contents in organic horizons. The cation exchange capacity (CEC) and exchangeable bases were determined using the BaCl2-triethanolamine pH 8.2 method and atomic absorption spectrometry. Carbonates were determined using the Dietrich-Frühling calcimeter. Non-crystalline and poorly crystalline iron (Feox) and aluminium (Alox) were extracted through the acid ammonium oxalate method, and were used to calculate Alox+1/2 Feox (IUSS Working Group WRB, 2006), otherwise known as the „spodicity index“ (SI).

The so-called pseudototal forms of trace elements were determined following the Bettinelli et al. (2000) procedure. About 250 mg of sample were transferred into microwave vessels with 8 ml of aqua regia and placed into the microwave carousel.

The heating program used in this digestion procedure is described in Table 1. After digestion the solution was filtered and transferred into a 50 ml volumetric flask and brought to volume with milli-Q water. Trace elements in soil samples and blanks were analysed following the FAAS procedure.

Soil classification was performed according to the World Reference Base for Soil Resources (IUSS Working Group WRB 2006).

4. Results and Discussion

4.1 Soils

General information on investigated sites and the soil classification according to the World Reference Base for Soil Resources (IUSS Working Group WRB 2006) are reported in Table 2. The main chemical properties of soils are reported in Table 3.

Survey data and laboratory results indicate that Quaternary soil forming processes similar to the melanization responsible for the development of modern steppe-chernozems are active even at very high elevations. Such processes seem to be most likely enhanced by the presence of both loess-like aeolian covers and particular climatic conditions (Comolli et al. 2003, Previtali et al. 1997).

On the contrary, in both surveyed districts, the B horizons

Tab. 1 – Heating program for microwave digestion

Step	1	2	3
Power (Watt) Hold time (min)	250 2	400 2	500 10

Tab. 2 – Soil profile location, environmental data and soil classification

NORTHERN DISTRICT						
Profile	Location	Elevation m a. s. l.	Aspect	Slope (%)	Classification (WRB 2006)	Parent material
No. 1	Ak-Su Stream 42°53'N 77°05'E	3,140	E	3–4	Haplic Regosol (Eutric, Gelic)	Bouldery, pebbly and loamy diamicton over schist debris
No. 2	Čong-Kemin River 42°54'N 77°03'E	2,980	360°	Level	Haplic Phaeozem (Silty)	Alluvial deposit, buried by aeolian material
No. 3	Prahodnaia Stream 43°03'N 76°55'E	2,160	W	80-100	Haplic Cambisol (Eutric)	Igneous rock debris and diamicton
EASTERN DISTRICT						
No. 4	South of Prževal'sk, Karakol Stream 42°19'N 78°26'E	2,755	SE	80	Phaeozem (Skeletic, Arenic)	Granite and marble talus deposit
No. 5	South of Prževal'sk, Karakol Stream 42°19'N 78°27'E	2,850	N	70	Haplic Phaeozem (Pachic, Episkeletic)	Slate debris of alluvial fan, buried by aeolian silt
No. 6	South of Prževal'sk, Kol-Ter Stream 42°17'N 78°31'E	3,455	NE	40	Mollic Leptosol (Humic, Gelic)	Silty loam colluvial mudflow over solid granite, buried by aeolian silt
No. 7	South of Prževal'sk, Uyun-Ter Stream 42°13'N 78°30'E	3,600	SSE	10	Haplic Regosol (Eutric, Gelic)	Bouldery sandy loam ancient diamicton, buried by aeolian silt
No. 8	South of Prževal'sk, Uyun-Ter Stream 42°14'N 78°31'E	3,600	NW	15	Haplic Regosol (Eutric, Gelic)	Recent bouldery diamicton
No. 9	South of Prževal'sk, Karakol Stream 42°19'N 78°29'E	2,450	360°	Level	Gleyic Mollic Fluvisol (Humic, Endoskeletic)	Alluvial deposits
No. 10	South of Prževal'sk, Karakol Stream 42°19'N 78°28'E	2,470	W	80	Haplic Regosol (Humic, Eutric)	Crystalline schists and serpentinites talus deposit
No. 11	South of Prževal'sk, Karakol Stream 42°19'N 78°27'E	2,695	E	70	Haplic Cambisol (Humic, Eutric)	Crystalline rocks talus deposit

Tab. 3 – Main chemical properties of soils

Profile	Horizon	Depth (cm)	Colour (moist)	pH (H_2O)	$CaCO_3$ (%)	Org. C (%)	O. M. (%)	CEC (cmol⁺ kg⁻¹ soil)	Spodi-city Index (%)	Particle size distribution sand (%)	silt (%)	clay (%)
NORTHERN DISTRICT												
No. 1	Ah	0–10	10YR 2/2	6.5	0.0	6.6		37.8	0.62	28	63	9
	BA	10–40	10YR 3/3	6.6	0.0	2.8		35.6	0.71	21	65	14
	C/R	40–50+										
No. 2	A	0–20	10YR 3/2	6.0	0.0	3.8		47.0	0.75	19	57	24
	AC	20–60	10YR 3/3	6.4	0.0	1.2		39.1	0.62	26	59	15
	2C	60–80+										
No. 3	Oe	5–0	10YR 2/1									
	Ah	0–10/15	10YR 3/2	5,7	0.0	4.8		27.8	0.34	47	38	15
	BA	10/15–25/30	10YR 3/3	5.9	0.0	0.7		9.1	0.21	40	22	8
	C	25/30–50+			0.0							
EASTERN DISTRICT												
No. 4	Ah1	0–9	10YR 2/2	5.9	0.5	12.5		63.8	0.31	63	31	6
	Ah2	9–15	10YR 2/2	6.0	0.0	9.2		56.5	0.38	53	38	9
	2A	15–38	10YR 3/2	5.9	0.2	2.1		30.9	0.35	26	55	19
	2Bw	38–58	10YR 4/3.5	5.8	0.7	0.6		19.6	0.20	59	29	12
	2CB	58–75+	10YR 5/3	5.3	0.9	0.4		20.8	0.17	39	43	18
No. 5	Oi	0.5–0										
	Oe	0–3	10YR 3/2	5.5	0.6		65.3		0.27			
	Oa	3–6	10YR 2/2	5.4	1.4		50.3		0.42			
	Ah1	6–12	10YR 2/2	5.7	0.6	13.6		74.0	0.42	14	75	11
	2Ah2	12–40	10YR 3/2	6.5	0.9	6.6		50.4	0.25	50	45	5
	2AC	40–55	10YR 3/3	7.2	0.1	2.1		15.7				
	2C	55–75+	10YR 4/2									
No. 6	Oi	0.5–0										
	Oa	0–2	10YR 2/2	5.8	0.8		51.2		0.27			
	Ah	2–4	10YR 3/3	5.5	0.0	8.0		41.1		33	62	5
	AB	4–24	10YR 3.5/3	5.2	0.0	2.6		26.2	0.41	19	72	9
	2R	24–45+										
No. 7	Oi	0.5–0										
	Oa	0–3	10YR 2/2	6.1	0.6		68.1		0.13			
	Ah	3–6	10YR 2.5/2	5.7	0.0	13.4		67.5		62	36	2

Tab. 3 – Main chemical properties of soils

Profile	Horizon	Depth (cm)	Colour (moist)	pH (H_2O)	$CaCO_3$ (%)	Org. C (%)	O. M. (%)	CEC ($cmol^+$ kg^{-1} soil)	Spodi-city Index (%)	Particle size distribution		
										sand (%)	silt (%)	clay (%)
	2A	6–9	10YR 3/2	5.6	1.1	6.1		48.4	0.47	33	63	4
	3CB	9–20	1Y 4/5	5.9	0.0	1.0		9.4	0.20	68	28	4
	3C	20–60+	2.5Y 4.5/3	6.6	0.3	0.5		9.3	0.18	70	25	5
No. 8	Oi	0.5–0										
	Oa/Oe	0–2	10YR 2/2	5.7	0.0		47.2					
	A	2–6	10YR 3/3	5.1	0.3	5.6		29.9	0.34	63	34	3
	CA	6–19	2.5Y 4/4	5.6	1.0	1.8		9.4	0.14	72	35	3
	C	19–45+	5Y 4/1	5.9	0.0	0.4		5.6	0.09	76	20	4
No. 9	Ap	0–8	10YR 3/1	7.1	0.3	6.1		27.4				
	C	8–45	2.5Y 4/2	7.5	1.7	1.4		14.0	0.13	42	50	8
	Cg	45–55	5Y 4/1	7.2	1.2	1.2		10.4	0.07	29	66	5
	2Cg2	55–65+	10YR 4/5	7.2	0.1	0.4		7.8	0.18	43	51	6
No. 10	Oi	2–0										
	Oe	0–5	10YR 2/1	5.0	1.4		52.1		0.33			
	Ah	5–21	10YR 3/3	4.5	0.6	6.4		49.1	0.40	40	45	15
	CA	21–65+	2.5Y 4/4	5.8	0.0	1.5		17.6	0.15	62	25	13
No. 11	Oi	2–0										
	Oe	0–2	10YR 2/1	6.0	0.0		45.0					
	A	2–7	10YR 3/2	5.7	0.0	13.6		72.9	0.24	31	55	14
	AB	7–16	10YR 3/3	5.4	0.5	2.4		30.5	0.30	49	37	14
	Bw	16–60	10YR 4/4	5.8	0.2	2.1		33.7	0.37	45	40	15

do not meet the diagnostic requirements of the different taxonomic systems for typical spodic (podzolic) B horizons. Only in the Northern District, profiles No. 1 and 2 show a marked increase in non-crystalline and poorly crystalline iron (Feox) and aluminium (Alox) with depth, probably as a result of the more abundant rainfall in the area.

4.2 Trace Elements

In order to assess the geochemical content of each individual soil sample and its possible contamination, values must be referred to average values, to the parent material background and to thresholds. Unfortunately, the mean and range concentrations of trace elements in soils proposed in the literature are significantly divergent (Allaway 1968; Kabata-Pendias, Pendias 1984, 2001;

Tab. 4 – Reports concentrations of six trace elements in Northern and Eastern district soil profiles

Profile	Horizon	Depth (cm)	Cu mg kg^{-1}	Cr mg kg^{-1}	Pb mg kg^{-1}	Zn mg kg^{-1}	Cd mg kg^{-1}	Ni mg kg^{-1}
NORTHERN DISTRICT								
No. 1	Ah	0–10	59.2	40.8	159.2	116.3	0.51	34.7
	BA	10–40	66.3	44.2	70.3	128.5	0.46	40.2
	C/R	40–50+						
No. 2	A	0–20	90.9	122.5	59.3	90.9	0.04	112.7
	AC	20–60	95.7	222.7	56.6	87.9	b.d.l.	197.3
	2C	60–80+						
No. 3	Oe	5–0						
	Ah	0–10/15	39.5	27.7	33.6	63.2	0.14	25.7
	BA	10/15–25/30	40.0	18.0	32.0	54.0	0.02	20.0
	C	25/30–50+						
EASTERN DISTRICT								
No. 4	Ah1	0–9	47.0	48.8	38.3	95.8	0.16	29.6
	Ah2	9–15	51.4	67.2	41.5	88.9	0.16	33.6
	2A	15–38	57.5	65.5	41.7	87.3	0.16	37.7
	2Bw	38–58	36.3	54.4	36.3	96.8	0.01	30.2
	2CB	58–75+	47.4	59.3	35.6	98.8	0.02	35.6
No. 5	Oi	0.5–0						
	Oe	0–3	40.0	38.0	34.0	106.0	0.60	18.0
	Oa	3–6	42.2	46.2	32.1	84.3	0.22	24.1
	Ah1	6–12	49.2	53.1	39.4	65.0	0.08	25.6
	2Ah2	12–40	59.4	57.5	40.2	63.2	0.04	34.5
	2AC	40–55						
	2C	55–75+						
No. 6	Oi	0.5–0						
	Oa	0–2	52.0	50.0	44.0	108.0	0.40	28.0
	Ah	2–4						
	AB	4–24	64.0	52.0	44.0	82.0	0.02	36.0
	2R	24–45+						
No. 7	Oi	0.5–0						
	Oa	0–3	22.4	13.3	20.4	41.8	0.15	8.2
	Ah	3–6						
	2A	6–9	42.0	60.0	54.0	70.0	0.08	22.0
	3CB	9–20	66.1	81.7	33.1	83.7	0.06	40.9
	3C	20–60+	82.3	74.3	52.2	80.3	0.20	40.2
No. 8	Oi	0.5–0						
	Oa/Oe	0–2						
	A	2–6	48.2	88.4	36.1	74.3	b.d.l.	42.2
	CA	6–19	88.4	100.4	24.1	62.2	b.d.l.	42.2
	C	19–45+	101.5	92.0	26.8	44.1	b.d.l.	40.2
No. 9	Ap	0–8						
	C	8–45	73.4	85.3	35.7	59.5	0.04	41.7
	Cg	45–55	84.0	74.0	34.0	64.0	0.08	46.0
	2Cg2	55–65+	58.7	62.5	26.5	47.3	0.04	32.2
No. 10	Oi	2–0						
	Oe	0–5	43.1	27.5	49.0	58.8	0.22	19.6
	Ah	5–21	56.0	54.1	54.1	67.6	0.10	25.1
	CA	21–65+	88.5	51.9	65.4	65.4	0.02	25.0
No. 11	Oi	2–0						
	Oe	0–2						
	A	2–7	43.3	53.1	39.4	84.6	0.18	23.6
	AB	7–16	61.1	61.1	43.9	78.2	0.17	36.3
	Bw	16–60	55.8	78.8	38.5	92.3	0.04	40.4

Gladney, Burns1985; Canepa et al. 1994; Baize 1997; Helmke 2000). Another factor of uncertainty is the lack of information in many papers on the form of occurrence of the trace elements in question: total, available, mobile, etc.

Moreover, data on relative mobilities through soil profiles are sometimes discordant, particularly those for Cu and Ni (Brooks 1983; Kabata-Pendias, Pendias 1984, 2001; Fujikawa et al. 2000). Only Pb and Cr are generally agreed to have very low mobility in the acid conditions of a supergene environment. Moreover, sampling and laboratory extraction methods greatly influence and complicate the interpretation of results (Tobias et al. 1997).

In addition, note that it is very difficult to establish geochemical background levels in periglacial environments, where the bedrock is covered with till, loess, fluvioglacial and fluvial deposits, and where soils have a cumulative character (Birkeland 1999). In such environments it is meaningless to consider trace element contents in the bedrock as background values. Moreover, neither the present depth of the bedrock nor the possible effects of past or active weathering and pedogenesis in the study area are well known. In recently active mountain ranges which experienced Alpine orogenesis, the products of intense physical weathering and continuous slope degradation overlap with debris flow, creep, cryoclastism and freeze-thaw processes, etc. Such processes may mask heavy metal translocation in soil profiles. Lastly, aeolian silt partly covers some soil parent materials.

For all these reasons, the present work adopted world soil average elemental contents as background and reference values (Tab. 4).

In the Northern District, Cd concentrations are low in all profiles except profile No. 1, where it is slightly over the world mean value. Cr is particularly abundant in profile No. 2, which also has high Ni and Cu concentrations. These high values testify to the genetic diversity of the parent materials of profile No. 2 with respect to the parent materials of other profiles in the district. Moreover, the different values within the same profile also highlight the internal genetic diversity between the two materials themselves. In short, profile No. 2, developed in a loess-like material which covered alluvial deposits, stands out from the others for its higher Cr, Cu, and Ni contents.

As for Pb, since this element has a very low mobility, its position in a profile can effectively indicate its atmospheric or lithological origin. In profile No. 1, the higher Pb contents and the fair amounts of Zn and Cd in the surface horizons indicate that these elements probably derived from an atmospheric source.

Cd shows an irregular distribution in all Eastern District soil profiles; it exceeds the world mean value only in the surface horizon of profile No. 5. Cr slightly increases with depth at all sites and has a very low mobility; it was likely inherited from the parent materials.

Ni and Cu, generally known to be easily mobilized during weathering, are nearly constantly present in high quantities at depth.

Since Zn is quite mobile, its high concentrations in the surface horizons of profiles No. 4, 5, 6 and 8 suggest the local contribution of atmospheric fallout.

Lastly, the so-called reference A-values (target values) and C-values (intervention values), calculated on the weighted average of whole profiles, were compared (Fig. 4) to trace element contents in the soils of the two districts following the procedure of the Dutch National Institute of Public Health and Environmental Protection (1991). This system of risk evaluation adequately takes into account the actual clay and organic matter content in soil, since these components are able to inactivate contaminants.

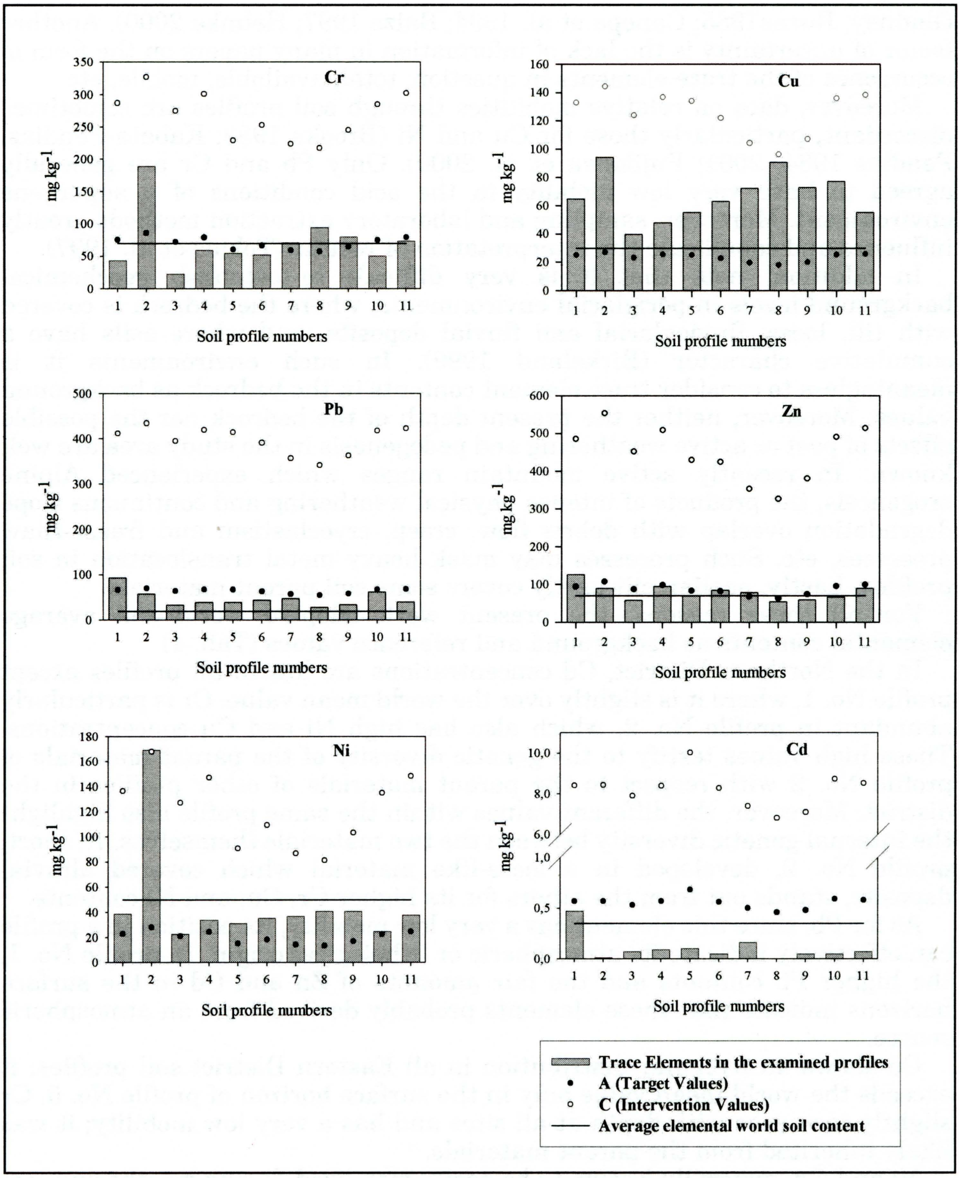

Fig. 4 – Weighted averages of trace element contents in whole profiles of investigated soils compared with the average world soil elemental concentrations (Logan 2000) and with the Target (A) and Intervention (C) values calculated according to the procedure of the Dutch National Institute of Public Health and Environmental Protection (1991)

Cd, Pb and Zn concentrations are commonly within the limits of the A value, while Cu contents were everywhere above the A value. Cr and Ni concentrations were particularly high in profile No. 2. When referred to the C values, Pb, Cr, Cd and Zn concentrations were everywhere well below values of ecotoxicological risk. Ni reaches the C threshold of 168 mg kg-1 in profile No. 2, and Cu the threshold of 90 mg kg-1 in site No. 8.

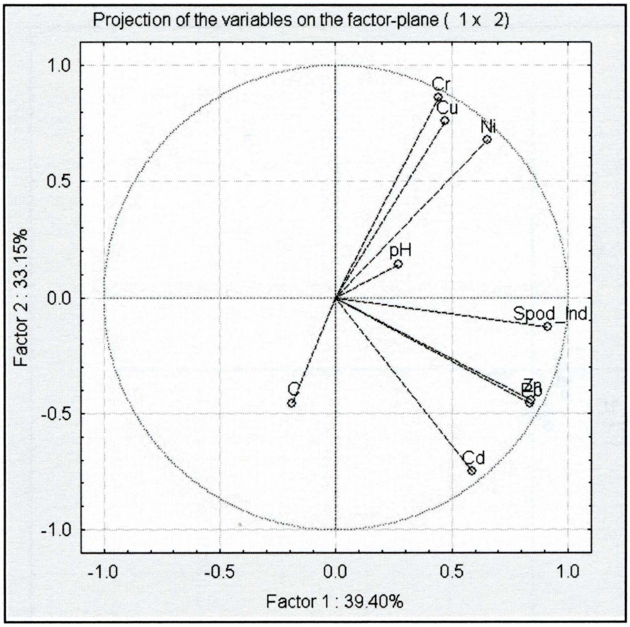

Fig. 5 – PCA of soil profile variables (weighted averages in the 0-30 cm depth range). Spod-Ind. – Spodicity Index (SI), C – Organic Carbon

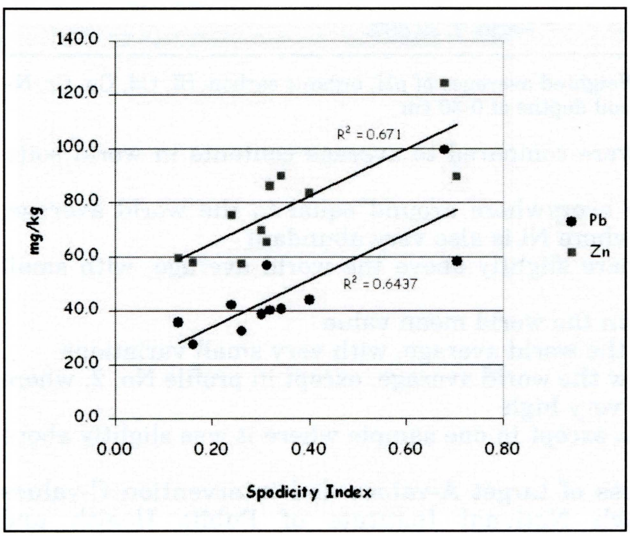

Fig. 6 – Correlation between Pb-Zn and the Spodicity Index

Principal Components Analysis (PCA) applied to the main soil parameters (Fig. 5) highlighted two groups of variables: Cr, Cu and Ni are linked to pH, whereas Cd, Pb and Zn are linked to SI. These relationships were also confirmed by the high statistical correlation between the variables.

It is highly meaningful ($p<0.005$) the correlation (Fig. 6) between Pb, Zn and the SI. These elements were concentrated likely in chelate forms, within the illuvial horizons with higher SI, as well as frequently mentioned in literature (Sartori et al. 2002). PCA applied to soil profiles (Fig. 7) shows that the soils of the Eastern District (Profiles No. 4 up to 11) are quite similar among themselves, whereas the soils of the Northern one are rather unlike, probably because more influenced by the geochemical variability of the parent material.

5. Conclusions

The first part of this paper showed how melanization prevails over podzolization in the surveyed region. Although the lithological characteristics of many acidic rocks, climate conditions and even altitude apparently favour the latter process, aeolian contributions in the Holocene and Pleistocene seem to have left on soils important marks of steppe pedoenvironments.

The second part examined trace elements contents and their ecotoxicity thresholds. Contents in the examined soils, as weighted averages in all the

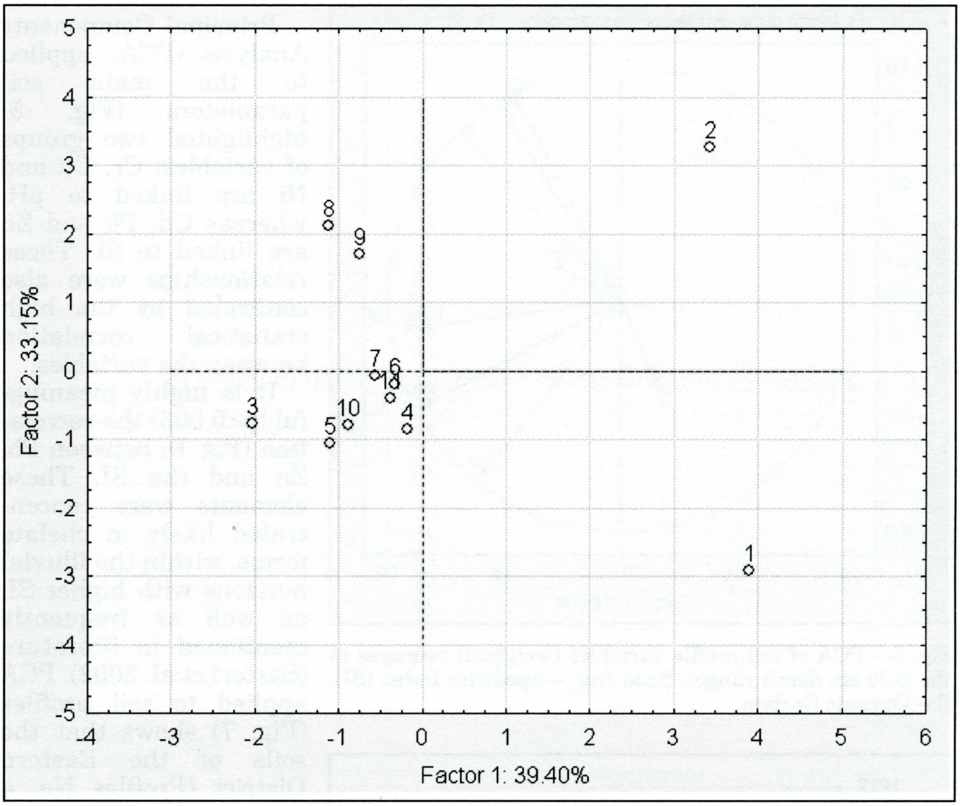

Fig. 7 – PCA for soil profiles. Weighted averages of pH, organic carbon, SI, Cd, Cu, Cr, Ni, Pb and Zn were calculated for soil depths of 0-30 cm

horizons of each profile, were compared to average contents in world soils. Results were as follows:

- Cr concentrations were everywhere around equal to the world average, except in profile No. 2, where Ni is also very abundant
- Pb was almost everywhere slightly above the world average, with small deviations
- Cu was fairly higher than the world mean value
- Zn was almost equal to the world average, with very small variations
- Ni was everywhere below the world average, except in profile No. 2, where the Cr content was also very high
- Cd was generally scarce, except in one sample where it was slightly above average.

Possible values in excess of target A-values and intervention C-values established by the Dutch National Institute of Public Health and Environmental Protection (1991) were then examined. The thresholds were calculated taking into consideration clay and organic matter contents in the examined soil. Results show that Cr is everywhere much lower than intervention C-values, Cu contents range between A and C-values, Pb and Cd contents are generally lower than A-values, and Zn concentrations oscillate above and below A-values, as do Ni contents (except in profile No. 2).

Based on trace elements contents, we conclude that the investigated soils generally show no significant contamination. The higher metal concentrations in soil profile No. 2 (developed from aeolian silt covering alluvial deposits) are probably due to contributions from distant areas which cannot be identified on the basis of collected data. This presumption is based on location of soil profile No. 2 in relation to the walley orientation and dominant wind direction and demands additional sampling in order to prove it.

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Shrnutí

STOPOVÉ PRVKY V PŮDÁCH V SEVERNÍ A CENTRÁLNÍ ČÁSTI POHOŘÍ TIAN-SHAN (KAZACHSTÁN – KYRGYSTÁN)

V rámci dvou vzájemně navazujících expedicí byly zkoumány půdy v oblasti severozápadně a jihovýchodně od jezera Issyk-Kul v centrálním Tjan-Šanu (Kazachstán a Kyrgystán). Půdy byly sledovány podél dvou transektů zahrnujících rozmezí nadmořských výšek 2 000 až 3 500 m. Souvislosti mezi půdami, klimatickými podmínkami, vegetací a reliéfem byly předmětem předchozích prací, tato je zaměřena na posouzení obsahu stopových prvků v půdě jako indikátoru možné kontaminace půd ve vysokých nadmořských výškách. Ta je zpravidla důsledkem jejich dálkového atmosferického přenosu.

Terénní popis půdních profilů a jejich polohy byl proveden podle směrnic FAO, barva půdy určena pomocí Munsellovy barevné škály a typologická klasifikace podle WRBS. Odebrané půdní vzorky byly analyzovány v souladu s metodickými postupy italského Ministerstva pro zemědělskou a lesnickou politiku. Po úpravě na jemnozem 2 mm byly ve vzorcích stanoveny pH/H2O, Corg., kationtová výměnná kapacita (CEC), obsah karbonátů, Feox a Alox k výpočtu indexu spodicity – SI (Alox+1/2Feo x). Pipetovací metodou byla určena zrnitost. Tzv. pseudototální formy stopových prvků Cd, Cr, Cu, Zn, Pb a Ni byly stanoveny ve výluhu lučavky královské podle postupu Bettinelliho metodou FAAS.

Polohu, environmentální data a půdně typologickou klasifikaci sledovaných profilů uvádí tabulka 2, základní chemické vlastnosti půd jsou uvedena v tabulce 3. Získaná data a laboratorní výsledky ukazují, že kvartérní procesy tvorby půd podobné melanizaci, zodpovědné za vznik současných stepních černozemí, jsou aktivní i ve velmi vysokých nadmořských výškách. Tyto procesy pravděpodobně podporuje přítomnost spraším podobného eolického překryvu a specifických klimatických podmínek.

V obou sledovaných oblastech nesplňují horizonty B diagnostická kritéria různých taxonomických systémů pro typické spodické (podzolové) B horizonty. Pouze v oblasti severně od jezera Issyk-Kul vykazují profily č. 1 a 2 s hloubkou stoupající obsah Feox a Alox, pravděpodobně jako důsledek vyšších srážek v tomto území.

Geochemické hodnocení jednotlivých půdních vzorků a odhad jejich možné kontaminace vyžaduje porovnání s průměrnými hodnotami, pozadím výchozího materiálu a prahovými obsahy. Vzhledem ke skutečnosti, že literární údaje jak o koncentracích stopových prvků, tak jejich formách a mobilitě v rámci půdních profilů se často liší, interpretace výsledků je také výrazně ovlivňována různým způsobem vzorkování a metodami laboratorní extrakce a navíc je velmi obtížné určit geochemické pozadí v periglaciálních podmínkách, kde je podklad překryt jílem, spraší, fluvioglaciálními a fluviálními sedimenty a kde mají půdy kumulativní charakter, byly v této práci jako pozadí a referenční hodnoty použity průměrné obsahy prvků v půdách světa (obr. 4). Koncentrace 6 sledovaných stopových prvků v půdách zájmového území uvádí zvlášť pro oblast severní a východní tabulka 4.

V severní části byly koncentrace Cd nízké ve všech profilech s výjimkou profilu č. 1, kde mírně převyšují světový průměr. U profilu č. 2 vyvinutého ze sprašového substrátu překrytého alluviálními sedimenty byla zaznamenána zvýšená koncentrace Cr, Ni a Cu.

U Pb lze, vzhledem k velmi nízké mobilitě, usuzovat z distribuce tohoto prvku v rámci profilu na jeho atmosférický nebo litologický původ. V profilu č. 1, indikuje vyšší obsah Pb a obsah Zn a Cd v povrchových horizontech pravděpodobný atmosférický zdroj.

Cd vykazuje ve všech profilech východní oblasti nepravidelnou distribuci; světový průměr přesahuje pouze v povrchovém horizontu profilu č. 5. Obsah Cr se mírně zvyšuje s hloubkou a na všech lokalitách vykazuje velmi nízkou mobilitu, lze tedy usuzovat na jeho geogenní původ. Ni a Cu, které jsou všeobecně pokládány za prvky lehce uvolnitelné v procesu zvětrávání, jsou téměř konstantně přítomny ve vyšším množství v hlouběji položených horizontech. Jelikož Zn je vcelku mobilním prvkem, je jeho vyšší koncentrace v povrchových horizontech profilů 4, 5, 6 a 8 přičítána atmosferickému spadu.

Vážené průměry obsahu stopových prvků v celých sledovaných profilech byly porovnány s průměrem koncentrace těchto prvků v půdách světa a s tzv. referenčními hodnotami A (target values) a C (intervention values) vypočtenými podle metody nizozemského Národního ústavu pro zdraví a ochranu životního prostředí. Tento systém hodnocení rizika bere v úvahu i aktuální obsah jílu a organické hmoty v půdách, jako složek schopných inaktivovat kontaminanty (obr. 4).

Existuje vysoce významná korelace mezi obsahem Pb, Zn a indexem spodicity SI (obr. 6). Tyto prvky jsou v illuviálních horizontech s vysokým SI koncentrovány pravděpodobně v chelátových formách.

Půdy východní oblasti vykazují menší variabilitu než půdy severní oblasti, což je s největší pravděpodobností způsobeno geochemickou variabilitou výchozího materiálu (obr. 7).

V první části textu je poukázáno na převahu melanizace nad podzolizací ve sledované oblasti, ačkoli litologické charakteristiky mnoha kyselých hornin, klima a nadmořská výška zjevně upřednostňují druhý z uvedených procesů. Důvodem je přítomnost holocenních a pleistocenních eolických sedimentů.

Druhá část se zabývá obsahem stopových prvků a jejich ekotoxicitou. Obsah ve sledovaných půdách byl jako vážený průměr všech horizontů každého profilu porovnán s průměrným obsahem v půdách světa s následujícími výsledky:

- koncentrace Cr se ve všech případech téměř rovnala světovému průměru s výjimkou profilu 2, který vykazoval také vyšší obsah Ni
- obsah Pb byl téměř vždy mírně nad světovým průměrem
- obsah Cu byl o dost vyšší než světový průměr
- koncentrace Zn bylatéměř rovna světovému průměru, s velmi malou variabilitou
- obsah Ni byl vždy pod úrovní světového průměru s výjimkou profilu č. 2, kde byl stejně jako obsah Zn velmi vysoký
- přítomnost Cd byla obecně velmi vzácná, s výjimkou jednoho vzorku, kde byla lehce nad průměrem.

Z porovnání s hodnotami A (target values) a C (intervention values) vyplývá, že obsah Cr byl ve všech případech mnohem nižší než hodnoty C, obsah Cu se pohyboval mezi hodnotami A a C, obsah Pb a Cd byl nižší než hodnoty A a koncentrace Zn oscilovala nad a pod hodnotami A, stejně jako obsah Ni (s výjimkou profilu č. 2).

Na základě obsahu stopových prvků vyvozujeme, že sledované půdy vcelku nevykazují výraznou kontaminaci. Vyšší obsah kovů v profilu č. 2 (vyvinutém na eolickém prachu překrytém alluviálními sedimenty) je pravděpodobně důsledkem dálkového přenosu a nelze ho identifikovat na základě získaných dat.

Obr. 1 – Geografická lokalizace zájmového území
Obr. 2 – Hlavní pohoří a řeky zájmového území. A–B a C–D jsou směry transektů
Obr. 3 – Příčný řez v profilech A–B a C–D znázorňující umístění půdních profilů
Obr. 4 – Vážené průměry obsahu stopových prvků v profilech sledovaných půd porovnané s průměrnými koncentracemi prvků v půdách světa (Logan 2000) a s hodnotami cílových limitů (A) a intervenčních limitů (C) podle metody Nizozemského národního ústavu pro zdraví a životní prostředí
Obr. 5 – PCA proměnných půdního profilu (vážené průměry v hloubce 0–30 cm). Spod-Ind. – Spodicity Index (SI), C – Organický uhlík
Obr. 6 – Korelace mezi Pb-Zn a spodicity indexem
Obr. 7 – PCA pro půdní profily. Vážené průměry pro pH, Cox, SI, Cd, Cu, Cr, Ni, Pb a Zn v hloubce 0–30 cm

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VÍT JANČÁK, TOMÁŠ HAVLÍČEK, PAVEL CHROMÝ, MIROSLAV MARADA

REGIONAL DIFFERENTIATION OF SELECTED CONDITIONS FOR THE DEVELOPMENT OF HUMAN AND SOCIAL CAPITAL IN CZECHIA

V. Jančák, T. Havlíček, P. Chromý, M. Marada: *Regional Differentiation of Selected Conditions for the Development of Human and Social Capitol in Czechia.* – Geografie–Sborník ČGS, 113, 3, pp. 269–284 (2008). – This article addresses the analysis of theoretical and methodological concepts of the quality of human and social capital and their relation to the theory of spatial polarisation. Selected conditions for the development of human and social capital and their territorial differentiation in Czechia are evaluated. On the basis of an evaluation of component indicators of human capital (the ratio of university educated residents in the population over 15 years of age as well as an economic burden index) and social capital (voter participation in municipal elections and the number of candidates divided by the number of offices to be filled in the 2006 municipal elections) problematic areas are identified at a micro-regional level (the network of municipalities having a certified municipal authority).
KEY WORDS: human capital – social capital – potential development – rural areas – periphery – regional differentiation – Czechia.

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Introduction

In connection with the post-communist transition, which resulted from the fall of the communist regime in Czechoslovakia in 1989 and 1990, and with the initiation and proliferation of integration processes and the gradual intensification of globalization processes during the 1990's, the territories of Czechia experienced significant increases in both vertical (societal) and horizontal (regional) differences. Geographers, who had been examining the development of the system of settlement or regional development for years, were faced with new research questions. These were especially related to identifying key issues and mechanisms that contribute to the growth of differences between regions, both at their various hierarchical levels as well as in light of the structure of conditions. This especially concerns searching for key aspects of differentiation (expressions and processes of socio-economic, socio-cultural and even physical-geographic nature), interpreting their changes over time and the intensity of their influence (separating general from specific / regular from chance processes and qualitatively new processes, etc.; for more information, see, for example, Hampl, Dostál, Drbohlav 2007; Havlíček, Chromý 2001; Jančák 2001; Kostelecký, Patočková, Vobecká 2007; Kuldová 2007b; Kuldová-Kučerová 2008; Marada 2001; Novotná ed. 2005).

On the basis of research projects already conducted on the geographic aspects of the transition of society (e.g. Hampl et al. 1996, 1999, 2001) and the polarisation of space (e.g. Blažek, Csank 2007; Jančák, Havlíček, Chromý, Marada 2006; Havlíček, Chromý, Jančák, Marada 2008), which were primarily carried out at the Department of Social Geography and Regional Development of the Faculty of Science at Charles University in Prague, we can establish that, in terms of a region's successfulness, in addition to the (development of) the region's location in its regional system (outward and inward), the level of concentration of its inhabitants (population density) or its function (for example administrative, or rather directive), that the activity of the subjects themselves, in general terms: the quality of human and social capital in the specified area, can be considered indicative.

We have defined the goals of the article on a number of levels. The main goal of the introductory theoretical, methodological discussion is to classify and define the terms human and social capital, as well as to justify and discuss the selection of possible and appropriate indicators for evaluating regional differentiation in their quality. The goal of the empirical section of the article is to, through the application of the selected indicators, complete an evaluation of regional differentiation of the selected conditions for the development of human and social capital in Czechia, at the beginning of the 21st century, and to identify problematic areas, which deserve further, special attention. We formulate the assumptions, which are verified in the empirical section, in the methods section of the article.

Theoretical concept and definition of terms

In recent decades, the terms human capital and social capital have become important for a series of studies in sociology, economics, political science and – over the last few years – in geography as well. In spite of the terminological similarity and topical „closeness" of these terms, they should not be confused (Field, Schuller, Baron 2000).

While human capital is defined primarily as an individual factor of qualifications, productivity, skills and capability; social capital is defined through mutual relations, cooperation, social cohesion, trust and the interactivity of individuals (Schuller 2000). The concept of human capital was first identified mainly through the benefits resulting from such investments in people as: education, trainings, health services, vitamin consumption and gathering of information about the economical system (Becker 1962). During recent years, this term has been extended to include such elements as: motivation, moral values and interpersonal attitudes and abilities (Cote 2001). „Human capital is most often determined as the knowledge, skills, competence and other attributes embodied in a human being that enable the establishment of personal, social and economic prosperity" (OECD 2001; Janc 2006, p. 40).

Since the end of World War II, proponents of neoclassical theories in economic and social sciences have argued that the quality of human capital, connected with increasing levels of education, is a basic element contributing to increases in the standard of living (Becker 1964). Such thinking resulted in an increase in investments into educational systems, which supported the human potential and economic growth of regions (Preston, Dyer 2003). Human capital, which is distinctively individual in nature, thus primarily includes education, skills, training and the experiences of individuals or of a defined community, who apply or who are capable of applying this capital in the labour market. Meanwhile, human capital theory argues that direct connections exist between the human capital of the labour force and labour productivity as well as between productivity and profit (Becker 1971). Participants in the labour market with higher human capital – meaning with higher education, greater skills and experience – are more productive and receive higher wages than employees with lower human capital. The accumulation of human capital is therefore a significant determinant of wages and, as a result, a higher standard of living. Human capital theory cannot, of course, be applied in this simplifying form, because other factors (unemployment, discrimination, complications with housing, etc.), which bring further problems to the labour market, enter into the process, as well.

Social capital is based on sources (human capital), which are held by the individual members of a network (Šafr, Sedláčková 2006). So, by creating social networks, individuals accumulate and multiply their individual (human) capital and reshape it into a (collective) social capital. The people, among whom such an exchange takes place, often create a variety of exclusive associations, in which the very contacts made through such associations are further strengthened. These networks can often arise spontaneously and naturally (Boundon, Besnard, Cherkaoui, Lécuyer 2004; Jandourek 2007). Coleman (1988) defines social capital as the ability of people to work together in the framework of groups and organizations in order to realise common purposes.

In geographic sciences, branches interested in the phenomenon of human and social capital include, primarily: theoretical concepts of regional development (e.g. the endogenous growth theory, Romer 1986), institutional directions of regional geography or „new“ economic geography (e.g. Krugman 1991, Martin 1999), branches which consider the quality of human and social capital to be an important part of the cumulative capital in a given area (Blažek, Uhlíř 2002). In relation to the development of regions over time, emphasis is placed primarily on the initiative of individuals, thus giving more weight to subjective („soft“) factors. In contrast, deterministic (e.g. structuralist) approaches (Blažek 1999). In this way, the prosperity of an area is primarily the result of high-quality social, cultural and institutional structures with adaptive and innovative human and social capital. The public sector should, therefore, support all efforts to improve living conditions in a given area, in all possible aspects. Increasing opportunities for engaging the largest possible constituency of individual members of society into processes of education and decision-making in public matters (e.g. participation in the administration of public issues in a manner such as active participation in local or regional government administration or referendums) and, by so doing, involving them in improving the quality of local, social capital can be included among institutional activities as well (Kuldová 2007a,b; Mohan, Mohan 2002; Putnam 1993, 2001).

From the above information it is evident that while human capital can be considered to be primarily a source of an individual nature, social capital is a collective source; wherein evaluation of the activities of the specific actors in a given area is always key (Pisseli 1999). It is necessary to view social capital as a dynamic element. It is perceived as an evolving structure, which regulates the varied behaviour of individuals on the one hand, while, on the other hand, it is formed and modified by this structure (Giddens 1984). Analysis of social capital should not, however, be reduced to or confused with research of networks, which is typical of structuralism.

From the above information it is clear that the quality of human and social capital is one of the significant factors determining the process of spatial polarisation, or rather the existence of problematic regions. Exploring the phenomenon of periphery originates primarily from an analysis of relations between core areas and their hinterland in the sense of the polarity model of a centre and periphery. It, however, has a series of specific forms in terms of evolution on the one hand and in terms of rank-size or scale, on the other. In general, however, it always expresses their asymmetrical relation. From the beginning, peripheral areas were described on a macro-structural level, wherein the main aspects that were applied in defining such areas were primarily physical geographic features, even though they were transformed into anthropo-geographic and political geographic effects (Havlíček, Chromý 2001). With the beginning of the 20th century, a shift in perception of peripheral areas to lower territorial orders (nodal regions). This occurred as a result of research of the development of settlement systems and the shaping of connections between settlements and their hierarchisation. In regards to this, Korčák (1973) indicated that a key role was played here by the work of Mackinder and Vidal de la Blache. Christaller (1933), while formulating his central place theory, also implicitly defined core and periphery. This, however, dealt mostly with the simplification of the spatial concentration of territorial organisation and not at all with principles and processes of development underlying its asymmetry. Dynamically conceived theories of regional development did not appear until after World War II. Economists were first to put forth an attempt to resolve regional disparity (Myrdal 1957, Hirschman 1959). Wirth (1963) utilised not only the physical geographic aspect, but also considered the historical and political aspects outlining differences between northern and southern Europe. In addition to this, a so-called inner periphery was also alluded to. An example is Myrdal's, or rather Hirschman's theory of cumulative causation (one of the core-periphery theories), in which the authors differentiate predominantly negative – so-called „polarising“ or „backwash“ – effects that are caused by more developed regions and affect less-developed regions, but also describe positive forces („spread“ or „trickle-down“ effects); for more information see Blažek, Uhlíř (2002).

Leimgruber (2001, 2004) considers the polarisation theory of core-periphery, which points out increasing differences between the rich and the poor, to be a better model for understanding the current state of affairs in the world than the theoretical concepts of neoclassicism, which assume that the normal operation of market mechanisms leads to a levelling out of differences between social and even spatial aspects. In these processes, key significance is attributed to human decisions, based in subjective interests and values (Leimgruber 1994, 1998). Again, this points to the significance of the activity of the subjects/actors in a given area, especially their ability (and their quickness) to accept new stimuli, information and innovations.

The dichotomous terms core and periphery are often anchored in the thinking and perceptions of interested subjects (Heintel 1998). The role of the distance/spatial factor (the horizontal element) is weakening, while, in contrast, the significance of the hierarchy of the political, social, economic and cultural organisation of geographic activity (the vertical element) is increasing.

The development of a wide variety of complicated political, economic, social and ecological relationships in an area, which is inherent to the process of spatial polarisation, can be abstractly expressed in four phases – growth, stagnation, decline and levelling out (Havlíček, Chromý 2001; Halás 2008). It is no less important to point out that core-periphery theories perceive merely a simplified dichotomy of core and periphery, even though the relationship often expresses itself as a continuum. Consequently, core areas are often described as „winners“ and peripheral areas as „losers“. This undermines opportunities for their mutual cooperation. The quality of social and human capital also is valuable in explaining the quality of life in a territory (for more about this see, for example Mourek 1998; Hurbánek 2005; Ira, Pašiak, Falťan, Gajdoš eds. 2005; Baxa 2008).

Methods

Based on the preceding observations and conclusions from thematically similar studies, the following, general assumptions can be formulated:

1. Key individuals and social networks are subject to regional/local development in a significant way. As a consequence of low population density and the overall population of municipalities/settlements in peripheral and rural areas, the quality of human and social capital can be considered a key element in their development and even plays a much greater role here than in core areas (Havlíček, Chromý, Jančák, Marada 2008).
2. Even though peripheral areas exhibit low human capital (primarily in terms of education), social capital is, in contrast, relatively high in rural areas. Due to the unique evolution of settlement in Czechia, however, significant differentiation of human and social capital can be expected in rural and peripheral areas. We assume that higher levels of their quality will be found in areas of continuous settlement (the inner periphery) and the main centres of settlement (the core areas). In contrast, lower capital quality can be expected in border regions that were settled after World War II, after the displacement of the Czech Germans (Chromý 2000; Kuldová 2005).

We evaluate the quality of the environment for developing human capital through the following indicators:

1. The ratio of people older than 15 with a university education, as a characteristic of the quality of human capital that, of course, has more of a „potential“ significance, without more specifically enumerating the actual utilisation of said capital and the reflexive action of the dynamic (growth) of education and of changes in its regional distribution (expressed as of 1.3.2001 from the results of the census).
2. An economic burden index, defined as the number of individuals of pre-productive age (0–14 years) plus the number of individuals of post-productive age (65+) divided by the number of individuals of productive age (15–64 years). This indicator „all-inclusively“ characterises a population's structure in terms of a modified definition of its economically active component. Higher index values indicate a larger economic burden on the

population in productive age, although, without accounting for mutual relations between the non-productive (categories residents of the recently settled border regions are demographically younger). The index was calculated from data from the 2001 census.

The quality of the environment for the development of social capital is characterised in this study by indicators that express the social atmosphere in the municipalities, exhibiting themselves as certain, collective, „customary“ behaviour, the motivation of the local community, the „mood“ and similar expressions, the activity of residents, or rather the interest and involvement of people in resolving public issues. We used the following indicators in our analysis:

1. Voter participation in 2006 municipal elections (as a %), which to a certain degree expresses the general interest of residents in public issues, specifically in the management of their municipality. This indicator can also illustrate the residents' efforts to resolve social, economic, political or other (mainly local) problems.
2. Ratio of candidates to the number of offices to be filled in the local council in the 2006 municipal elections, which can be considered an expression of the willingness to involve themselves in the management of their municipality (city-country dichotomy). This indicator can also be a sign of problems in the local society.

The evaluation of conditions for the development of human and social capital is carried out at the territorial administrative level of municipalities having a certified municipal authority (CMA). These can be considered to be relatively natural, regional units, enabling one to appropriately identify problematic areas within Czechia. The regional level of territorial units with a certified municipal authority, of which there are – with the exception of military training bases – a total of 389, was chosen for its good explanatory ability in terms of territorial unit similarity as well as the relatively simple accessibility of secondary data. Information for the individual municipalities or, in contrast, for larger units (e.g. districts or the territories of municipalities with extended powers) documenting territorial differences is too generalised.

All indicators were expressed for the territorial units of municipalities with a certified municipal authority (hereafter „CMA's“), naturally, as averages of the aggregate data for the municipalities belonging to these units (Table 1). For each indicator (for human capital HP, the ratio of university educated and the economic burden index and for social capital SP, voter participation and the number of candidates per number of offices to be filled) the CMA units were placed in a sequence according to the corresponding values and subsequently given points according to their position (1–389). The lowest values, therefore, represent areas with the lowest potential for the development of human or social capital. In the next step, the sequential order values of the various indicators for each CMA were added together with their corresponding indicator to create aggregate HC and SC indicators and the CMA's were placed in sequential order (1–389). The territorial differentiation of the resultant summary sequence of the various CMA's in Czechia is evident in Figures 1 through 3 (Fig. 1 – Territorial differentiation of the potential for HC development, Fig. 2 – Territorial differentiation of the potential for SC development and Fig. 3 – CMA's with the lowest potential for the development of HC and SC).

Tab. 1 – Overview of indicators for evaluating the territorial differentiation of potential for the development of human capital and social capital

Indicator	Procedure during analysis
Ratio of university educated individuals in the population older than 15	CMA's were arranged in ascending order by the ratio of university educated residents in the population older than 15. Those CMA's that have a low ratio of university educated residents have a low sequential rank. A direct proportion applies, meaning the higher the ratio of university educated, the greater the potential for the development of human capital (thereby an even better position of the CMA).
Economic burden index	CMA's were arranged in descending order according to the economic burden index, which is the number of individuals of pre-productive age (0–14 years) plus the number of individuals of post-productive age (65+) divided by the number of individuals of productive age (15–64 years). Those CMA's that have a low economic burden index, have a high sequential rank. An indirect proportion applies: the lower the economic burden index, the greater the potential for the development of human capital in the sense of an available labour force (and thereby, the better position of the CMA). We end up with high index values, when there is a high number in the numerator, that means either a large number of residents in the age category 0–14 or a large number of residents in the 65+ category. In the absence of further demographic indicators, it is impossible to definitively say which component of the population is determinative for the index. The index can show the same values, whether the CMA population is older or younger then average. A definitive dependence of greater development potential upon lower economic burden does not hold true, because a higher portion of children can, in the future, represent greater potential. It is, however, definitely true that if a high economic burden index is caused be a large number of residents in the 65+ category, development potential is lower as is the potential for the development of human capital.
Voter participation in 2006 municipal elections	CMA's were arranged in ascending order according to voter participation in elections for the local councils of the municipalities in 2006. Those CMA's that have low voter participation have a low sequential rank. A direct proportion applies: the higher the voter participation, the better the conditions for the development of social capital (thereby, the better position of the CMA).
Number of candidates per offices to be filled in 2006 municipal elections	CMA's were arranged in ascending order according to the number of candidates divided by the number of offices to be filled in the 2006 municipal elections. Those CMA's that have a low number of candidates per office to be filled, have a low sequential rank. A direct proportion applies: the greater the number of candidates per office to be filled, the better the conditions for the development of social capital (thereby, the better position of the CMA).

Regional differentiation of the indicators and their relation to the core-periphery theory

The regional differentiation of the potential for the development of human capital (Fig. 1), based on territorial units with a certified municipal authority,

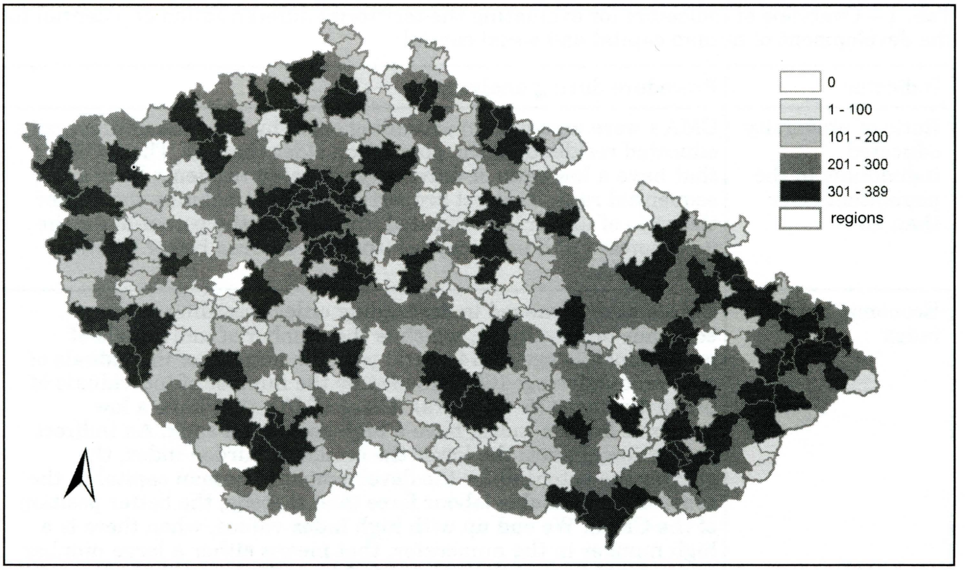

Fig. 1 – Potential for the development of human capital (resultant comprehensive rankings of CMA's according to the ratio of university educated residents and the economic burden index for 2001). Note: CMA's are arranged in ascending order according to values of potential for the development of human capital. Those CMA's that have low values of potential for the development of human capital have a low sequential rank.

is, as indicated in the methods section, evaluated with the help of two indicators: the ratio of university educated residents in the population older than 15 and the economic burden index. The regional differentiation of the first of these indicators, basically corresponds with the core-periphery theory. The core areas, as holders of innovation and centres concentrating tertiary functions of the highest orders, also concentrate the population with the highest levels of education. A weakening of this education level is shown with increasing distance from core areas, especially from regional centres. At the same time, specific regional conditions express themselves here, which also influence the specialisation of regional economies as well as connected professional and general school facilities and thereby influence the education of the local population, in return. It is necessary to recognise a significant momentum in the focus of schools (for lack of human capital, among other reasons), which changed only slightly – in contrast to economic specialisations – in peripheral areas during the transformation period. For these reasons, the Hradec Králové Region, for example, attains more favourable values than the Pilsen Region or „basin" regions.

A somewhat different regional pattern is shown by the second indicator, the economic burden index, whose highest values are concentrated in the so-called inner periphery (Musil 1988; Musil, Müller 2008), generally, with highly fragmented settlement patterns. Some of the border peripheral areas, for example Broumovsko, Osoblažsko, Jablunkovsko and the White Carpathians, also exhibit unfavourable results. After their post-war resettlement, the border areas as a whole have rather a younger population than the continuously inhabited interior, where peripheral areas have evolved in the classical sense.

The resulting potential for the development of human capital in a regional view (Fig. 1) verifies that potential for the development of human capital cannot be evaluated in the traditional dichotomy of interior vs. resettled border areas, but rather in a dichotomy of core vs. long-term economically weak areas. As expected, the Prague metropolitan area and regional capital cities show the greatest potential for the development of human capital; however, CMA's with a dominant position as regional centres (e.g. the Mladá Boleslav, Tábor and Třebíč regions) also showed the greatest potential. In contrast, CMA units along the regional borders (e.g. the divide between the Pardubice and Vysočina Regions, as well as between the Central Bohemian, Pilsen and South Bohemian Regions or between the South Bohemian, South Moravian and Vysočina Regions) can be considered problematic areas. In such areas larger clusters of CMA's, which can be labelled as more extensive, problematic regions, are evident.

The regional differentiation of potential for the development of social capital (Fig. 2), based on territorial units with a certified municipal authority, was analysed through the application of two indicators: voter participation in 2006 municipal elections and the number of candidates per offices to be filled in the local councils of the municipalities in the 2006 municipal elections. In terms of the first indicator used, the residents of the so-called inner periphery, the traditional rural regions, often with a higher portion of religious adherents, appeared to be more involved. In contrast, border regions showed weaker voter participation. This indicator also differs the „candidate-active" Sudeten area from south Moravia, when the latter region also exhibits higher voter involvement.

The somewhat contrasting picture shown by the second of the indicators used is interesting. In terms of the number of candidates for local/municipal

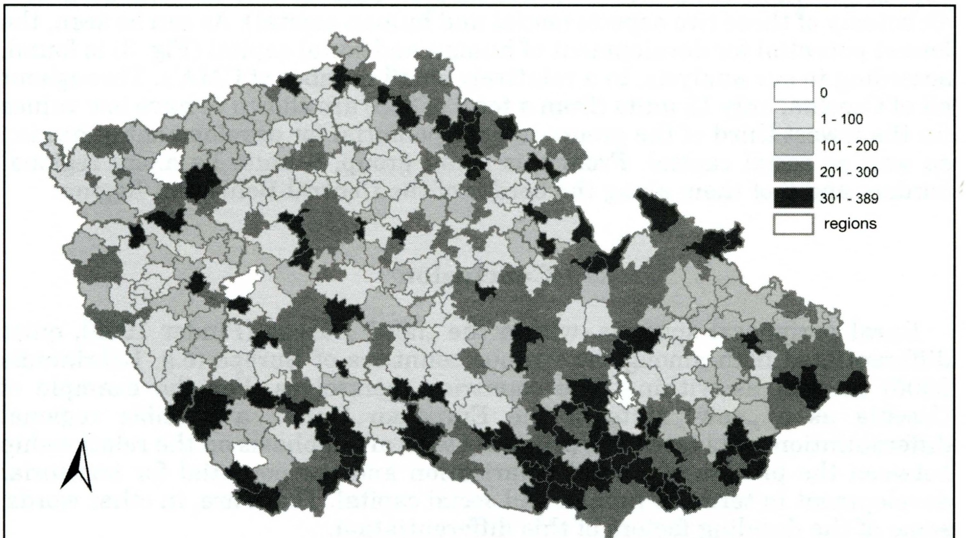

Fig. 2 – Potential for the development of social capital (resultant comprehensive rankings of CMA's according to voter participation and the number of candidates per offices to be filled in 2006 municipal elections). Note: CMA's are arranged in ascending order according to values of potential for the development of social capital. Those CMA's that have low values of potential for the development of social capital have a low sequential rank.

councils divided by the number of offices to be filled, the recently settled border regions, in particular the Sudeten area and then the south Moravia border areas, expressed themselves as the more active, with a higher level of involvement in public administration. Both of the regions named also rank among the traditional supporters („bastions") of KSČM (the Communist Party of Bohemia and Moravia), or KDU-ČSL (the Christian Democratic Union – Czechoslovak People's Party), which could play a key role. The ideological and party influence on this indicator is, of course, speculative and would require a noticeably deeper analysis of the situation, for example, through qualitatively focused, field research. Further it is necessary to take into consideration the fact that when interpreting voter participation, the size of the municipality also expresses itself as an important factor (the smaller the municipality, the greater the voter participation). In terms of the number of candidates divided by the number of offices to be filled, it is necessary to proceed with caution, when formulating conclusions and interpretations, because, in the smallest municipalities, nominating potential candidates for the local council is a problem (Perlín 2006).

The resulting potential for the development of social capital in a regional view (Fig. 2) verifies the polarisation of the territory of Czechia into a dichotomy of Bohemia – Moravia and partially shows a west-east gradient in terms of industrialised („more modern") and traditional areas. The greatest potential for development of social capital is shown by CMA's in Moravian regions (mostly in the South Moravian Region), but also in the South Bohemian Region. The lowest values are found in CMA's in Bohemian regions (including a large portion of Vysočina Region).

Results from this evaluation of the development of human and social capital potential show that the territory of Czechia can be evaluated in a dichotomy of these two aspects (social and human capital). As can be seen, the lowest potential for development of human and social capital (Fig. 3) is found, according to our analysis, in a relatively small number of CMA's. Throughout all of Czechia, only 13 units (from a total of 389) are shown to have low values (in the lowest third of the group) in both potential for development of human as well as social capital. From this small group, 9 units lie along regional borders and 6 of them along the border of the Central Bohemian Region.

Conclusion

Rural peripheral space is, within the „new" Europe (Pinder 1998), quite differentiated both among the various countries of Europe (e.g. Labrianidis 2006) as well as within these countries themselves. For the example of Czechia as a „new" state of the European Union, a possible regional differentiation of its territory, primarily with an emphasis on the relationship between the process of spatial polarisation and the potential for territorial development in terms of human and social capital. These are, in other words, some of the deciding factors of this differentiation.

Based on the theoretical-methodological discussion it is evident that definitions and approaches to evaluating human and social capital differ both in terms of the approach of the various authors, or rather disciplines as well as from a regional perspective. The majority of authors have a differing approach in their selection of indicators as a result of their motivation to resolve different types of problems. With nearly all of the authors (without

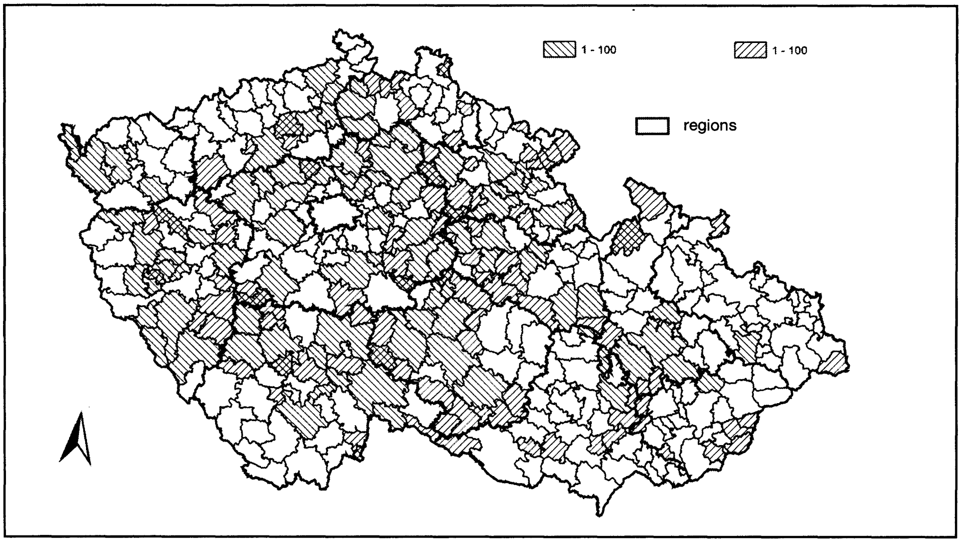

Fig. 3 – CMA's with the lowest potential for development of human and social capital

specialty and regional categorisation), it is possible to note an emphasis on the quality of human capital expressed by distance and by the position of actors in the age structure of the economically active. With social capital, there is a clear emphasis on the willingness of residents to take part in, what could generally be called: activities in networks (including participation in the administration of public issues).

In this sense, both limitations in the possibilities of research, in terms of accessibility of information and especially in terms of the extreme breadth of the observed indicators in sufficient territorial detail; as well as the absolute necessity of comprehending all evaluations carried out, on the basis of quantitative data, as an evaluation of an indicative nature become clearly fundamental elements. It turns out that the results of „hard" data must, in the spirit of critical realism, be combined with examination approaches of a qualitative nature. It is, therefore very difficult to carry out analyses with international comparisons of the quality of human and social capital. For this reason, we selected for our initial analysis an evaluation of indicators, which explain more the potential for development of human and social capital, primarily aimed at identifying problematic areas in the sense of a core-periphery dichotomy. Moreover, we are aware that the indicators were observed in only one of the dimensions of social capital, i.e. civil participation (passive and active voter participation). Social networks, which represent another dimension and are measured more by the frequency of contact with acquaintances–friends–relatives and the extent of such virtual networks, however, are not available at the selected, administrative level of the regions. It is, therefore, necessary to view the results presented in this article as the output of the initial phase of research, that will be further expanded and specialised.

The completed evaluation of the territorial differentiation of the selected conditions for the development of human and social capital, in Czechia, at the beginning of the 21st century, enables the following conclusions to be formulated:

– The first of the general assumptions that we formulated in the methods

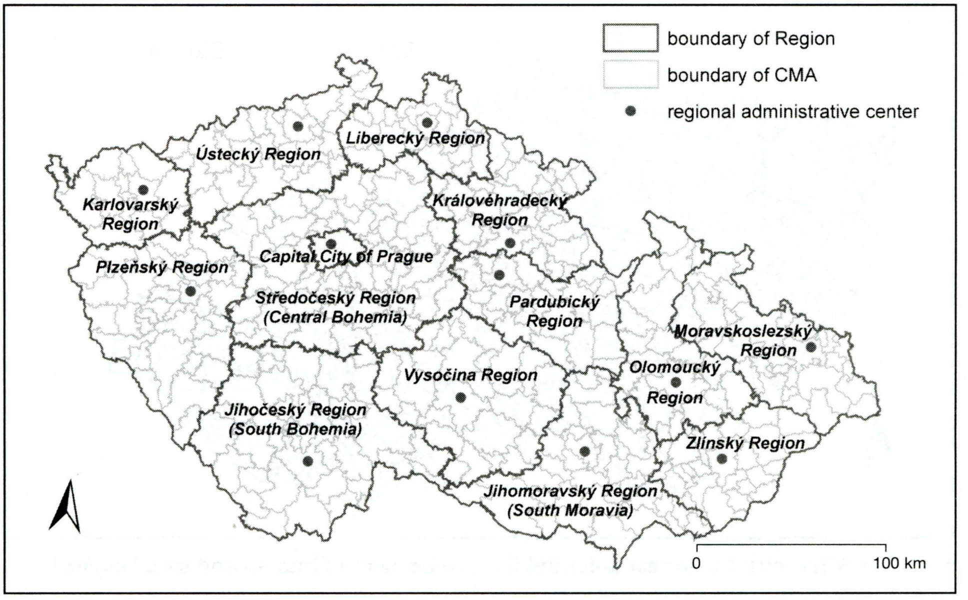

Fig. 4 – Administrative division of the Czech Republic (2008). Regions (kraje), regional centres and territorial units of municipalities with a certified municipal authority (CMA).

section was confirmed. The core-periphery dichotomy, in the Czech environment, can be considered key primarily in the sense of regional centres/long-term economically weak (rural) areas.

- Distance from a settlement centre, especially a regional centre, or rather, proximity to regional borders, is therefore a determining factor in the incidence of areas with lower potential for development of human and social capital.
- From the evaluation of the potential for development of human and social capital it is evident that, on the basis of CMA's within Czechia, a relatively small number of units were identified that can be considered problematic in both aspects. This is significant from a regional differentiation standpoint that these units mostly lie near the border of the Central Bohemian Region (Fig. 4), which in a large measure correlates with the presence of an inner periphery in these areas.
- The anticipated differentiation in the quality of human and social capital in the sense of a dichotomy of continually inhabited interior vs. border areas resettled after World War II was not confirmed (the second general assumption listed in the methods section of this paper). In spite of this, it should be recognised that, for example, in the structurally disadvantaged areas of northern Czechia, there is a high portion of residents of productive age, but these could have lower qualifications (see the ratio of university educated), they are often unemployed, or in similar situations. Their potential is, therefore, not sufficiently utilised.
- With a certain degree of generalisation, it is possible to observe the dichotomy of Bohemia and Moravia with both types of capital.
- In terms of the differentiation of potential for development of human capital, the relatively equal distribution of CMA's with greater potential for development of human capital, or rather the non-existence of this aspect in

large, problematic areas at the regional level (with the exception of the relatively sparsely populated inner periphery) can be assessed positively.

– On the other hand, in terms of the differentiation of potential for development of social capital, it is possible to outline large, territorial areas, in which the willingness of local residents to engage in networks and participate in the administration of public issues is significantly different. The reasons for this differentiation can clearly be sought in the quality of the socio-cultural environment and its long-term evolution (traditions).

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Shrnutí

REGIONÁLNÍ DIFERENCIACE VYBRANÝCH PODMÍNEK PRO ROZVOJ LIDSKÉHO A SOCIÁLNÍHO KAPITÁLU V ČESKU

V průběhu postkomunistického období došlo v Česku k prohloubení společenských (vertikálních) i regionálních (horizontálních) rozdílů. Tématem geografického výzkumu je tak mj. identifikace klíčových problémů a mechanizmů, které přispívají k růstu rozdílů mezi regiony, jakož i vymezení problémových oblastí, které si zasluhují zvláštní pozornost z pohledu regionálního, sociálního, ekonomického i socio-kulturního rozvoje. Z hlediska úspěšnosti rozvoje regionů lze za stěžejní považovat, vedle polohy regionu v regionálním systému, míry koncentrace obyvatelstva/funkcí, zejména aktivitu subjektů (iniciativu jednotlivců), resp. kvalitu lidského a sociálního kapitálu (součást celkového kapitálu v území). Předmětem odborných diskuzí se tak stává zejména výběr ukazatelů pro hodnocení regionální diferenciace jejich kvality, jakož i podmínek pro jejich rozvoj (roste váha subjektivních/„měkkých" faktorů). Prosperita území je výsledkem kvalitních sociálních, kulturních a institucionálních struktur s adaptivním a inovativním lidským a sociálním kapitálem. Jeho kvalita je také jedním z faktorů determinujících proces polarizace prostoru (v důsledku nižší hustoty zalidnění a populační velikosti obcí/sídel periferních a venkovských oblastí zde má mnohem větší roli, než v oblastech jádrových).

Lidský kapitál se definuje jako individuální faktor kvalifikace, produktivity, dovedností a akceschopnosti (zahrnuje např. vzdělání, zkušenosti jednotlivců/společenství, které uplatňují či mohou uplatnit na trhu práce). Sociální kapitál je určen vzájemnými vztahy, spoluprací, sociální kohezí, důvěrou a interaktivitou jedinců (založen na zdrojích – lidském kapitálu). Kvalita lidského kapitálu spojená s rostoucím vzděláním je podstatným prvkem růstu životní úrovně (zvýšení investic do vzdělávacích systémů podporuje lidský potenciál a ekonomický růst regionů). Vytvářením sociálních sítí jedinci kumulují a násobí svůj individuální (lidský) kapitál a přetváří jej v (kolektivní) kapitál sociální.

Definice a přístupy k hodnocení lidského a sociálního kapitálu se liší jak z hlediska přístupu jednotlivých autorů, resp. disciplín, tak z hlediska regionálního. Většina autorů má odlišný přístup k výběru ukazatelů v důsledku jejich motivace řešit odlišné typy problémů. Téměř u všech autorů (bez oborového a regionálního rozlišení) lze zaznamenat důraz na kvalitu lidského kapi-

tálu vyjádřenou vzdělaností a pozicí aktérů ve věkové struktuře ekonomicky aktivních. V případě sociálního kapitálu je pak patrný důraz na ochotu obyvatel podílet se, obecně řečeno, na činnostech v sítích (včetně participace na správě věcí veřejných).

Kvalita prostředí pro rozvoj lidského kapitálu byla hodnocena prostřednictvím podílu vysokoškolsky vzdělaných starších 15 let (má spíše „potenciálový" význam) a indexu ekonomického zatížení (charakterizuje strukturu obyvatelstva z hlediska omezení aktivní složky populace). Kvalita prostředí pro rozvoj sociálního kapitálu byla hodnocena ukazateli, které vyjadřují společenskou atmosféru v obcích, resp. zájem a zapojení lidí do řešení věcí veřejných. Tedy volební účastí v komunálních volbách (vyjadřuje obecný zájem obyvatel o věci veřejné, konkrétně o řízení své obce) a podílem kandidátů na počet mandátů v zastupitelstvu obce v komunálních volbách (vyjadřuje míru ochoty angažovat se v řízení své obce). Analýza byla provedena v řádovostní úrovni územních obvodů obcí s pověřeným obecním úřadem (389 jednotek na území Česka s výjimkou vojenských újezdů).

Výsledný potenciál pro rozvoj lidského kapitálu v regionálním pohledu dokládá, že jej nelze hodnotit v tradiční dichotomii vnitrozemí vs. dosídlené pohraničí, ale spíše v dichotomii jádrové vs. hospodářsky dlouhodobě slabé oblasti. Nejvyšší potenciál pro rozvoj lidského kapitálu vykazuje podle očekávání Pražský metropolitní areál a krajská města, dále pak oblasti s dominantním postavením regionálních center. Za problémové oblasti lze pokládat území při krajských hranicích.

Výsledný potenciál pro rozvoj sociálního kapitálu v regionálním pohledu dokládá polarizaci území Česka v dichotomii Čechy – Morava, částečně se ukazuje západo-východní gradient ve smyslu industrializovaných („modernějších") a tradičních oblastí. Nejvyšší potenciál pro rozvoj sociálního kapitálu vykazují oblasti v moravských krajích, ale také v kraji Jihočeském. Nejnižších hodnot dosahují oblasti v českých krajích (včetně velké části Vysočiny). Předpokládaná diferenciace kvality lidského a sociálního kapitálu ve smyslu dichotomie kontinuálně osídlené vnitrozemí vs. pohraničí dosídlené po 2. světové válce se nepotvrdila. Za klíčovou lze označit dichotomii jádro–periferie, v českém prostředí zejména ve smyslu regionální centrum–hospodářsky dlouhodobě slabá (venkovská) oblast. Pro výskyt oblastí s horším potenciálem pro rozvoj lidského a sociálního a kapitálu je určující vzdálenost od sídelního (krajského) centra, resp. blízkost krajské hranice. Na území Česka lze identifikovat relativně malý počet jednotek problémových v obou aspektech. Z pohledu regionální diferenciace je signifikantní, že tyto jednotky většinou leží při hranicích Středočeského kraje, což do značné míry koreluje s výskytem vnitřních periferií v těchto oblastech.

Pro naše vstupní analýzy jsme tak vybrali hodnocení ukazatelů, které vypovídají spíše o potenciálu pro rozvoj lidského a sociálního kapitálu, a to zejména s cílem identifikovat problémové oblasti ve smyslu dichotomie jádro-periferie. Z těchto důvodů je třeba na výsledky prezentované v tomto příspěvku nahlížet jako na výstupy první fáze výzkumu, které budou dále doplňovány a precizovány.

Obr. 1 – Potenciál pro rozvoj lidského kapitálu (výsledné souhrnné pořadí obvodů obcí s pověřeným obecním úřadem podle podílu vysokoškolsky vzdělaných obyvatel a indexu ekonomického zatížení 2001). Poznámka: Obvody obcí s pověřeným obecním úřadem jsou vzestupně seřazeny podle hodnot potenciálu pro rozvoj lidského kapitálu. Ty obvody obcí s pověřeným obecním úřadem, které mají nízké hodnoty potenciálu pro rozvoj lidského kapitálu, mají nízké pořadové číslo.

Obr. 2 – Potenciál pro rozvoj sociálního kapitálu (výsledné souhrnné pořadí obvodů obcí s pověřeným obecním úřadem podle volební účasti a počtu kandidátů na počet mandátů v komunálních volbách 2006). Poznámka: Obvody obcí s pověřeným obecním úřadem jsou vzestupně seřazeny podle hodnot potenciálu pro rozvoj sociálního kapitálu. Ty obvody obcí s pověřeným obecním úřadem, které mají nízké hodnoty potenciálu pro rozvoj sociálního kapitálu, mají nízké pořadové číslo.

Obr. 3 – Obvody obcí s pověřeným obecním úřadem s nejnižším potenciálem pro rozvoj lidského a sociálního kapitálu.

Obr. 4 – Administrativní členění České republiky (2008). Kraje, krajská města a obvody obcí s pověřeným obecním úřadem.

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TRANSPORT AND GEOGRAPHIC ORGANIZATION OF SOCIETY: CASE STUDY OF CZECHIA

M. Marada: *Transport and geographic organization of society: Case study of Czechia.* – Geografie–Sborník ČGS, 113, 3, pp. 285–301 (2008). – This article seeks a solution to the mutual association of transport and the complex hierarchy of selected Czech settlements. Evaluation of 144 centres of micro-regional and separately of 12 centres with meso-regional importance was based on public and automobile transport and complex importance indicators. The mutual "closeness" of hierarchies according to the various indicators used was evaluated by a correlation analysis, the level of hierarchization is distinguished with help of rang size rule.
KEY WORDS: hierarchy – public transport – automobile transport – complex importance – settlement centres.

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1. Introduction

The frequency of studies focused on transport issues, in current international geographic literature, has increased lately. This is due, not only to the urgency of transport issues observed in everyday life, but also to the evident return of quantitative methods into research on these issues, as well as to a certain approximation of processes used by technical sciences, which predominantly study transport issues. Also in the field of transport geography we can confirm the Hampl's often repeated opinion (e.g. Hampl 2004) that research is aimed more at studying the "geographic organization of development" and less at necessary, generalizing studies on the "development of geographic organization". Hampl further develops this idea by affirming that in the first case "it is about searching for and differentiating the significance of geographic factors conditioning the differentiation of social and economic development..." (p. 206) and in the second case "...it is necessary to seek answers to these questions: how does the character of concentration processes change, how does a settlement hierarchy develop, how does the core function (in the sense of core vs. periphery) of cities change in terms of both overall extent and function, or rather quality." (p. 206).

From the discipline of transport geography, for example, classical geographic studies on the regional differentiation of transport infrastructure quality and its relation to other socio-geographic characteristics can be included in the first type of studies. For instance, Marada (2003a), when comparing Czech border regions with the interior, showed that in Czechia's specific circumstances, higher quality transport infrastructure in a region does not necessarily correspond to better economic conditions. Research also frequently focuses on urgent transport problems in cities (especially competition between individual automobile transport and public transit – see, for example, Marada 2006; Ouředníček 2006; de Palma, Rochat 2000 and others) or, in contrast, on transport in peripheral, rural areas (accessibility in connection with social exclusion of certain groups of the population – e.g. Nutley 1998; Farrington, Farrington 2005; McDonagh 2006; Marada, Hudeček 2006 and Květoň 2006). At present, transport is primarily conceived as a significant contributing factor in the differentiation of regional development (e.g. Bruinsma, Rietveldt 1998; Bryan et al. 1997; Vondráčková 2006; Lehovec 2003 etc.) and numerous studies in this field, at least in the interpretation of their results, deal with the second type of problems described by Hampl. Thus, it becomes necessary to specify the questions, with which Hampl generally characterized studies of this second type (the "development of geographic organization"), in this case, in terms of transport issues:

- How and to what degree does transport influence the concentration of job opportunities?
- How does transport contribute to intensification of the settlement hierarchy? Is its role in this process increasing?
- Does a good transport system increase the regional role of cities and promote the spatial enlargement of their hinterland?
- How does time accessibility support the competition and cooperation of centres?

The above examples of questions illustrate three spheres of problems, into which the discussed relation of transport to changes in the geographic organization of society can be subdivided in a simplified way. Transport factors have a clear impact on changes in the concentration of job opportunities and progressive activities, i.e. on processes leading to the intensification of the settlement hierarchy. In these processes, transport plays a significant role, for example, by improving time accessibility through the development of transport networks or by improving the quality of transport services in city centres. The respective transport significance of the various centres – both in terms of their position in transport networks as well as the intensity of transport – is however the result of relations between the centre and its micro-regional hinterland along with relations existing between centres themselves, which are expressed within the various regional levels of centres (e.g. the contact of micro-regional centres with their relevant, superior meso-regional centre), but also between centres at the same level (e.g. between meso-regional centres). Hierarchically higher centres, therefore, cumulate their functions (including transport functions) in varied regional arrangements. The two basic realms of the problem discussed here, outline the issue of relations among centres and core-hinterland relations; a third realm is the inherent relation between the resulting transport and complex hierarchy of centres. In the subsequent text, the levels described are only briefly discussed, due to the limited extent of this article. The third sphere is empirically evaluated with the example of the hierarchy of the main centres of settlement in Czechia.

2. Relations among centres and between centre and hinterland

The mutual interconnection of significant centres of settlement by transport routes allows for the development of both competitive processes, i.e. "growth of stronger centres to the detriment of weaker centres", as well as cooperative processes, i.e. territorial specialization, diffusion of progressive activities from core regions to peripheral areas, etc. In this sense, transport systems can contribute to the intensification and weakening of the settlement hierarchy. Processes of concentration and cooperation are, however, difficult to evaluate considering the present state of statistics.

It is clear that the mutual time accessibility of core settlement areas, which facilitates or, on the contrary, impedes their contact, plays an indispensable role in the intensity of their interactions. Increasing intensities of transport relations with deceasing distance between settlements have been proven by numerous "classical" models, for instance, the so-called distance-decay or gravitational models (see e. g. Hagget, Chorley 1969; Luoma et al. 1993 etc., from Czech authors e. g. Řehák 1992 or Rölc 2004). The growth of cooperation or competition among centres is manifested by a variety of elements, including an increase of transport between centres, as well as a shortening of transit time, which is often related to quality improvements in the transport network. Development of better transport infrastructure is, in fact, called for by the needs of the strongest centres. In the case of Czechia, however, the development of networks lags significantly behind the intensity of transport contacts among centres, because of the great financial costs involved in infrastructure construction (see also studies by Marada 2006 evaluating the relation of the horizontal and vertical position of centres in terms of their complex size).

The issue of the role of transport in the core – hinterland relationship can be divided into two levels that are, of course, closely interconnected. The first is the impact of the transport infrastructure's quality on the growth of the city's (or town's) significance as a centre attractive for investment allocation and for new progressive activities connected with the availability of job opportunities. Naturally, the importance of transport factors is not considered the most important in this case. For instance, Blažek points out that the distribution of firms in the progressive tertiary sector in Czechia, during the 1990s, show no apparent relation, for example, between the size of centres, the level of socio-economic development of the districts or their geographic position, verifying the significant influence of subjective factors such as entrepreneurial incentive or the existence of governmental supporting programmes. In this way, Blažek builds on the opinion of Dicken and Lloyd (1992, quoted in Blažek 2001) that the great concentration of firms in the progressive tertiary sector "...into central regions, which, in developed countries, is usually similar in principle to the distribution of the headquarters of large firms, is due to the irreplaceablility of personal contact when solving certain problems" (p. 238). The influence of the presence of an airport in the region on the localization of progressive tertiary firms is difficult to prove. It is true that a significant portion of these firms are transnational, creating high demands for contact with supervising or cooperating branches in foreign countries. In addition, metropolitan areas regularly have international airports and strengthening connections with a required destination is a matter of adapting supply to demand. Consequently, in this sense, it is more correct to evaluate the development of airport efficiency in the context of other air transport centres. Simply put, the position of an airport in international ranking lists does not sufficiently determine the degree of the airport's impact as a localization factor and it is, again, only one of several contributing localization factors.

In terms of evaluating motorways as factors of local and regional development, authors agree almost unanimously that the presence of a motorway is only one – and certainly not a sufficient – condition for the development of adjacent regions. Probably the most detailed study of this nature in Czechia was carried out by Jeřábek, Marada (2003) and Vondráčková (2006) on a segment of the D8 motorway between Prague and Lovosice. The observations revealed that the presence of this motorway encouraged the construction of residential areas as well as the placement of certain types of economic activities, primarily in hinterland areas near Prague and to a lesser degree around Lovosice. In the Prague suburban area, such activities simply represented a transfer of existing economic activities to the motorway. Motorways encourage the territorial concentration of certain types of activities (logistics centres, shopping centres, etc.) which, of course, could be a mere spatial redistribution of previously existing activities (Bruinsma, Rietveldt 1998, speak about the distribution effect of transport infrastructure). An overview of significant, recent case studies from the Anglo-Saxon region is presented in an article by Preston (2001). For the most part, the studies listed in Preston's article failed to prove the existence of a significant impact – or showed only a small impact – of a motorway or high-speed railway on improvements in the employment rate. Preston, however, urges geographers not to be needlessly sceptical in their conclusions concerning the impact of transport on the development of localities and regions and he offers a provocative question: "Do we really believe that, for example, the development of the motorway network in Britain over the last forty years or so has had no impact on socio-economic activities?" (Preston 2001, p. 22). Even though all of these findings represent conclusions of localized case studies, the conformity of their results enables one to make a claim that the main impulse for motorway construction is not to support the development of economically weaker regions (as decision-makers often proclaim), but rather the need of centres at a higher level to become interconnected with faster and larger infrastructure. Although those deciding on such construction may not be aware, the main driving force behind quality improvements to networks is pressure from general regional development.

The second, but corresponding, level in the discussion of the role of transport in the contact of a centre with its hinterland is the view of transport as a means enabling the mobility of inhabitants, or rather a means of fulfilling the need to commute to centres with a concentration of job opportunities. Analyzing this connection is difficult primarily because of the uncertain causality of both phenomena. Would the central role of meso-regional centres, or of Prague for that matter, be as high without a functional transport system? Would job opportunities (in Prague, for instance) increase if there were an insufficient labour force, because of difficulties commuting, among other problems? Or does the number of job opportunities increase regardless of the availability of labour on the market? Does the market rely upon the attractiveness of working in centres and on the adaptation of prospective employees? These questions are intentionally formulated in a rather extreme manner to stress the relationship being discussed. It is probable that the indicated relationship applies in both directions. Demand for jobs, in Prague for example, along with existing deformations in the housing market (inland migration is to a certain degree replaced with daily and even non-daily commuting to work – see, for example, Čermák 2001, etc.) create pressure on transport services for commuting to Prague. On the other hand, progressive economic sectors, especially, develop in response to economic needs and are allocated to Prague as Czechia's leading settlement centre. The higher income level of employees at such firms enables them to lease apartments directly in the locality and, consequently, to not be dependent on commuting.

It is generally presumed that the intensity of commuting to a centre is tied to the widely perceived, transport availability (see also the gravitational model mentioned above). Even from a brief comparison of the socio-geographic regionalization of Czechia in 1991 and 2001 (Hampl, Müller 1996; Hampl 2005) it is clear that enlargement of the commuting hinterland of micro-regional centres or, depending on the situation, enlargement of metropolitan areas, occurred in many cases in the direction of important surface roadways. This is because commuting time is clearly a more important deciding factor than is the actual distance (in kilometres) in the daily commuting habits of the population. In the case of Prague as the strongest centre, it is evident that its significance as a commuting centre (to work or to school) has expanded, in terms of area, between 1991 and 2001, mainly along important transport corridors – see also Hampl 2004), primarily motorways and important railways. By 2001, in comparison with 1991, a total of eight meso-regional centres out of eleven (these include all Czechia's regional capitals, with the exception of Prague and Jihlava) newly oriented themselves towards Prague as did 19 micro-regional centres (out of 132). In a study mentioned above, Vondráčková (2006) used a comparison of data from the 1991 and 2001 censuses to show that the D8 motorway has not promoted a reorientation of the strongest directions of commuting to work, which have remained focused on micro-regional centres. In the majority of concerned municipalities, however, the second strongest commuting direction has been replaced by easily accessible Prague.

It remains true, however, that the high-order transport network, which is, as a rule, the conveyor of improved time accessibility, has not changed significantly in the greater Prague area during the period of time between censuses (1991–2001). Some small, additional segments of the D8 motorway were completed and the railway No. 011 in the direction of Kolín (which is part of rail corridor I) received technical improvements. In addition to the time aspect, transport expenses, closely related to the trip's actual kilometre distance, are also an important factor in the decision process for residents about the goal of their commute. Beginning with a certain limit, daily commuting is replaced with non-daily movements (see also the new orientation of relatively inaccessible and economically poorly developed territories towards Prague in the Hampl's study mentioned above – the areas of Jeseníky mountains and Orlické hory mountains for example). Not only the time accessibility of commuting centre, but also its attractiveness as a place to work plays an important role in the spatial organisation of population movements. A commuting region, therefore, is a result of the interference of these two factors.

Bruinsma, Rietveld (1998) conclude that the impact of transport infrastructure on the labour market and commuting manifests itself both through the arrival of new firms in the region as well as through a possible decrease in the productivity of local enterprises due to increased competition from neighbouring, more developed regions. Without a flexible labour force, i.e. without workers willing to attend retraining courses or to commute longer distances to work, negative impacts of a new transport corridor could significantly outweigh those on the positive side. The conditioning impact of transport is, in terms of the concentration of job opportunities, rather insignificant, because the creation of firms in progressive economic sectors is influenced by a series of additional factors, including the flexibility of human resources, the hierarchical importance of the centre in question, its geographic position, etc. Transport can, however, influence the quantity of the available labour force, because the volume of residents daily commuting to the core is significantly limited by the time accessibility of the centre. This limiting function of transport should, however, be further verified empirically.

3. Relation between the transport and the complex-settlement hierarchy

The aspects discussed in the preceding text have a resulting impact on the differentiation of centres in terms of their complex importance and their transport importance and thus, they also have an impact on relationships and conformity of both types of hierarchies. The following summary focuses on examining the mutual conditionality of both hierarchies and results in a determination of prerequisites for the subsequent empirical section.

First it should be stressed that transport is a manifestation of the mobility of the human population and their spatial differentiation is, naturally, strongly tied to the concentration of population and to its activities. The intensity of transport in centres is therefore connected with the population size of cities/towns. It is influenced not only by the population living in the centres, but also by those commuting to this centre for job opportunities, i.e. to the extent of the centre's hinterland and its relations with other centres. In this sense, we can expect a mutual size conditionality of transport and complex-settlement hierarchies. This conditionality is certainly positive, has corresponding development tendencies and the ascertained association of transport importance of centres with their complex significance will probably be very close.

A connected question is the causality of the interaction between the settlement hierarchy and the transport hierarchy. The impact of rail transport on the development of settlements in the 19th century is sufficiently recognised. Many examples of medium-size cities, whose importance has noticeably increased after being connected to a railway, can be given. Such cities have also taken over the role of more important historical cities, which have been relegated to a worse position in terms of transport (see, for example, Kolín – Kutná Hora or Pardubice – Chrudim). Connection of a centre to a railway led, in certain cases, even to gaining administrative (i. e. governing) functions. Also, current development of the motorway network is conditioned by a need to connect the most important centres of the national and transnational hierarchy. Its growth impact is, however, more evident in the strongest centres and less so in weaker, intermediate centres. Both these simple examples prove that, in addition to the mutual influences between settlement and the transport systems, there is also a certain difference between the two main types of transport infrastructure in our country. The roadways, as a more flexible and historically younger network, more closely reflect the present hierarchy of settlements, while the earlier developed rail network arose from the economic needs of the industrial era, its network is, in general, sparser and its maximum extent has already been reached. Therefore railways have "out of necessity" a linear character and are used more for long-distance transport. This very position, the distinct transport position of a centre in both main types of transport networks is, especially in the case of the rail network, a frequent cause of differences in the transport and geographic position of settlements and consequently a disturbance of the concordance of both evaluated hierarchies. Large differences arise, therefore, mainly in the case of smaller centres, the position of which in both types of transport networks is not balanced and which frequently "profit" from their position on transport lines connecting hierarchically more important nodes.

The position of a centre in transport networks is also manifest in the structure of transport in the centre itself, specifically as a ratio of train and bus connections and also as a ratio of international, long-distance and local connections. Especially smaller settlements at important transport lines can, in this way, have significantly better transport services. Transport conditions in a centre in terms of the structure of transport means are to a certain degree conditioned by the character of the centre's hinterland. Earlier studies (e. g. Květoň 2006, Seidenglanz 2007, Kraft 2007) make it clear that sparsely populated territories are more poorly served by public transport and are more dependent on individually ensuring accessibility with privately owned automobiles. These tendencies, however, influence the transport typology of centres rather than their hierarchization. It is, of course, clear that the horizontal transport position of a centre in transport networks influences its vertical position, the transport importance in terms of transport intensity, for example.

Hypotheses on the relation between transport and complex settlement hierarchy of centres can be established as follows. The relation between transport and complex settlement hierarchy of centres of settlement in Czechia will be observed both in terms of the degree of hierarchization of the observed group of centres according to various characteristics and also in terms of the degree of concordance of transport hierarchies with the complex hierarchy. Because of the conditionality of size mentioned above, we can assume a strong association of the hierarchies of both types exists. Partial transport systems (bus, automobile and rail transport) will, of course, be associated with the complex hierarchy to a different degree. In light of planned, "all-inclusive" bus services and the weaker determination of road transport by networks, closer relations will be found in bus and automobile transport than in rail transport, which, due to their dependence on the historical rail network, manifest a somewhat "linear" differentiation and a stronger focus on long-distance transport. For similar reasons, out of the transport characteristics, the level of hierarchy of automobile and bus transport will most closely approximate the complex hierarchy.

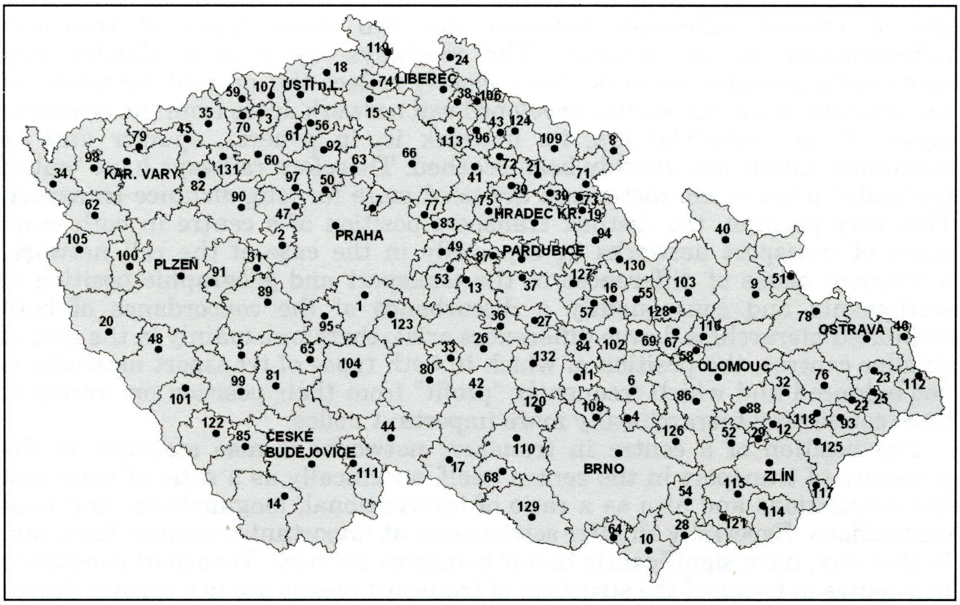

Fig. 1 – Socio-geographic micro-regions and its centres in Czechia (2001). Centres of higher importance – macro-regional (Prague) and meso-regional one (regional capitals excerpt Jihlava) – are described. Other centres of micro-regional importance (in alphabetical order): 1–Benešov, 2–Beroun, 3–Bílina, 4–Blansko, 5–Blatná, 6–Boskovice, 7–Brandýs nad Labem-Stará Boleslav, 8–Broumov, 9–Bruntál, 10–Břeclav, 11–Bystřice nad Pernštejnem, 12–Bystřice pod Hostýnem, 13–Čáslav, 14–Český Krumlov, 15–Česká Lípa, 16–Česká Třebová–Ústí nad Orlicí, 17–Dačice, 18–Děčín, 19–Dobruška, 20–Domažlice, 21–Dvůr Králové nad Labem, 22–Frenštát pod Radhoštěm, 23–Frýdek-Místek, 24–Frýdlant, 25–Frýdlant nad Ostravicí, 26–Havlíčkův Brod, 27–Hlinsko, 28–Hodonín, 29–Holešov, 30–Hořice, 31–Hořovice, 32–Hranice, 33–Humpolec, 34–Cheb, 35–Chomutov, 36–Chotěboř, 37–Chrudim, 38–Jablonec nad Nisou, 39–Jaroměř, 40–Jeseník, 41–Jičín, 42–Jihlava, 43–Jilemnice, 44–Jindřichův Hradec, 45–Kadaň, 46–Karviná, 47–Kladno, 48–Klatovy, 49–Kolín, 50–Kralupy nad Vltavou, 51–Krnov, 52–Kroměříž, 53–Kutná Hora, 54–Kyjov, 55–Lanškroun, 56–Litoměřice, 57–Litomyšl, 58–Litovel, 59–Litvínov, 60–Louny, 61–Lovosice, 62–Mariánské Lázně, 63–Mělník, 64–Mikulov, 65–Milevsko, 66–Mladá Boleslav, 67–Mohelnice, 68–Moravské Budějovice, 69–Moravská Třebová, 70–Most, 71–Náchod, 72–Nová Paka, 73–Nové Město nad Metují, 74–Nový Bor, 75–Nový Bydžov, 76–Nový Jičín, 77–Nymburk, 78–Opava, 79–Ostrov, 80–Pelhřimov, 81–Písek, 82–Podbořany, 83–Poděbrady, 84–Polička, 85–Prachatice, 86–Prostějov, 87–Přelouč, 88–Přerov, 89–Příbram, 90–Rakovník, 91–Rokycany, 92–Roudnice nad Labem, 93–Rožnov pod Radhoštěm, 94–Rychnov nad Kněžnou, 95–Sedlčany, 96–Semily, 97–Slaný, 98–Sokolov, 99–Strakonice, 100–Stříbro, 101–Sušice, 102–Svitavy, 103–Šumperk, 104–Tábor, 105–Tachov, 106–Tanvald, 107–Teplice, 108–Tišnov, 109–Trutnov, 110–Třebíč, 111–Třeboň, 112–Třinec, 113–Turnov, 114–Uherský Brod, 115–Uherské Hradiště, 116–Uničov, 117–Valašské Klobouky, 118–Valašské Meziříčí, 119–Varnsdorf–Rumburk, 120–Velké Meziříčí, 121–Veselí nad Moravou, 122–Vimperk, 123–Vlašim, 124–Vrchlabí, 125–Vsetín, 126–Vyškov, 127–Vysoké Mýto, 128–Zábřeh, 129–Znojmo, 130–Žamberk–Letohrad, 131–Žatec, 132–Žďár nad Sázavou.
Source: Hampl 2005

4. Empirical analysis of settlement centres' hierarchization

4.1 Methods of research

The main methodological problem when studying transport and the complex importance of centres and their relations is to determine a monitored group of centres and, at the same time, to choose representative indicators characterizing the transport and complex importance of centres.

Settlements were chosen for monitoring on the basis of the socio-geographic regionalization carried out by Hampl according to the Population and Housing Census from 2001 (Hampl 2005). This paper outlines, according to the prevailing commuting orientation of the population to work and school, a total of 144 micro-regional centres, out of which were determined (on the basis of their mutual relations) 11 centres of meso-regional importance (these include all Czechia's regional capitals, with the exception of Prague and Jihlava) and one centre of macro-regional importance – Prague (see Fig. 1). Four of these selected centres have a double core and were therefore agglomerated (Česká Třebová-Ústí nad Orlicí, Zlín-Otrokovice, Žamberk-Letohrad and Rumburk-Varnsdorf).

The selection of relevant indicators was conducted in an effort to characterize both the size and quality of transport services in the centres. Consequently, both individual and public transports were monitored. Moreover, data in public transport timetables enable distinguishing local and long-distance (among centres) connections which, as a more selective segment of transport, deepen the transport hierarchy. The importance or extent of *public rail and bus transport* in centres was evaluated according to the number of connections departing from the centre on Wednesday 24 May 2006. In this way, the availability of public transport on working days is expressed. This simple indicator has a limited informative value, because data on the actual use of these connections (occupancy level) are not available for such an extensive group; however, because of the interconnection of transport supply and demand in larger centres this index can be considered sufficiently representative. These data were taken from the electronic IDOS timetable (CD ROM version from the firm CHAPS Brno). Long-distance train connections (labelled *LONGTRAIN*) were determined as the sum of express, fast and rapid train connections, the category of long-distance bus connections is labelled *LONGBUS*. The remaining connections are of a local nature and are marked as *LOCALTRAIN* (local train connections), or *LOCALBUS* (local bus connections). In light of the greater importance of long-distance connections in the hierarchical position of centres and also due to greater capacity (and at the same time a lower number) of train connections, different weights were utilised when determining the total important transport characteristics of these connections: aggregate passenger rail transport *TRAIN* was defined as the sum of long-distance train connections (*LONGTRAIN*) multiplied by three plus the number of other (local) connections (*LOCALTRAIN*); the aggregate for bus transport: *BUS*, was constructed in the same manner (i.e. 3 x *LONGBUS* + 1 x *LOCALBUS*). The total transport hierarchization of centres in terms of public transport was then carried out with a summarizing transport aggregate *(PUBLIC) TRANSPORT*, determined—again because of higher capacity, but lower frequency of connections—as the sum of three times the value of the *TRAIN* aggregate plus the value of the *BUS* aggregate.

The second method used to evaluate the transport importance of centres was enumerating the transport load of centres in terms of *automobile transport intensity* (Hůrský 1978, discusses the "attractiveness" of towns). Results from the census of transport frequency on main roads in 2005, conducted every five years by the Road and Motorway Directorate of the Czech Republic, were used for this evaluation. The statistic used is, in fact, the sum of all transport volume measured at census points situated in the proximity of the centre, i.e. a total amount of vehicles entering or departing from the centre in the course of a 24 hour period on an "average" day (for more about methods, see the website of the Road and Motorway Directorate, www.rsd.cz). The structure of the traffic stream was also monitored, but individual categories were not analysed, as this would be very time demanding. Private cars represent more than three quarters of the traffic stream (75.6 % in 2005) in the group of centres. The majority of the remaining volume consisted of lorries of all weight categories and marginal amounts of motorcycles and bikes. Unfortunately, the available database does not allow for the exclusion of bus transport, which is included in the evaluation through timetables described above, but their frequency is negligible and does not influence the analyses carried out. The transport importance of centres in terms of road transport intensity was enumerated for 2005, due to the availability of data in five-year period, and labelled *AUTO*.

Finally, an index of *complex size of centres* (*CS*) for the year 2001, also taken from Hampl's publication (2005), was used to evaluate the complex importance of settlement centres. Construction of the index is based on the number of residents living in the area and the number of job opportunities located there, meaning that it combines the residential and labour functions of the centre and makes them relative with regard to the national system.

Hierarchization of the various groups is evaluated with the help of basic characteristics from descriptive statistics as well as by employing the rank size rule (Auerbach 1913, quoted in Hampl, Gardavský, Kühnl 1987), used here as comparative model for distinguishing the level of hierarchization. Calculations are carried out here only for the first five defined categories, that is, up to the 98th unit. In this way, the most significant, upper and middle part of the hierarchy of centres is included. Hierarchization is evaluated in a double manner – both by the degree of diversification of the centre and by its degree of concordance.

4.2 The results: State, development and implications of the transport and complex hierarchization of centres

Even in the early comparison of average, median and modal values of the monitored groups, a varied level of the asymmetric (hierarchical) differentiation of the groups of centres according to the monitored characteristics was already evident. The hierarchization of the groups is better characterized by a comparison with the rule of the size sequence of cities (Tab. 1). As presumed, these values also verify the sequence predicted above concerning the level of hierarchization of a group according to the selected characteristics. The overall transport hierarchy of centres in terms of public transport (according to the *TRANSPORT* index) has developed to a much weaker degree than the most developed complex settlement hierarchy. This is caused partly by the necessity to ensure spatially inclusive transport services (after falling to a certain size of settlement, the quantity of departures practically do not decrease with size) and partly by the limited explanatory value of the data used, as discussed above, because the number of connections does not accurately represent the volume of passengers. We can further state that centres have naturally higher levels of hierarchization

Tab. 1 – Size hierarchization of centres according to transport indicators and their complex size (size of the first centre = 100.00)

Order	LONG-TRAIN	LOCAL-TRAIN	LONG-BUS	LOCAL-BUS	TRAIN	BUS	TRANS-PORT	AUTO	CS
1st	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100,00
2nd–4th	200.00	136.30	104.80	157.80	166.00	112.30	125.00	127.74	73,62
5th–12th	351.70	286.10	121.50	262.70	322.50	180.60	221.20	170.16	62,64
13th–34th	543.30	600.00	209.80	466.50	533.70	313.00	380.00	296.15	83,18
35th–98th	719.20	1105.30	285.40	801.80	871.20	531.40	698.60	518.36	103,84
1st–98th	1914.20	2227.70	821.50	1788.80	1993.40	1237.30	1524.80	1212.41	423.28
Degree of hierarchization	23.76	13.86	41.36	20.33	18.93	25.14	20.86	27.96	92.83

Notes: 1. Names and description of indicators – see chapter 4.1.
2. Public transport indicator 2006, AUTO 2005, CS 2001.
3. Degree of hierarchization = 100 times ((size of the 1st–4th centre) / (size of the 13th–98th centre)), i.e. size of the largest centres in proportion to the size of middle and small centres. Values lower than 100.0 correspond to a lower degree of hierarchization than presumed by the rank size rule, values higher than 100.0 to a higher degree.
4. The line 1st–98th gives the sum of percentage points from the five categories given. If the size distribution of centres corresponded to the presumption of the rank size rule, the value of this sum would be 500.0. Values lower than 500.0 correspond to a higher degree of hierarchization than presumed by the rank size rule, values higher than 500.0 to the lower degree.
Source: electronic IDOS timetable, Transport census ŘSD ČR, ČSÚ, Hampl 2005

in terms of long-distance transport than local transport. A higher level of hierarchization is manifested by *LONGBUS* and *LONGTRAIN* groups as more selective types of connections, which are represented mainly in centres at the top of the list and whose proportion quickly decreases in "lower levels" of the hierarchy. This is the principal difference against groups with a lower level of hierarchization in terms of local rail and bus transport which, due to the necessity of minimal transport services in settlements, practically do not change after falling below a certain size of centres. The majority of smaller centres have only scarce long-distance transport or none at all. In contrast with the complex settlement hierarchy, the developmental extent of the hierarchy of centres in terms of long-distance transport is caused rather by the weak – or even the complete absence of – importance of small centres than by significant differences among large centres.

The lowest degree of hierarchization of centres according to *LOCALTRAIN* and *LOCALBUS* naturally also inhibits the level of hierarchization according to the *BUS* and *TRAIN* aggregate characteristics. In spite of a generally low level of hierarchization in terms of transport importance, it is evident that centres have a more developed hierarchy in terms of their available bus services, than in terms of rail transport services. The main reason is the nodal-like concentration of bus transport as well as the linear concentration of rail transport, as mentioned above. In other words, the availability of bus transport in centres is conditioned more by the hierarchy of nodes, while rail transport services available in centres are determined to a greater degree by the hierarchy of transport networks or axes. It is however necessary to stress once again, that the hierarchy of transport axes is primarily conditioned by the hierarchy of nodes and, naturally, most significantly by the hierarchy of nodes of the highest orders.

Tab. 2 – Paired correlations of transport characteristics and CS – the entire group of 144 centres

	LONG-TRAIN	LOCAL-TRAIN	LONG-BUS	LOCAL-BUS	TRAIN	BUS	TRANS-PORT	AUTO	CS
LONGTRAIN	1.000	0.766	0.518	0.531	0.975	0.577	0.862	0.692	0.611
LOCALTRAIN	0.766	1.000	0.661	0.654	0.891	0.723	0.890	0.806	0.743
LONGBUS	0.518	0.661	1.000	0.653	0.597	0.898	0.812	0.870	0.884
LOCALBUS	0.531	0.654	0.653	1.000	0.604	0.919	0.827	0.823	0.787
TRAIN	0.975	0.891	0.597	0.604	1.000	0.660	0.920	0.770	0.691
BUS	0.577	0.723	0.898	0.919	0.660	1.000	0.902	0.930	0.916
TRANSPORT	0.862	0.890	0.812	0.827	0.920	0.902	1.000	0.928	0.876
AUTO	0.692	0.806	0.870	0.823	0.770	0.930	0.928	1.000	0.927
CS	0.611	0.743	0.884	0.787	0.691	0.916	0.876	0.927	1.000

Notes: 1. Names and description of indicators – see chapter 4.1
2. Public transport indicator 2006, AUTO 2005, CS 2001
3. All correlations are significant at the level 0.01 (2-tailed).
Source: electronic IDOS timetable, Transport census ŘSD ČR, ČSÚ, Hampl 2005

AUTO, the index expressing the quantity of motor vehicles passing through the centre during for 24 hours on an "average" day in 2005, is, of course, the transport group exhibiting the highest level of hierarchization. The degree of hierarchization in this group is even higher than the level of hierarchization according to aggregate bus connections and exhibits, to a certain degree, nodal conditionality. However, it still does not reach the development extent of the complex hierarchization of centres.

The mutual "closeness" of hierarchies according to the various indicators used was evaluated by a correlation analysis (see Tab. 2). The generally high association of monitored hierarchies can be characterized as expected, because transport hierarchy is a partial component of the complex hierarchy. As assumed, both monitored types of the transport system display a different relation. The importance of bus transport is correlated with the complex importance of centres more closely than the importance of rail transport. The cause for this is primarily the higher nodal conditionality of the organization of bus transport mentioned. Association of partial transport characteristics with *CS* is significantly lower than in the case of relevant aggregate characteristics. It can, however, be confirmed that the number of long-distance connections is in both cases less correlated with *CS* values than is the number of local connections (in the case of express train connections it is the lowest correlation at all). In terms of the finding that groups of long-distance connections exhibit, in general, more extensive hierarchization, their low correlation with the complex importance group, showing the most extensive hierarchization, is somewhat surprising. Especially in rail transport, a repeated difference between the hierarchy of transport nodes and the hierarchy of transport networks is expressed here. Another conditioning factor is the fact that the importance of local transport is more inclined to nodal organization and that rail transport is more specialized in long-distance transport. A consequence is that the hierarchy of centres, in terms of rail transport, "must" correspond to the complex settlement hierarchy less "precisely" overall than does the hierarchy in terms of bus transport. Table 2 further verifies that the relation of long-distance bus connections and train connections is less correlated than the relation of local bus and train connections. It shows a certain complimentary nature of long-distance bus

Tab. 3 – Paired correlations of transport characteristics and complex size – the 12 most significant centres

	LONG-TRAIN	LOCAL-TRAIN	LONG-BUS	LOCAL-BUS	TRAIN	BUS	TRANS-PORT	AUTO	CS
LONGTRAIN	1.000	0.833	0.663*	0.651*	0.977	0.712	0.868	0.799	0.760
LOCALTRAIN	0.833	1.000	0.909	0.736	0.931	0.898	0.958	0.933	0.934
LONGBUS	0.663*	0.909	1.000	0.702*	0.784	0.934	0.912	0.943	0.926
LOCALBUS	0.651*	0.736	0.702*	1.000	0.710	0.910	0.864	0.817	0.845
TRAIN	0.977	0.931	0.784	0.710	1.000	0.812	0.938	0.883	0.858
BUS	0.712	0.898	0.934	0.910	0.812	1.000	0.964	0.959	0.963
TRANSPORT	0.868	0.958	0.912	0.864	0.938	0.964	1.000	0.972	0.963
AUTO	0.799	0.933	0.943	0.817	0.883	0.959	0.972	1.000	0.966
KS	0.760	0.934	0.926	0.845	0.858	0.963	0.963	0.966	1.000

Notes: 1. Names and description of indicators – see chapter 4.1
2. Public transport indicator 2006, AUTO 2005, CS 2001
3. Correlations significant at the level 0.05 (2-tailed) are signed by *, all other are significant at the level 0.01 (2-tailed).
Source: electronic IDOS timetable, Transport census ŘSD ČR, ČSÚ, Hampl 2005

and train transport, which is ,by the way, confirmed primarily with the fact, that by aggregating transport characteristics, the degree of association of the transport hierarchy and complex hierarchy increases.

The number of vehicles passing through (*AUTO*) shows a close association with the complex importance of centres, similar to the *BUS* index, confirming that automobile transport, as the most flexible transport mode, will correspond the most to the complex importance of centres. At the same time, the *AUTO* index has a significantly closer relationship with local connections (both bus and train) than with the long-distance connections, which indicates the dominant use of cars for ensuring functions of centres at the micro-regional level, i.e. for supplementing the frequently insufficient public transport services.

The comparison of monitored transport hierarchies mentioned with the rank size rule led to a conclusion that the hierarchical principle is most extensively developed, in their case, at the "upper levels" of the hierarchy, although the hierarchization as whole is strongly conditioned, especially by the relatively weakly differentiated "lower levels" of the hierarchy. It seems, therefore, useful to make a correlation analysis not only for the entire group of 144 centres, but also within its subdivided, hierarchical categories. For this reason, Table 3 provides the values of paired correlations of the indicators used only for the group of 12 centres of meso-regional importance and for the macro-regional centre, Czechia's regional capitals with the exception of Jihlava. A comparison of values for the entire group and its hierarchically most significant portion shows above all a general increase in the closeness of correlations. The relation of aggregate characteristics and partial indicators is stronger, especially in the case of rail transport. This shows the impact of the position of centres in the transport network, because in the case of regional capitals, the position within road and rail networks is relatively equal. However, a higher nodal conditionality of bus and automobile transport, manifested by a higher correspondence with the complex hierarchy, remained in force. With the largest centres, harmony between the hierarchy of transport nodes and transport networks, which is reflected in the high degree of correspondence between the transport and complex hierarchy (the greatest nodes of the networks hierarchy are decisive) can be pointed out. An increase in the level of association between the transport and complex hierarchies with aggregating the characteristics again verifies the complementary nature of both types of public transport monitored in the centres. At the same time, the level of specialization in bus and rail transport between local and long-distance transport has decreased and it can be said that the largest centres have complex transport services.

5. Conclusion

The analyses performed have verified the assumed mutual size conditionality of the transport and complex importance of centres, which is manifested by a close correlation of general characteristics. At the same time, the significant impact of the position of centres in transport networks was clearly expressed, with bus and automobile transport being the most closely associated with the complex hierarchy, because, in contrast to rail transport, they are less determined by their transport network and can respond "more independently" to the current demand for transport. The position in networks also leads, to a certain degree, to the transport specialization of centres, when important centres of rail transport also have a high number of long-distance connections and bus transport is more focused on providing links at the local level. Both types of public transport are thus complementing one another. Automobile transport is, in terms of transport distance, probably rather autonomous, of course with dominant use in local transport.

A comparison of relations within the entire group of 144 centres of micro-regional importance and of the results for the 12 most significant centres has shown that the impact of transport networks and the specialization of various types of transport are less evident in this case. An explanation can be found in the relatively equalized position of regional capitals in both types of transport networks.

Further monitoring should be aimed primarily at the situation of centres at "lower levels" of the hierarchy, which exhibit only low levels of hierarchization (as a consequence of planned transport services and of efforts to ensure, at least, spatially inclusive transport availability along with other contributing causes) and in such circumstances, the transport importance of centres corresponds to a lesser degree with their complex importance. The main public transport mode there is bus transport and, primarily, individual automobile transport, which probably compensates for insufficient public transport services. The number of persons who because they are not able to drive their own car, are placed in a situation of "transport exclusion" may therefore increase. This issue, connected with the significant applications for transport policy can become a hot topic for further transport geography research.

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Shrnutí

DOPRAVA A GEOGRAFICKÁ ORGANIZACE SPOLEČNOSTI: PŘÍPADOVÁ STUDIE ČESKA

Také o geografii dopravy lze konstatovat několikrát opakovaný názor M. Hampla (např. Hampl 2004), že geografický výzkum se zaměřuje spíše na studium „geografické organizace vývoje“ a méně už na potřebné zobecňující studium „vývoje geografické organizace“. Přitom „...je potřebné hledat odpovědi na otázky: jak se mění charakter koncentračních procesů, jak se vyvíjí sídelní hierarchie, jak se mění středisková působnost měst ve smyslu rozsahovém i funkčním, resp. kvalitativním.“ (s. 206) Při zohlednění dopravněgeografických aspektů lze zmíněnou problematiku zjednodušeně rozčlenit do tří okruhů. Zřejmý je vliv dopravních faktorů na proměny koncentrace pracovních příležitostí a progresivních aktivit, tedy na procesy vedoucí k prohlubování sídelní hierarchie. Vlastní dopravní význam jednotlivých středisek – jak z hlediska postavení v dopravních sítích, tak z hlediska intenzity dopravy – je ovšem výsledkem vztahů střediska s jeho mikroregionálním zázemím a také vztahů mezistřediskových, které probíhají v rámci jednotlivých regionálních úrovní středisek, ale i mezi středisky stejné úrovně navzájem. Hierarchicky výše položená střediska pak kumulují své funkce (i dopravní) na různých regionálních řádech. Problematikou mezistřediskových vztahů a vztahů středisko–zázemí jsou dány dva základní okruhy diskutované problematiky, třetím je pak vlastní vztah mezi výslednou dopravní a komplexní hierarchií středisek. Z důvodu omezeného rozsahu článku je empiricky blíže vyhodnocen pouze okruh třetí na příkladu hierarchie hlavních středisek osídlení Česka.

Vzájemné ovlivnění dopravní a komplexně-sídelní hierarchie středisek lze předpokládat v několika aspektech. Za prvé je to samozřejmá velikostní podmíněnost dopravní a komplexně-sídelní hierarchie. Tato podmíněnost je jistě pozitivní, má souhlasné vývojové tendence a zjištěná asociace dopravního významu středisek s významem komplexním bude pravděpodobně velmi těsná. Častým důvodem rozdílů v dopravní a geografické poloze sídel, a tak narušením souhlasnosti obou hodnocených hierarchií, je odlišná dopravní poloha střediska v dopravní síti. Ta se projevuje také z hlediska struktury dopravy ve středisku, konkrétně v poměru vlakových a autobusových spojů i v poměru spojů mezinárodních, dálkových vnitrostátních a místních. Dopravní poměry ve středisku z hlediska struktury dopravních prostředků jsou do jisté míry určeny také charakterem zázemí střediska (řídce zalidněná území jsou hůře obsluhována veřejnou hromadnou dopravou a jsou více odkázána na individuální automobilizaci).

Vzhledem ke zmíněné velikostní podmíněnosti můžeme předpokládat silnou asociaci hierarchií obou typů. Parciální dopravní systémy (autobusová, automobilová a železniční doprava) ovšem budou asociovány s komplexní hierarchií různou měrou. Z důvodu plánované, „plošné“ obslužnosti obyvatelstva autobusovou dopravou a menší determinace silniční dopravy

sítěmi bude těsnější vztahy ke komplexní hierarchii vykazovat doprava autobusová a automobilová, než doprava železniční, která svoji vázaností na historické železniční sítě projevuje jakousi „liniovou“ diferenciaci s větším zaměřením na dálkovou dopravu. Z obdobných důvodů se z dopravních charakteristik bude mírou hierarchizace nejvíce přibližovat komplexní hierarchii automobilová doprava a doprava autobusová.

Empirické hodnocení bylo provedeno na souboru 144 středisek osídlení, kterým podle sociogeografické regionalizace k roku 2001 (Hampl 2005) přísluší alespoň mikroregionální význam. Význam, resp. rozsah veřejné osobní železniční a autobusové dopravy ve střediscích byl hodnocen pomocí počtu spojů odjíždějících ze střediska, a to ve středu dne 24. května 2006 („běžný“ všední den). Zároveň byly rozlišovány spoje místní a dálkové. Kromě těchto parciálních ukazatelů byly vytvořeny agregátní ukazatele VLAK, BUS a DOPRAVA, ve kterých byla počtu dálkových a vlakových spojů přisouzena vyšší váha. Druhým způsobem hodnocení dopravního významu středisek bylo vyčíslení intenzity automobilové dopravy, která byla stanovena jako součet celkových dopravních intenzit v bodech Sčítání dopravy (ŘSD 2005) ležících nejblíže středisku. Komplexní význam středisek byl hodnocen ukazatelem komplexní velikosti středisek (KV) za rok 2001 (Hampl 2005).

Podle předpokladu je celková dopravní hierarchie středisek z hlediska veřejné hromadné dopravy (ukazatel DOPRAVA) vyvinuta podstatně slaběji než nejrozvinutější hierarchie komplexní sídelní (tab. 1). Dále lze konstatovat, že z hlediska dálkové dopravy jsou střediska pochopitelně více hierarchizována než z hlediska dopravy lokální. Přes celkově nízkou hierarchizaci dopravního významu je patrné, že střediska z hlediska vybavení autobusovou dopravou jsou hierarchizována výrazněji než z hlediska obslužnosti dopravou železniční. Jinými slovy, vybavení středisek autobusovou dopravou je podmíněno spíše hierarchií nódů, zatímco železniční obslužnost středisek je dána spíše hierarchií dopravních sítí či os. Nejvíce hierarchizovaným dopravním souborem je AUTO a vykazuje tak rovněž určitou nodální podmíněnost. Rozvinutosti komplexní hierarchizace středisek však samozřejmě rovněž nedosahuje.

Naznačenou míru souladu hierarchií podle jednotlivých ukazatelů statisticky potvrzují hodnoty párových korelací (viz tab. 2), která také naznačuje určitou doplňkovost dálkové autobusové a vlakové dopravy. Tu potvrzuje především skutečnost, že agregací dopravních charakteristik se míra asociace dopravní hierarchie a hierarchie komplexní zvyšuje. Vysokou asociaci s komplexním významem středisek (jako agregát BUS) vykazuje počet projíždějících vozidel (AUTO), což potvrzuje, že automobilová doprava jako nejflexibilnější dopravní mód bude nejvíce odpovídat komplexnímu významu center. Zároveň má ukazatel AUTO výrazně těsnější vztah ke spojům místním (autobusovým i vlakovým) než ke spojům dálkovým, což naznačuje dominantní využívání automobilů k zajištění funkcí středisek na mikroregionální úrovni, tedy k doplnění často nedostatečné obslužnosti hromadnou dopravou.

Srovnání sledovaných dopravních hierarchií s pravidlem velikostního pořadí měst vedlo k závěru, že hierarchický princip je u nich nejvíce rozvinut na „vrchních patrech“ hierarchie, avšak celková hierarchizace je výrazně podmíněna především relativně málo diferencovanými „spodními patry“ hierarchie. Jako účelné se proto jevilo provedení korelační analýzy nejen za celý soubor 144 středisek, ale také v rámci dílčích kategorie 12 středisek mezoregionálního významu a střediska makroregionálního, tj. krajských měst Česka bez Jihlavy (tab. 3). V případě největších středisek lze hovořit o souladu hierarchie dopravních nódů a dopravních sítí, který se odráží ve vysoké souhlasnosti dopravní a komplexní hierarchie (největší nódy hierarchii sítí určují). Zároveň došlo k rozvolnění specializace autobusové a železniční dopravy na místní a dálkové přepravy a lze konstatovat, že největší střediska jsou dopravně obsluhována komplexním způsobem.

Obr. 1 – Sociogeografické mikroregiony a jejich střediska v Česku (2001). Střediska vyššího významu – makroregionálního (Praha) a mezoregionálního (krajská města bez Jihlavy) – jsou popsána. Ostatní mikroregionální centra jsou uvedeny v abecedním pořadí.

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RELIGIOUS LANDSCAPE IN CZECHIA: NEW STRUCTURES AND TRENDS

T. Havlíček, M. Hupková: *Religious landscape in Czechia: new structures and trends.* – Geografie–Sborník ČGS, 113, 3, pp. 302–319 (2008). – The intent of this paper is to analyse trends and processes in the religious landscape in Czechia during the transformation period. In Czechia, society has been secularized to an extent unprecedented in the rest of Europe. The paper also uses the term sacralization of landscape, which is primarily connected with the restoration of sacred places. It has often been used in this context after 1989, creating a certain contradiction to the general trend of secularisation in Czech society and to the diversification, near disintegration, of religious communities. This research attempts to monitor the main reasons for the transformation of sacral objects as well as to seek fundamental consequences of these changes with the examples of select locations.
KEY WORDS: geography of religion – Czechia – religious landscape – transformation.

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Introduction

This paper intends to describe and analyse, primarily, new structures and trends in studying the geography of religion, or the religious landscape, with the example of Czechia during the transformation period, beginning after 1989. The term religious landscape (e.g. Zelinsky 2001, Knippenberg 2005) is initially perceived in a broader sense mainly as both the territory and society of a selected, larger territorial unit (e.g. Czechia) which is influenced by general religious impacts and, in a stricter sense, as individual sacral objects completing or even forming and defining the landscape's character in the given region (e.g. sacral structures as dominant features in rural landscapes). Religious landscape will first be analysed on the basis of the regional differentiation of religiosity in the society of Czechia during the transformation (e.g. Siwek 2005, Havlíček 2006a, Siwek 2006), which is also perceived to be a contribution to the mosaic of research on the organization of society during the transformation process (Hampl 2001). The second main research theme is a reflection on the development of religious landscape in selected micro-regions of Czechia, both on the basis of the affirmations of key actors and the transformation of sacral objects in the given territories. For a better understanding of some trends it is necessary to remember their historical context.

Czechia, situated in central Europe, has been, due to its geographic position, influenced in the past by a variety of religious streams and trends. In the period of early Christianity, an eastern form of Christianity, represented by Cyril and Methodius, began to penetrate the territory of present-day Czechia, beginning in the 9th century, while, on the other hand, the Catholic Church, with its pope in Rome, was presenting an increasing influence from the west. Before the Hussite movement and Protestantism in the 15th century, the Roman-Catholic religion was predominant in the Kingdom of Bohemia. Then a significant increase of reformed, protestant, religious movements occurred, such as, for instance, the Czech Brethren (Herrnhuter) in Eastern Bohemia. After defeat in the Battle of White Mountain in 1620, the Czech lands were again subject to re-catholicization. Frequent fluctuation of the dominant religious orientation and a general heterogeneity of religious beliefs have continued to the present time. In contrast with other European countries, a strong religious tradition has not been formed here. In addition to this, Czechia, or Czechoslovakia, was exposed, during the second half of the 20th century, to strong pressure from the communist dictatorship aimed at the complete removal of God and the supernatural from the thinking of the people. This process was supported by the transfer of the German, mostly Catholic, population from the Czech border areas. These facts, and certainly many additional circumstances, have caused Czechia to enter the 21st century as one of the most secularized countries in the world. Almost 60% of population (2001) indicate that they are nondenominational. This phenomenon is nevertheless very unevenly distributed throughout the country. How is the religious persuasion of the Czech population distributed in the territory? Which are now the dominant religious orientations and where are their centres? Are there any areas being formed or even strong polarizations? Which have been the main trends in the development of religious landscape after 1989? Is the growing secularization of society reflected by the secularization of religious objects in the landscape?

New geography of religion

During the last twenty years, research on the interaction of religion and space has significantly changed and therefore we can speak about a so-called „new“ geography of religion (e.g. Kong 1990, Pacione 1999, Kong 2001, Henkel 2004, Proctor 2006, Havlíček 2007). In this context, two basic directions (Henkel 2004), which also generally correspond to both tendencies in the socio-geographic research, exist. On the one hand, there is the predominantly qualitative empirical research of the so-called „Caliban School“ and, on the other hand, the predominantly post-modernist papers of the new cultural geography of the so-called „Hamlet School“ (Peach 1999). Within the first school, atlases of the religions of various states (Henkel 2001, Knippenberg 2005), for example, can be mentioned. These are, however, focused, not only on the cartographic presentation of religious manifestations, but also at their historical contexts and explanation. This category also includes predominantly quantitative research into the religious landscape of selected territories (e.g. Zelinsky 2001, Knippenberg 2005).

The second school of the new cultural geography, with a post-modernist orientation, is represented above all by papers from Lily Kong (2001, 2004), which characterize, through qualitative research, the significance of religious symbols and objects for the identity of people in a certain space, among other things. This also causes possible conflicts impacting both sacral and secular institutions. Another paper summing up this research into schematic frameworks is a publication from the „Heidelberg School“ of geography of religion by Edgard Wunder (2005).

Lily Kong (1990, 2004) gives six main research trends or themes within the new geography of religion:

1. Research on society and landscape with various religious orientations, including secularization and the isolation of smaller religious groups and cultures (e.g.. Henkel 2001; Knippenberg 1998; Wunder 2005; Bilska-Wodecka 2005, 2006; Matlovič 1997).
2. Increased investigation of links between sacral and secular objects, or between cultural and political ones (Huntington 1996) as well as investigation of religious and secular landscapes.
3. Studies of religious groups and communities in their social and political context, studying identity.
4. Increased interest in symbolic religious localities and their description („Cracow School“).
5. An effort to understand processes through which objects, landscapes and buildings manifest religious attributes (e.g. new post-modern temples).
6. Sacral experiences with religious localities („Cracow School“).
7. In contrast to the United States or North America, in Europe and Czechia there is a significant lack of religious geographic research, as if the idea that the topic of religion is not compatible with the enlightenment, modern spirit and science prevails in the European, geographic sciences. In this regard, geography is isolated from other branches of science. Religious issues are much more intensely investigated by sciences that are topically very similar to geography, like sociology or history. Because geographers do not study interactions between religion and space, such topics are for the most part covered by scientists specialized in the sociology of religion (e.g. Flere 2001, Tomka 2001, Borowik 2004).

In general, it is possible to define several main aspects of research within the new geography of religion. In terms of perception of the term „sacred place“ (Matlovič 2001, Havlíček 2006b), it is mostly a majority-minority relationship (e.g. mosques in Germany, Schmidt 2003). Important attributes are also religious conflicts (Islamic terrorism, Israel, Maluku, etc.) and also the relation between religion and human rights in selected regions (Leimgruber, Gill 2003). A very frequently quoted study on conflict of civilizations (Huntington 1996) has started discussion on the relation of religion and globalization as well as the relation of Church and state. Research on the sites and trails of pilgrimage („Cracow School“, Graham a Murray 1997) also remains relevant. The explanation of tensions between sacral and secular phenomena (e.g. the secularization, or sacralization of Czechia) is also an important theme within these recent trends.

Studies integrating evolution in the post-modern, or „post-religious“ society (Wunder 2005) are also generally applicable. Fundamental research is carried out mainly on a micro-regional scale with significant sociological aspects as well as in minority religious groups (Islam in Germany, Hutterites in Canada, etc.).

These principal research trends are framed by the great interdisciplinary nature of research (sociology, political science, science on religion) with more or less spatial aspects, such as, for example, studying the development of religious landscape, which is, with the example of Czechia, one of the major themes of this paper.

Religious processes in Czech society during the transformation period

It is clear that religious processes must be understood in the general context of the development of Czech society (Hampl 2001). An important trend of the Czech society during the period of transformation has been a significant decrease in persons declaring their support of churches and religious communities. Much more than in the rest of Europe, a high secularization of society exists in Czechia (Lužný, Navrátilová 2001). Religious institutions along with religious consciousness and behaviour are losing their social significance. There is an ongoing shift away from religious control to profane forms of control. People devote increasingly less time and resources to supernatural things. In terms of this, Lužný (1999) affirms that the basic condition is thus the dualism of the profane and ecclesiastical power and the separation of sciences, defining their branch of study without theology or interpretation of myths. The process of secularization is accelerated even more and backed by authoritative regimes (in Czechia this was the case of the communist dictatorship), which see religious communities as their enemies. Park (1994) understands secularization in a triple sense: a) the exclusion of religious belief (increasing separation of church and State), b) a lack of importance, rejection of religious ideas (decreased interest in religious traditions, lower awareness and respect of church representatives) c) secularization of thinking and behaviour, no interest whatsoever in religious ideas. Secularization is thus one of the most visible processes in the religious landscape, not only in Czechia, but also throughout contemporary Europe.

From 1991–2001, some religious communities manifested a different development than during the period of communist rule. A population census was done in Czechia in 1991 and again in 2001. The religiosity of the population was also ascertained during the census, according to data of a subjective nature, as individual respondents were asked to classify themselves as members of a certain religious group. The Czech census of 1991 and 2001 was the first since 1950 to pose a question on religion. There are three ways in which to examine religion: belief, practice and affiliation. The Czech census question was in the category of affiliation and each person could classify themselves in two main categories: without denomination and believer. There were no separate tick boxes for specific denomination. Each person has the freedom to write his denomination in the special field. The census question on religion were not compulsory as far as answers were concerned it can be seen from Table 1 that 16.2 % (1991) and 8.8 % (2001) of population did not answer this question.

A decrease in the largest group, the Roman Catholic Church, continued – from 39 % (1991) to 26.7 % (2001) as larger protestant churches also lost more than one third of their members. In the Czechoslovak Hussite Church, the

Tab. 1 – Distribution of religious denominations in Czechia in 1991–2001

Denomination	1991 (number)	1991 (%)	2001 (number)	2001 (%)	Change 91/01 (number)	Change 91/01 (%)
Roman Catholic Church	4,021,358	39.0	2,740,780	26.8	–1,280,578	–31.8
Evangelic Church of Czech Brethren	203,996	2.0	117,212	1.1	–86,784	–42.5
Czechoslovak Hussite Church	178,036	1.7	99,130	1.0	–78,906	–44.3
Jehovah's Witnesses	14,575	0.1	23,162	0.2	8,587	58.9
Orthodox Church	19,354	0.2	22,968	0.2	3,614	18.7
Evangelic Silesian Church	33,130	0.3	14,020	0.1	–19,110	–57.7
Brethren Evangelical Free Church	2,759	0.0	9,931	0.1	7,172	259.9
Adventists	7,674	0.1	9,757	0.1	2,083	27.1
Greek Catholic Church	7,030	0.1	7,657	0.1	627	9.2
Evangelical Free Church	3,017	0.0	6,927	0.1	3,910	129.6
Apostolic Church	1,485	0.0	4,565	0.0	3,080	207.4
Baptist Church	2,544	0.0	3,622	0.0	1,078	42.4
Methodist Church	2,855	0.0	2,694	0.0	–161	–5.6
Old Catholic Church	2,725	0.0	1,605	0.0	–1,120	–41.1
Judaism	1,292	0.0	1,515	0.0	223	17.3
New Apostolic Church	427	0.0	449	0.0	22	5.2
Unitarian	365	0.0	302	0.0	–63	–17.3
Mormons	–	–	1366	0.0	–	–
Islam	–	–	3699	0.0	–	–
Buddhism	–	–	6817	0.1	–	–
Hinduism	–	–	767	0.0	–	–
Movement Hare Krishna	–	–	294	0.0	–	–
Others	21,085	0.2	208,858	2.1	187,773	951.9
Believers (total)	4,523,734	43.9	3,288,088	32.2	–1,235,646	–27.3
Non–denominationalists	4,112,864	39.9	6,039,991	59.0	1,927,127	46.9
Not identified	1,665,617	16.2	901,981	8.8	–763,636	–45.8
Czech population (total)	10,302,215	100	10,230,060	100	–72,155	–0.7

Source: ČSÚ – Czech Statistical Office (2004)

figure decreased from 1.7 % (1991) of inhabitants to 1 % (2001). On the contrary, smaller Christian communities, such as the Brethren Evangelical Free Church, Baptists, Evangelical Free Church, Apostolic Church, etc., recorded strong growth. Also the number of members of the religious community of Jehovah's Witnesses, which is not included in a classification of Christian churches, has increased by more than 40 % to reach some 23,000 members throughout Czechia. Although the absolute numbers of worshippers of these Churches reach thousands and even tens of thousands of members, it is evident that the Czech population is not heading towards an almost absolutely profane society, but that interest in God has been growing in smaller communities. Only during the last monitored period, membership in these Churches has grown by more than seven times. The Orthodox Church also manifests an increase, mainly due to high immigration from Ukraine and Russia to Czechia. Also due to emigration, the number of Jews in Czech society has increased slightly. What was the trend towards increased secularization of society like at the turn of the millennium? According to census results, there is a clearly increasing trend towards a profane culture and society. During this period, the percentage of the non-denominational

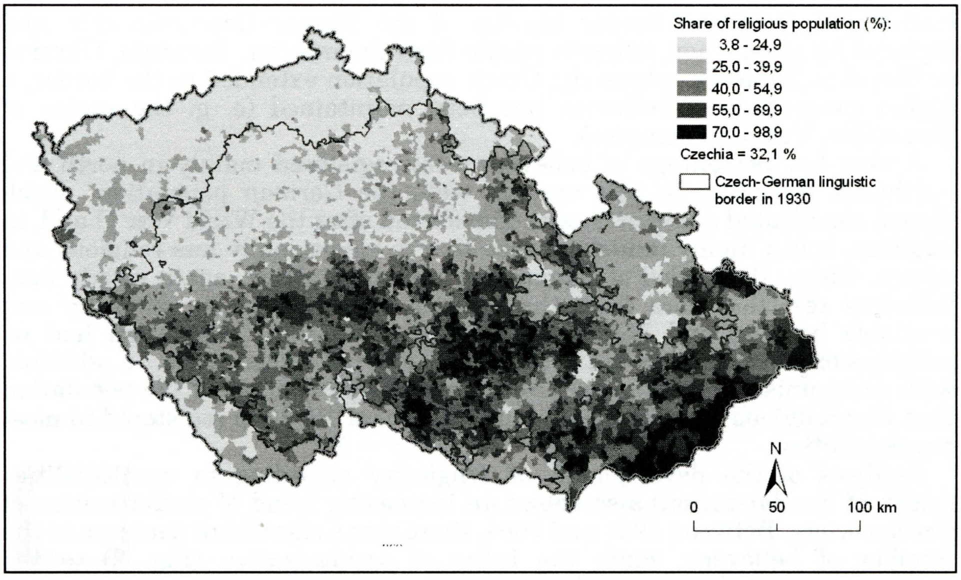

Fig. 1 – Percentage of religious population in Czechia by municipalities (2001)

population grew from 39.9 % (1991) to 58.2 % (2001). We can only add that a lower percentage in this category in 1991 was due, primarily to a temporary higher receptivity of society to transcendent phenomena following the fall of the communist regime.

The next reason for the distinctive decrease of believers between the years 1991 and 2001 can we observe in the mortality of old generation who got religion during the period before WWII und this generation has a very high level of religiosity. The similar development is also in the other European countries, e.g. Germany, The Netherlands, Finland (Knippenberg 2005).

On the contrary, the number of inhabitants refusing to answer the question about their faith fell from 16.2 % (1991) to 10 % (2001). In general, it can be said that the Czech religious scene is becoming more and more diversified. Large churches are losing their worshippers and, on the contrary, smaller Christian communities have increasingly more members. In addition, religious communities in Czechia are becoming more and more split up.

For a higher degree of clarity and to stress the high regional differentiation, the boundaries of municipalities were used as basic territorial units. With the first glance at the territorial distribution of believers in Czechia (Fig. 1), a strong territorial polarization is already quite clear:

1. Non-religious north (below 25 %) and a relatively religious south (40–70 %)
2. Weakly religious west (Bohemia) and strongly religious east with 60 to 95 % believers (Moravia and the Bohemian-Moravian Highlands).

In addition, primarily communities along the border with Slovakia and in the Bohemian-Moravian Highlands manifest relative numbers of believers above 70 % of the total population. When observing percentages of the population that believe in the southern and western border regions in greater detail, the former border of the Protectorate of Bohemia and Moravia, i.e. between former predominantly Czech and German populations, is evident. After World War II, the German population, which was mostly Catholic, was transferred from the border regions of the former Czechoslovakia and replaced by mostly non-religious people from the interior, Romania, Ukraine or Slovakia. In areas, where the Czech population extended to the border, a higher percentage of believers has been maintained (e. g. the region of Domažlice, Velenice, Jemnice).

A very low percentage of believers were registered mainly in north and northwest Bohemia. In this area as well, the German population, which almost constituted a majority, was transferred after the World War II and, in addition, it is a highly industrial area that is traditionally less religious and where, during the period of communist industrialization, again mostly non-believers resettled here from the interior, mainly because of cheap and available housing and higher wages. This immigrant population had no religious or cultural links to the areas and was not rooted there. In addition, with communist, anti-religious propaganda the percentage of the population that was religious steadily decreased to a level of 10–20 % registered in most municipalities.

Analysis of the development of religiosity according to municipalities (index of secularization) also shows an increasing trend of secularization of Czech society. Between 1991 and 2001, there was a significant decrease in the number of believers, while the index of secularization (Fig. 2) in the municipalities of Czechia reached 31.8.

In addition to the previously mentioned and most significant process of secularization, there is also a trend towards higher diversification, or de-monopolization of religious communities leading to a high degree of separation or even the complete disintegration of various religious movements within Czechia (Table 1). On the one hand, the largest churches (Roman Catholic, Evangelic Church of Czech Brethren and Czechoslovak Hussite Church) register a high decrease in their number of worshippers, and on the contrary, smaller, mostly protestant or evangelical churches (e.g. Brethren Evangelical Free Church, Evangelical Free Church) register a steady increase in worshippers. However, the highest increase, in Czech society, is registered in occultism (horoscopes, divination, etc.) where the trend seems to change from the once dominant Christianity to occultism (Hamplová 2000). At the turn of millennium, Christianity lost its dominant position and more than half of the population (52.1 %) declared, either partly or entirely, their support for occultism (Hamplová 2000, Havlíček 2004b). An ISSP survey (Hamplová 2000) also showed frequent interpenetration of both spiritual streams as well as the fact that one third of the respondents professing Christianity are entirely settled, while in occultism this portion only reaches one fifth.

The religious landscape of Czechia during the transformation period

To truly grasp the central structures and trends present in the religious landscape of Czechia it is not sufficient to merely analyse quantitative changes and the differentiation of the religiosity of the population, it is also necessary to take the consequences of this development into account with qualitative research focused on model territories. As part of this research on the development of the religious landscape, qualitative research was carried out from 2005 to 2007 in 27 micro-regions (model territories) of Czechia (Fig. 2) to analyse the role of the religion and the character of the religious landscape. Initially, sacral objects in the landscape were monitored and documented then we sought to explain the obtained results by analysing the historical development, relations within the territory and the specific traits of the area. Because of Czechia's geographic variability, several hypotheses, which should be valid for the model territories, can be determined, even before monitoring the religious landscape.

Field research was carried out by students from the Department of Social Geography and Regional Development, Charles University in Prague, from July through September in 2005, 2006 and 2007. Each model territory was studied for approximately seven days. Table 2 gives basic data on the various model territories – their name, year of field research, type of territory (rural or urban area) and level of religiosity. Model territories were selected on the basis of two factors. The first was an attempt to employ the general geographic variability of Czechia through selecting model areas so as to take into account both vertical and horizontal variability (e.g. town – countryside, interior – border region, Bohemia – Moravia). The second factor for selecting territories was the individual, i.e. subjective, knowledge of the given territory by the researchers. Contacts within a territory are important when looking for sacral objects and local people often know about the connections of, for example, the origin or disappearance of sacral objects. Model territories were determined by municipal boundaries, because of the availability of statistical data for these territorial units, or by cadastral boundaries in larger cities. The size of the model territories corresponded with the size of the municipalities; they were 5 each of rural municipalities, quadrants or sections of large cities (Prague, Plzeň, Liberec, Hradec Králové, Olomouc).

Before the field inquiry, working hypotheses on the quantity and state of sacral monuments were determined according to the character of the territory and the level of religiosity. The goal of the field inquiry was to reveal causes for the development and the general state of the religious landscape in each model territory and to grasp the phenomena and specific characteristics of the given territory, both as part of the social capital and in the relation between the profane and sacral sphere to religious objects (the relationship between church and state, or municipality). Initially, sacral objects were monitored and their position was mapped. Each object was assigned values from a qualitative and a quantitative typology. Qualitative categories are defined according to the physical state and the age of objects: a) sacral objects built before 1989; b) sacral objects built or made accessible after 1989; c) sacral objects reconstructed after 1989.

Quantitative typology is based on the repartition of sacral objects according to their importance and size: a) multi-religious and multicultural buildings (community centres, building complexes, e. g. Hare Krishna), b) utilised one-purpose buildings (church, mosque, etc.), unused church („abolished"), c) chapels, oratories, rooms for oracles, etc. (mostly only one room), d) small sacral buildings in landscape (crosses, Calvaries, pictures, statues, etc.), e) small sacral objects on buildings (e.g. statues on houses, etc.), f) cemetery objects.

After analysing sacral objects in the field, we proceeded to direct interviews with „key personalities" which helped us to elucidate the religious climate in the model territory. The first personality was a church representative. This interview helped answer questions on attendance at worship services

Tab. 2 – Survey of model territories, including their basic characteristics, selected results and the aggregate „level of sacralization“ index

Model area	Year	Type	Religiosity	1	2	3	4	Sacralization rate	
Rakvicko	2007	rur	55.1	+	+	+	+	++++	high
Vranovsko	2007	rur	38.6	+	+	+	+	++++	high
Bohutínsko	2005	rur	38.9	+	+	+	+	++++	high
Kamýcko	2006	rur	45.4	+	+	+	0	+++	high
Milevsko	2006	urb	37.9	+	+	+	0	+++	high
Olomouc	2006	urb	38.9	+	+	+	0	+++	high
Hořovice	2007	urb/rur	17.7	–	+	+	+	++	medium
Čerčansko	2005	rur	27.3	0	+	+	0	++	medium
Choceňsko	2006	urb/rur	27.8	0	+	+	0	++	medium
Plzeň	2007	urb	18.9	–	+	+	+	++	medium
Praha	2007	urb	27.9	0	+	0	+	++	medium
Roztocko	2006	urb	25.5	0	+	+	0	++	medium
Říčansko	2007	urb/rur	24.9	0	+	+	0	++	medium
Soběslav	2007	urb	29.3	0	+	+	0	++	medium
Suchdolsko	2007	rur	30.6	0	+	+	0	++	medium
Sušicko	2005	urb	35.7	+	0	+	0	++	medium
Hradec Králové	2005	urb	21.8	–	+	+	0	+	medium
Kounovsko	2007	rur	52.7	+	0	0	0	+	medium
Netolicko	2005	urb	34.5	0	+	0	0	+	medium
Svatojansko	2006	rur	17.3	–	+	+	0	+	medium
Liberec	2006	urb	17.1	–	+	0	0	0	low
Moravskokrumlovsko	2006	urb	39.7	+	–	0	0	0	low
Stanovicko	2005	rur	24.8	0	+	–	0	0	low
Čelákovicko	2007	urb	20.5	–	–	0	+	–	low
Neratovicko	2007	urb/rur	21.4	–	+	–	0	–	low
Pečky	2007	rur	22.8	–	+	–	0	–	low
Velkopopovicko	2005	rur	26.0	0	–	0	0	–	low

Note. Type: urb = urban character of the territory, rur = rural character of the territory, urb/rur = intermediate character of the territory. Religiosity: as a portion of inhabitants from the total population in 2001 in the model territory (data for municipalities): 1. Level of religiosity: + (above average), 0 (average), – (below average). 2. Relationship between church and the state: + (good), 0 (neutral), – (bad). 3. Qualitative state of sacral objects: + (good), 0 good only in the case of larger objects or in the centre), – (bad). Existence of new sacral objects built after 1989: + (they exist), 0 (they do not exist).

(average attendance, age or nationalities represented), on church activities and on the interviewee's opinion concerning the role of religion in society. The second „key personality“ was a representative of the municipal authority responsible for monument preservation. This interview helped elucidate property rights to sacral objects in the territory, monument preservation issues and possibilities for the reconstruction of sacral objects. We also ascertained the mutual relationship and cooperation between churches and the municipality. Finally we evaluated the validity of our pre-defined working hypotheses and subjectively assessed the character of the religious landscape in the model territory with an emphasis placed upon the causes of the present situation.

Table 2 gives a survey of model territories along with selected results from the field monitoring. Evaluation of the religious landscape and the religious climate in model territories exhibited a subjective character. The tentative synthesis of these data helped build a „level of sacralization“ index, which schematically expresses the level of sacralization in the model territory, not only in terms of the quality of sacral objects, but also in terms of the warmth of the local religious climate. The „level of sacralization“ index was construed by combining four characteristics assessed by a three-degree scale where „+“ indicates a positive, „0“ a neutral and „-“ a negative occurrence of the phenomenon. The characteristics included in the aggregate index are the following:

The level of sacralization can be divided into three categories: high (++++, +++), average (++, +) and low (0, -). Model territories with the lowest level of sacralization are situated in the hinterland or in areas adjacent to Prague. This is indicative of the character of life in Prague's suburbia (low levels of religiosity, commuting to Prague for work and services, generally low relationships with the territory, newly developed areas). According to these results, a claim could be made that the level of sacralization increases along a northwest to southeast axis as well as with the decreasing size of municipalities and in proximity to sites of pilgrimage. In general, large cities manifest an average level of sacralization, with the exception of Olomouc and Liberec. These two large cities manifest a level of sacralization corresponding to their geographic position (compare Fig. 1). The high level of sacralization in Olomouc is also accentuated by the significance of the city as the seat of an archbishopric and as a UNESCO monument. A unique situation exists in the area of Moravský Krumlov which has, contrary to expectations, a very low level of sacralization. This is probably due to the existence of an significant communication barrier among the local government, public administration and the Church. Local factors that influence the development of the sacral landscape and the religious climate in model territories (i.e. those that were used for assessing the level of religiosity) are described further in the text.

It is presumed that due to the transfer of Germans from border regions after World War II the so-called Sudeten region will have more devastated or completely destroyed/removed religious objects (Valenčík 2006). At the same time, we presume that differences in the character of the religious landscape increase in a northwest to southeast direction. In the southeast direction, religiosity of the population increases (Fig. 1), so a higher number of sacral objects along with their better physical condition are expected. In this direction we also expect a higher frequency of building new sacral objects. Comparison of the field monitoring results from the model areas (Fig. 2) with the expected results indicates whether the character of the religious landscape is developing according to the expected formula. This formula is understood as the general geographic variability of Czechia (presupposed differences: town – rural area, town – hinterland, industrial area – agricultural area, so-called Sudeten land – interior) along with location of believers and tendencies in the number and location of believers within Czechia (number of believers, index of secularization).

The factor of human and social capital

The results of this field monitoring (the monitoring of sacral objects and interviews with key actors in micro-regions) show that the religious landscape develops only partly according to the general presumptions (see above). A second variable influencing the character of the religious landscape as well as the role of religion in a given territory is the human and the social factor. By synthesising the ascertained information it is possible to distinguish three key positions, a good customised mixture of which can significantly

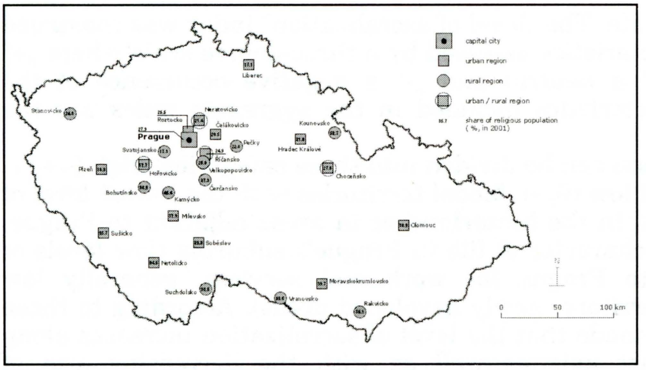

Fig. 2 – Model areas for field monitoring of the religious landscape

strengthen the role of religion in society. According to the research in model areas, the three key positions are: a) a religious representative (e.g. priest), b) involved subjects (e.g. municipal and regional authorities, councillors), and c) the local population (believers, patrons or sponsors).

An important factor influencing the position of religion in an area is the approach of the priest. The results of our monitoring show that a helpful approach of the religious representative both to believers and unbelievers is very important. In the monitored areas, religious representatives, with an active and informal manner of communicating and discussing, arouse the interest of young people in religion. In these areas, cooperation between churches and schools was also more frequent, the Church participated more in local cultural life. Key actors (e.g. priest) as well as the relations between these representatives have an impact on the importance of the role of religion in a given area. A priest's personality ensures not only communication between local people and the Church, but also between the Church and local government.

Communication between the Church and the municipality, represented by officials with jurisdiction over heritage protection, is an important step towards the renewal and safeguarding of sacral objects in the landscape – mainly in terms of acquiring financial means for reconstruction. It is positive that bad relations and cooperation between the Church and the municipality were registered in only 5 % of the monitored areas. Opinions of the elected local representatives (municipal council, mayor) can also strengthen or cut down the role of religion in the municipality. A higher portion of the local political elite belonging to political parties backing religion can result in more significant support of religion and religious objects in the area. In Czechia, the correlation of the political party with Christian characteristics (Christian Democratic Union) and religiosity is very high (Havlíček 2005).

Local people can also contribute to the proliferation of religion and sacral objects in their hometown. However, this phenomenon occurs primarily in smaller municipalities (with less than 5,000 inhabitants). If there is a group of actively participating believers in such a municipality, they are able, by their joint effort, to maintain religious life and to ensure the good condition of sacral objects. In smaller municipalities, there are religious objects of local importance, the maintenance and reconstruction of which can be financed from financial sources obtained by collections. State subsidies are not necessary as is the case with larger buildings. According to representatives of both municipalities and churches, reconstruction of sacral objects without financial contribution from local people would be problematic or even impossible. In addition to the local religious population, an involved corporation participated in repairs in 15 % of municipalities – either through a financial contribution for reconstruction or by entirely financing it. These

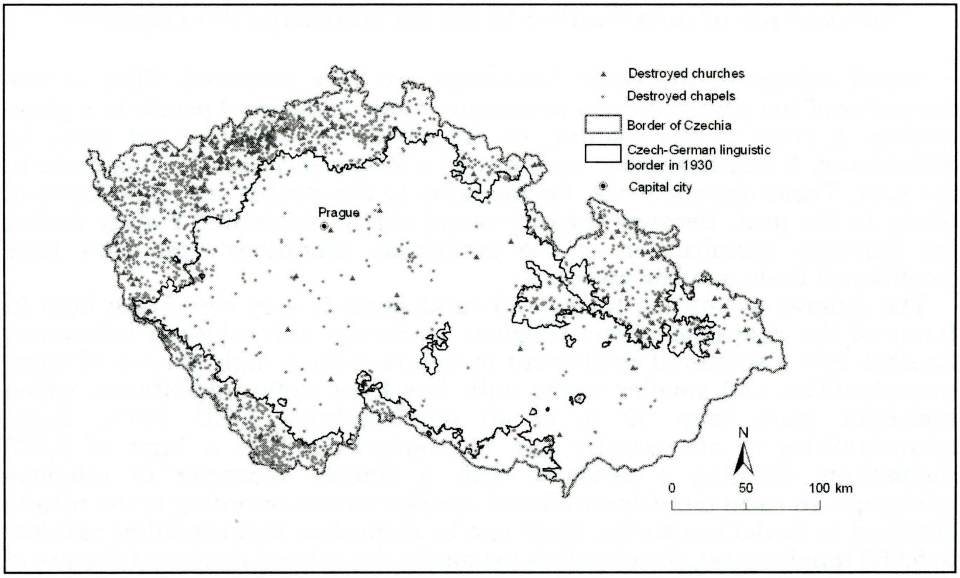

Fig. 3 – Churches and chapels destroyed in Czechia during the communist period 1948-1989. Source database: Valenčík (2006)

were mostly non-believers with a strong interest in history and monuments, but it is difficult to ascertain whether such patrons or sponsors were also interested in the spiritual dimension of the entire affair.

Many sacral buildings in the so-called Sudeten area were destroyed after the transfer of Germans after World War II (Valenčík 2006). This example also attests to the prevailing existence of the so-called relict border which was, in 1930, the language border between the Czech and the German speaking populations (Fig 3). This pronounced polarization between border regions and interior shows the consequences of the exchange of population in the borderland, which is also reflected in the religious landscape. Sacral objects in the Sudeten areas are being renewed there largely thanks to the backing of German and Austrian citizens, who, or whose families, were transferred from these border regions. In addition to this help, which is historically motivated, we also find cross-border cooperation in the renewal of sacral objects (in the model areas this was cooperation with Austria). The development of sacral objects is different in Bohemia than in Moravia (the already mentioned gradient northwest – southeast). In Moravia, i.e. in the southeast, the state of sacral objects is visibly better thanks to the greater significance of religion.

The research done in model areas makes it clear that only one key actor is significantly active in the area. For good development of the role of religion in the area it is therefore not necessary that all relationships are in place and that highly educated people hold the positions of key actors, but in many cases the existence of one strong personality at one key post (priest, municipality or local people) is sufficient. Good mutual relations are nevertheless an indubitable advantage for further development of the sacral landscape.

An example of polarization in sacral landscape development

Sacral objects in the Czech landscape are very scattered. They invoke memories of the past and are a testimony of the history and people in a given locality. A cross in the country, in the middle of a field, is not there by coincidence; it testifies to the existence of a former pathway leading there in the past. These objects attest, for instance, to the wealth and importance of towns in the past. Because existing sacral objects originated mainly during the Baroque sacralization of the landscape, conditions from that time conditioned their number and size.

The difference between towns and rural areas is very significant both in terms of the character of the religious landscape and religious behaviour. Czechia has a scattered settlement structure with a high portion of rural municipalities and smaller towns with less than 5,000 inhabitants, which represent more than 90 % of all municipalities (ČSÚ 2007). Rural municipalities in our country can be characterized by a limit of 3,000 inhabitants defining a territory with a similar character of religious landscape. In rural municipalities and smaller towns (according to the results obtained in model territories, these can be defined as municipalities of 3,000 to 5,000 inhabitants), the church is primarily the natural dominant feature of the municipality. According to the representatives of local governments, it is inadmissible that such an object be in a bad condition. It is to the credit of the municipality, not only from a believers' point of view, but also from that of disbelievers. For this reason, 95 % of churches (in the model territories) are now in good condition (Fig. 4). In larger cities, surrounding higher buildings suppress the dominance of religious objects.

In smaller towns and rural areas, religious objects are not too large and therefore they can be more easily repaired from financial means obtained by local representatives (municipalities, churches, patrons or sponsors as well as local people). In larger cities, religious objects are often part of an urban conservation area or even a cultural heritage monument. In such cases, reconstruction or any intervention concerning the object is subject to special rules according to the Act on Preservation of Monuments (Act No. 20/1987 Coll.). Increased obligations are nevertheless compensated by the opportunity of obtaining subsidies for reconstruction from public administration bodies. The destiny of a sacral building is conditioned by financial possibilities and by the priorities of its owner. An example of the importance of ownership of sacral buildings is the situation of two Jewish cemeteries in the same municipality (Sušice). The cemeteries are 500 m apart from each other and are situated

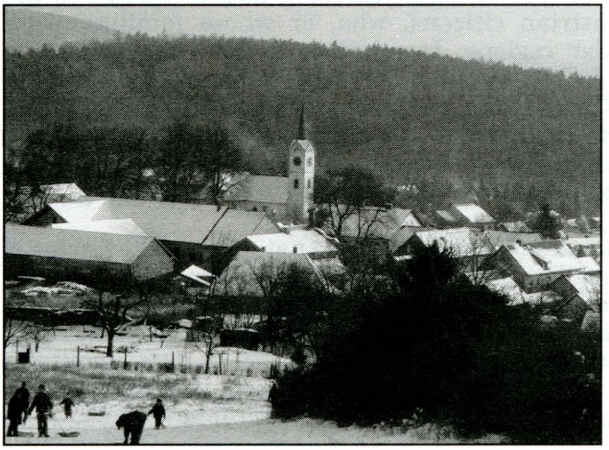

Fig. 4 – Church as the dominant feature of a municipality (Pyšely). Source: authors.

near the town centre. The first, owned by the Jewish community, is in a catastrophic state, while the second, owned by the municipality, was reconstructed in 2004–2005. This reconstruction was not done for religious reasons, but for cultural ones as the goal was to increase the aesthetic quality of the town and to make it more attractive for tourists.

Data furnished by priests on attendance of divine services were evaluated in the model territories. When comparing the average attendance of services at the local church with the number of proclaimed members of the given Church in the municipality, we obtained values between 5 and 50 %. This percentage expresses the „activity of believers in the municipality". The resulting value was significantly influenced by the size of the municipality. We obtained data about 20 churches in different municipalities of 100 to 16,000 inhabitants. A correlation coefficient of -0.6 shows a negative correlation between the activity of believers and the size of the municipality. This means that in smaller municipalities the attendance at worship services is relatively higher than in larger municipalities (the existence of multiple churches with services in one municipality was taken into consideration). The described dependence can be explained by stronger traditions in rural areas than in cities as well as by a generally hectic way of life in cities.

In several municipalities, worship services in churches were cancelled for economic reasons. As a consequence, active religious life in the municipality has decreased. Direct contact of the priest with believers in the municipality itself is irreplaceable and due to the age of believers, attendance at services in other municipalities is problematic. Between 1991 and 2001, the portion of believers older than 50 years of age within the total number of believers grew by approximately 10 % to reach some 55 % of all believers in 2001 (ČSÚ 2007). Attendance at worship services is seasonal – in summer it is higher than in winter; the highest attendance occurs on holidays (nearly double). A specific position is held by pilgrimage sites (model territories Svatý Jan and Bohutín) which, due to their significance, attract believers from the entire region and attendance at masses in pilgrimage churches is very high. Pilgrimage sites also have a higher number of sacral objects than other territories of comparable size.

What characteristics do sacral objects in model territories manifest? In cities, there are, in accordance with our presumptions, more sacral objects of higher significance and size (churches, chapels, multi-religious and multicultural buildings). These objects are in very good physical condition, primarily thanks to financial backing from the municipality and the state aimed at maintaining their representative function. In smaller municipalities sacral objects are smaller (chapels, crosses, statues) and they are scattered throughout the landscape. Opportunities for their renewal are conditioned by the quantity of financial means available and gifts from the population. New sacral places do not appear often and in the model regions, there were only four religious objects built during the period of transformation, after 1989. In the landscape, there are often visible remnants of small sacral objects which were stolen. The disappearance of sacral objects is due not only to their devastation and theft, but also to changes in their function, or to their destruction on a mental level (Fig. 5).

Fig. 5 – Example of the transformation of a sacral object (former synagogue, now a research library for the Vyškov district archives in Slavkov u Brna). Source: authors.

Conclusion

Analysis of the development of religiosity according to municipalities also shows an increasing trend of secularization in Czech society. There is trend for higher diversification, or the de-monopolization of religious communities leading to a high dismembering or even to disintegration of various religious movements. The highest increase, in Czech society, is registered in occultism (horoscopes, divination, etc.), where the trend is a change from the once dominant Christianity to occultism. Many sacral buildings in the so-called Sudeten area were destroyed after the transfer of Germans, after World War II. This example also validates the prevailing existence of the so-called relic border which was, in 1930, the language border between the Czech and the German speaking populations. Communication between churches and the municipality, represented by officers with jurisdiction over heritage protection, is an important step to the renewal and safeguarding of sacral objects in the landscape – mainly as a means of acquiring financial means for reconstruction. Model territories with the lowest level of sacralization are situated in the hinterland or in areas adjacent to Prague. This is indicative of the character of life in Prague's suburbia (low levels of religiosity, commuting to Prague for work and services, generally low relationships with the territory, newly developed areas). According to these results, a claim could be made that the level of sacralization increases along a northwest to southeast axis as well as with the decreasing size of municipalities and in proximity to sites of pilgrimage. In general, large cities manifest an average level of sacralization, with the exception of Olomouc and Liberec. These two large cities manifest a level of sacralization corresponding to their geographic position. The research carried out in model areas makes it clear that only one key actor is significantly active in the area. For good development of the role of religion in the area it is therefore not necessary that all relationships are in place and that highly educated people hold the positions of key actors, but that in many cases the existence of one strong personality at one key position (priest, municipality or local people) is sufficient.

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Shrnutí

RELIGIÓZNÍ KRAJINA V ČESKU: NOVÉ STRUKTURY A TRENDY

Předkládaný příspěvek si klade za cíl popsat a analyzovat především nové struktury a trendy ve výzkumu religiózní geografie, resp. religiózní krajiny na příkladu Česka v období transformace po roce 1989. Česko ležící ve střední Evropě bylo v minulosti díky své geografické poloze ovlivňováno různými náboženskými proudy a směry. Časté střídání hlavních náboženských proudů a heterogenita v náboženském myšlení zůstaly zachovány až do dnešní doby. Nepodařilo se jako tomu je v jiných evropských zemí zde vytvořit silnou náboženskou tradici. Česko resp. Československo bylo poté ještě vystaveno během druhé poloviny 20. století silnému tlaku ze strany komunistické diktatury za účelem vymazání Boha a nadpřirozena z myšlení lidí. Tento proces byl ještě zvýrazněn odsunem německého převážně katolického obyvatelstva z českého pohraničí. Všechny tyto skutečnosti a jistě i mnohé další způsobily, že Česko vstupuje do 21. století jako jedna z nejvíce sekularizovaných zemí na světě. Téměř 60 % obyvatelstva (2001) udává, že je bez náboženského vyznání.

Během posledních dvou desetiletí se výzkum interakce náboženství a prostoru významně proměnil, a proto lze jistě v tomto směru hovořit o tzv. „nové“ religiózní geografii (např. Kong 1990, Pacione 1999, Kong 2001, Henkel 2004, Proctor 2006, Havlíček 2007). V této souvislosti lze objevit dva základní směry (Henkel 2004), které také obecně odpovídají oběma tendencím v sociogeografickém výzkumu. Na jedné straně se jedná o převážně kvalitativní empirický výzkum tzv. „školy Caliban“ a na straně druhé o převážně postmoderní práce z nové kulturní geografie tzv. „školy Hamlet“ (Peach 1999). Lily Kong (1990, 2004) uvádí šest hlavních výzkumných směrů, resp. témat v rámci „nové“ religiózní geografie:

1. Výzkum společnosti a krajiny s různorodou náboženskou orientací vč. sekularizace a izolovaných menších náboženských skupin a kultur (např. Henkel 2001, Knippenberg 1998, Wunder 2005).
2. Nárůst zkoumání vazeb sakrálního a sekulárního objektu, resp. kulturního a politického (Huntington 1996) a také religiózní a sekulární krajiny.
3. Studium náboženských skupin a komunit v sociálním a politickém kontextu, studium identity.

4. Nárůst zájmu o symbolická, religiózní místa a především jejich deskripce.
5. Snaha porozumět procesům, při nichž objekty, krajiny a budovy vykazují náboženské atributy (např. nové chrámy postmoderny).
6. Sakrální zkušenost s náboženskými místy.

Tyto hlavní výzkumné trendy jsou zarámovány velkou interdisciplinaritou výzkumu (sociologie, politologie, religionistika) s méně či více prostorovými aspekty jako je například studium vývoje religiózní krajiny, což je také na příkladu Česka jedním z hlavních témat tohoto příspěvku.

Je zřejmé, že religiózní procesy je nutné chápat v obecném kontextu vývoje české společnosti (Hampl 2001). Významným trendem v české společnosti v období transformace je značný úbytek lidí hlásící se k církvím a náboženským společnostem. Daleko více než v ostatní Evropě se tak v Česku prosadila značná sekularizace společnosti. Také analýza vývoje religiozity podle obcí (index sekularizace) poukazuje na prohlubující se trend, který výše zmíněnou sekularizaci české společnosti nadále prohlubuje. Mezi roky 1991 a 2001 došlo k výraznému propadu počtu věřících, kdy v rámci obcí Česka dosáhl index sekularizace (obr. 2) hodnoty 31,8. Kromě zmíněného nejvýznamnějšího procesu sekularizace zaznamenává Česko také trend větší diverzifikaci, resp. demonopolizaci náboženských komunit, který vede k výraznému rozdrobení až atomizaci jednotlivých náboženských hnutí.

V rámci studia vývoje religiózní krajiny bylo v letech 2005 až 2007 provedeno kvalitativní šetření v 27 mikroregionech (modelových územích) Česka (obr. 3), ve kterých je analyzována role náboženství a charakter religiózní krajiny. Z výsledků terénních výzkumů (monitorování sakrálních objektů a řízené rozhovory s klíčovými osobnostmi v mikroregionech) vyplývá, že religiózní krajina se podle obecných předpokladů (viz výše) vyvíjí jen zčásti. Druhou částí, která udává charakter religiózní krajiny i roli náboženství v konkrétním území je lidský a sociální faktor. Syntézou zjištěných informací je možné rozlišit 3 klíčové posty, jejichž kvalitní personální obsazení může velmi výrazně posílit roli náboženství ve společnosti. Třemi klíčovými posty jsou podle výzkumu v modelových oblastech: a) náboženský představitel (např. farář), b) zainteresované subjekty (např. obecní a krajské úřady, zastupitelé), c) místní obyvatelstvo (věřící, mecenáš nebo sponzor). Rozdíl mezi městem a venkovem je z hlediska charakteru náboženské krajiny i náboženského chování výrazný. Z vyjádření představitelů samospráv je nepřípustné, aby sakrální objekt byl v neuspokojivém stavu. Jedná se o jakousi vizitku obce nejen pro věřící ale také nevěřící obyvatelstvo. Z toho důvodu je v současnosti 95 % kostelů (v modelových územích) ve velmi dobrém stavu. V menších městech a na venkově nenabývají religiózní objekty přílišné velikosti, proto jsou snáze opravitelné z finančních zdrojů získaných místními představiteli (obec, církev, mecenáš nebo sponzor a také místní obyvatelé). Ve větších městech jsou často religiózní objekty součástí památkové zóny obce nebo jsou vyhlášeny za kulturní památku. Specifické postavení mají poutní místa (modelová území Svatojansko a Bohutínsko), která svým významem přilákávají věřící ze širšího okolí a účast na bohoslužbách v poutním kostele je velmi vysoká. Poutní místo vykazuje i vyšší počet sakrálních objektů než jiné území srovnatelné velikosti. Modelová území s nejnižší mírou sakralizace se nacházejí v zázemí či okolí Prahy. Je to dáno charakterem života v suburbiu Prahy (nízká míra religiozity, dojížďka do Prahy za zaměstnáním a službami, nepříliš vysoký vztah k území, nová rozvíjející se zástavba). Podle výsledků lze obecně říci, že míra sakralizace narůstá ve směru severozápad – jihovýchod. Přičemž se snižující se velikostí obcí a blízkostí poutního místa se míra sakralizace jeví vyšší. Velká města vykazují průměrnou míru sakralizace, s výjimkou Olomouce a Liberce. Tato dvě velká města mají míru sakralizace takovou, jakou lze očekávat vzhledem k jejich geografické poloze

Obr. 1 – Podíl věřících v Česku podle obcí (2001)
Obr. 2 – Modelové oblasti terénního výzkumu religiózní krajiny
Obr. 3 – Zničené kostely a kaple v Česku během komunistického období v letech 1948–1989
Obr. 4 – Kostel jako dominanta obce (Pyšely)
Obr. 5 – Příklad transformace sakrálního objektu (bývalá synagoga, nyní badatelna státního okresního archivu Vyškov ve Slavkově u Brna)

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MARTIN BALEJ, JIŘÍ ANDĚL, TOMÁŠ ORŠULÁK, PAVEL RAŠKA

DEVELOPMENT OF ENVIRONMENTAL STRESS IN THE NORTHWESTERN PART OF CZECHIA: NEW APPROACHES AND METHODS

M. Balej, J. Anděl, T. Oršulák, P. Raška: *Development of environmental stress in the northwestern part of Czechia: new approaches and methods.* – Geografie–Sborník ČGS, 113, 3, pp. 320–336 (2008). – This article deals with the theoretical background to environmental stress theory that includes a multivariables system of indicators and the application of such theory. The environmental stress lies at the intersection of the stressors in the subsystems of a landscape, that is: natural (e.g. relief topography, air, water, soil, and biota) and/or social (e.g. demographic and economic variables). The methodological concept used can be applied to other areas of study because of its broader spatial and functional applications. In comparison to other methodologies used to evaluate the anthropopressures on the landscape (those that monitor changes in land use), the environmental stress assessment is directed at locating 'stressors' beyond the study areas that can significantly impact on future studies.
KEY WORDS: environmental – stress – cultural landscape – northwestern Czechia.

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Introduction

The term stress often is used to describe medical, psychological, biological and physical conditions. It denotes a 'system of power' that causes strain or even produces deformity that damages the 'host' system. The factors producing 'stress' are referred to as: a stressor. For Míchal (1992) such 'outer disturbing factors' are the direct result of a stressor. Stress is the affect or influence of a stressor on a particular system. In the case of a landscape, the system consists of biotic, abiotic and human elements, and 'stress' represents all the deformities that exist in a system. Every impulse that exceeds standard levels of intensity within a system (whether physiological, natural, generally social or economic) is called: stress (or pressure, strain, disturbing force, trouble, and difficulty). It represents an extraordinarily powerful even intensive phenomenon resulting in a series of deviations from common fluctuations. Reactions to stress include resistance (effective) or the opposite – inertia. The ability to react to 'stress' is related to the ability to compensate (remove) the effects. The first phase of the reaction to stress stems from the principle of resilience. Resistance in this case is interpreted as successful.

However, in the final phase a system either collapses (changes its character) or is neutralized by the stress and continues to function. The 'stress' can be thus set off wholly, incompletely or if the 'stress' is not compensated for at all, the system will collapse. Ingegnoli (2002) also argues that if the source of the stress is constant (chronic) or even too strong, this will lead to what is termed: endangering the 'health' of a landscape.

The theory of landscape ecological stressors was developed in Slovakia (Šúriová, Izakovičová 1995; Atlas krajiny Slovenskej republiky 2002). Others, Lipský (1998), Erickson (1999), Antrop (2000), or Ingegnoli (2002) also use the terms environmental stressor, anthropopressure or landscape strain to describe forms of degradation of the natural landscape, natural conditions otherwise seen as: landscape pathology or anthropogenic disturbances.

The identification of such anthropogenic stressors and accounting for these through the concept of 'stress' reveals humans' influences in/on the landscape. The advantage of using terms like 'stress' and 'stressor' helps in identifying the causes as well as the consequences of such environmental effects. Stress is used to describe a meaning broader than its usual context. It covers both 'stress' in the natural and the human landscape subsystems. We can talk about it in connection with all landscape components (natural and human). Stressors also include disturbances, but not only these. Included too are the transformations of land use through anthropogenic activities or noise, odour et cetera. Stress in the human subsystem (e.g. social pathological phenomena, delinquency, unemployment, divorce rate, the rate of natives) and its consequences on the landscape character, landscape structure, and landscape ecological processes, very often remain unnoticed although it is a significant force to "landscape" a system (Hobbs 1997, Risser 1999). Efforts have been made to also quantify the rate of anthropopressure through a ratio that includes land use types (Skowronek et al. 2005). But these are partial views that reflect only certain given environmental issue. The environmental stress assessment can be one of the most suitable methodological concepts to ascertain landscape development trajectories (cf. Conway, Lathrop 2005; Pauleit, Ennos, Golding 2005).

In our research we asked the following questions:

- How will ecological and social stress evolve in different landscape types and at various time periods?
- Is it possible to integrate social and ecological stress into a comprehensive indicator to predict what the complex/negative effects of humans are on landscape subsystems?
- Can the changes in ecological and human stresses be related to each other?
- If so, which has the greater dynamics?
- What are the reasons for the most striking way in which changes in the intensity of stressors can be noted as well as in the subsequent occurrence of stress?
- Where are we to look for the main driving forces?
- What connections are there between individual partial variables?

Case study: the northwestern part of Czechia

The research includes the three studies conducted alongside the Czech–German borderland (the northwestern part of Czechia) where the areas are marked by partially different development, mainly induced by

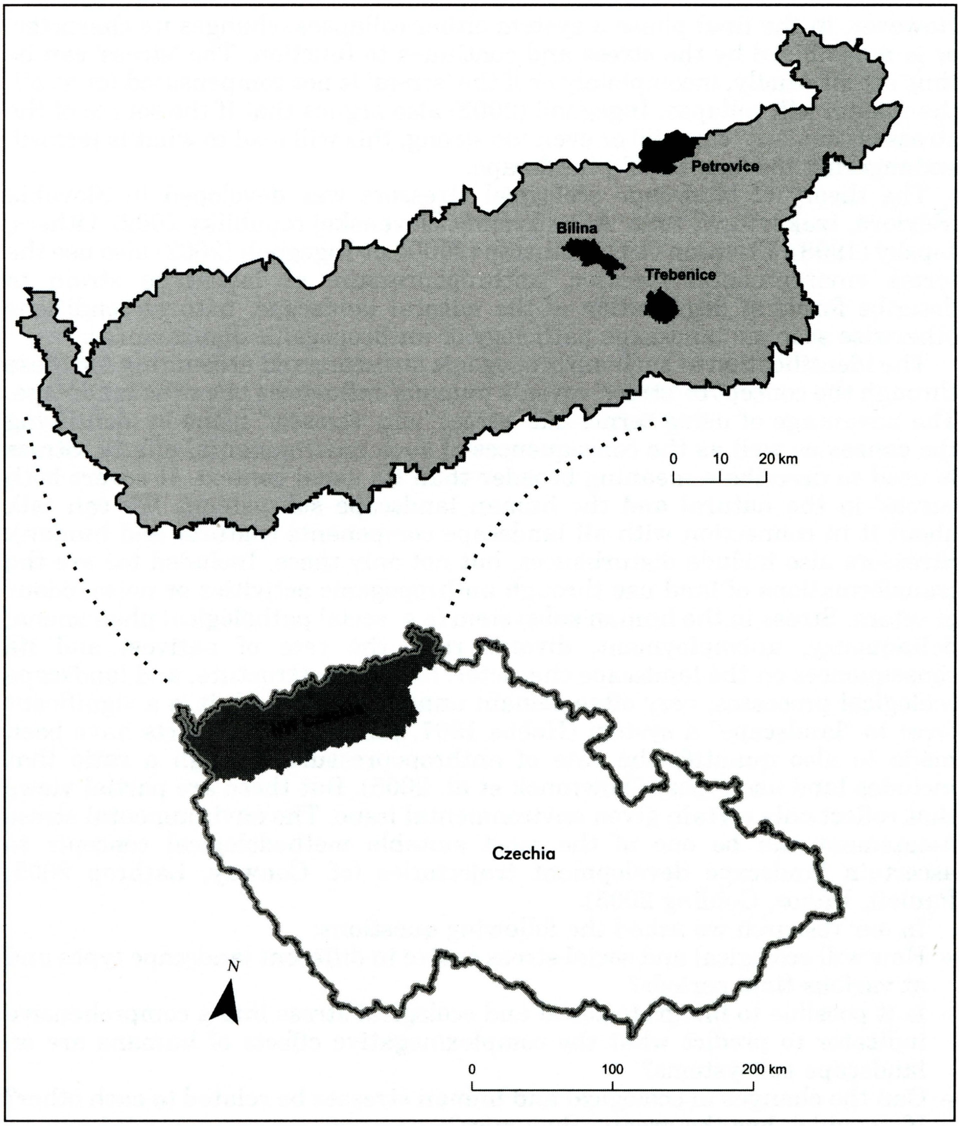

Fig. 1 – Study areas Bílina, Petrovice and Třebenice and their surroundings within the northwestern part of Czechia.

different geographical conditions, and then these were analyze in terms of land use and environmental stress changes from the mid 20th century (Fig. 1).

The northwestern part of Czechia was in the past a "barometer" to measure fundamental changes in the development of the Czech landscape. The changes were mostly brought about by industrialization and urbanization processes causing ecological problems as far back as the Saxon towns of the mid 19th century. In the 1950s the environmental stresses increased and by the 1980s (30 years later) this former region known as

Czechoslovakia was in need of critical interventions. At this stage all the natural components of the landscape system were damaged. This high environmental stress now also is visible in the health and demographical variables of the population.

The study area where the environmental stress has the highest intensity is represented by the Bílina area. This study includes the town of Bílina and wider still, also the destroyed settlements. The second, slightly different type of area is more hilly, the border area of Petrovice that lies northwest of the city Ústí nad Labem. The Petrovice area is mountainous, the areas of the Ore Mountains (Krušné hory) significant for its dynamic development until the end of the 19th century. Its subsequent stagnation – both economic and demographical development – further more after World War II resulted in markedly regressive trends that have changed not only the function but the character of the landscape. The third study area is Třebenice where the indications are that this is an intensively agriculturally exploited landscape. Here the landscape function remained stable during its whole development. The Bílina, Petrovice and Třebenice areas are different analogical landscape types in the northwestern part of Czechia.

Environmental stress: methodological concept

The negative influence on the landscape, i. e. of the changes of the environmental stressors that cause ecological or social stress in the landscape, generally can be grouped according to different characteristic periods of human history (Agnew, Livingstone, Rogers 1996). We can distinguish three basic evolution phases in the development of societies (Hampl 1998):

- The pre-industrial period characterized and determined by natural subsystem, the distribution of settlement structures and economic activities.
- The industrial society marked by the development of a secondary sector that has distinct dynamics of change. Ecological determinations gradually are overcome and the role of socio-geographical factors increase (Berry 1973; Broek, Webb 1978). In our case, this phase is represented by the so-called totalitarian period (the German occupation and the period of communism) which actually represents the final phase of the industrial society and a decline from the natural trajectory of Western Europe (here certain features of a post-industrial society are already revealed). For the northwestern part of Czechia this period means a break in the existing continuity of development.
- The post-industrial society in the Czechia is characterized by an intensive development of communication and information contacts (pressure on transport and communication networks) and by developing tertiary economic sectors such as services and tourism. In the settlement structure there appears to be an integration of all systems. Also, trends focus on depopulating developmental tendencies in large cores ("gravity centers, nodes") in the place of areas in their background (Hampl et al. 2001).

We will focus on the last period of the industrial society in Czechia, i. e. on the totalitarian period, and on the post-industrial phase, where the essential changes of the ecological and social stress development in the study areas can be documented.

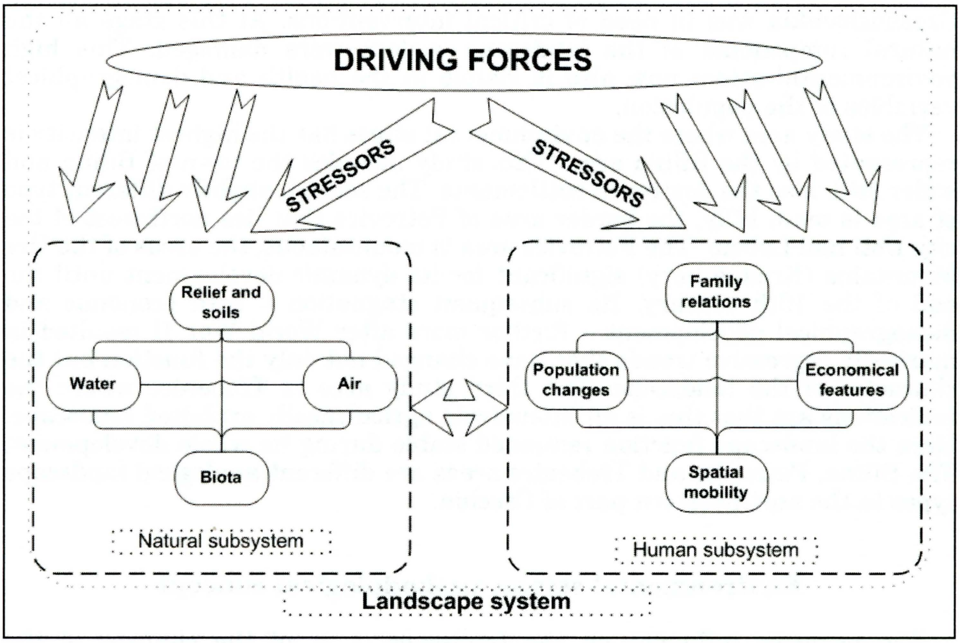

Fig. 2 – The general scheme of the stressor influences and stress occurrence in the landscape system

Marsh, Grossa (2004) consider the presence of the excessive environmental stress level in the landscape system to be the basic factor distinctively determining the so-called environmental quality. The environmental quality, as a fundamental attribute of the landscape system, is threatened by synergic influences of environmental stressors on both natural and human subsystems (Fig. 2).

In the methodical procedure of the ecological and social stress accounting we divide the period of the second half of the 20th century (totalitarian and post-industrial period) into five time horizons for which there are valid databases available. Approximately in 1950 the final stage of the industrial period begins. In the totalitarian period environmental stressors start to intensify dramatically. The two following time horizons (1970 and 1980) indicate dynamic changes in the totalitarian era. This ends in the year 1990 when the post-industrial period arrives. The last horizon – 2005 – documents the phase of inhibition of stressors in the post-industrial period.

The focus of the article is to obtain our own methodology to assess the environmental stress and the latter's application in specific geographical conditions. The methodology of evaluating the ecological and social environmental load developed by The Research Institute of Constructing and Architecture (VÚVA) in Prague in 1991, becomes an accounting system for ecological load evaluation as well as experimental and social load evaluation (Anděl 1993). The VÚVA methodological concept was applied to the whole territory of Czechia in 1991. Comparative studies in development after 1989 used identical parameters to measure conditions in eight study areas in the Ústí nad Labem region in 2001 (Balej 2004).

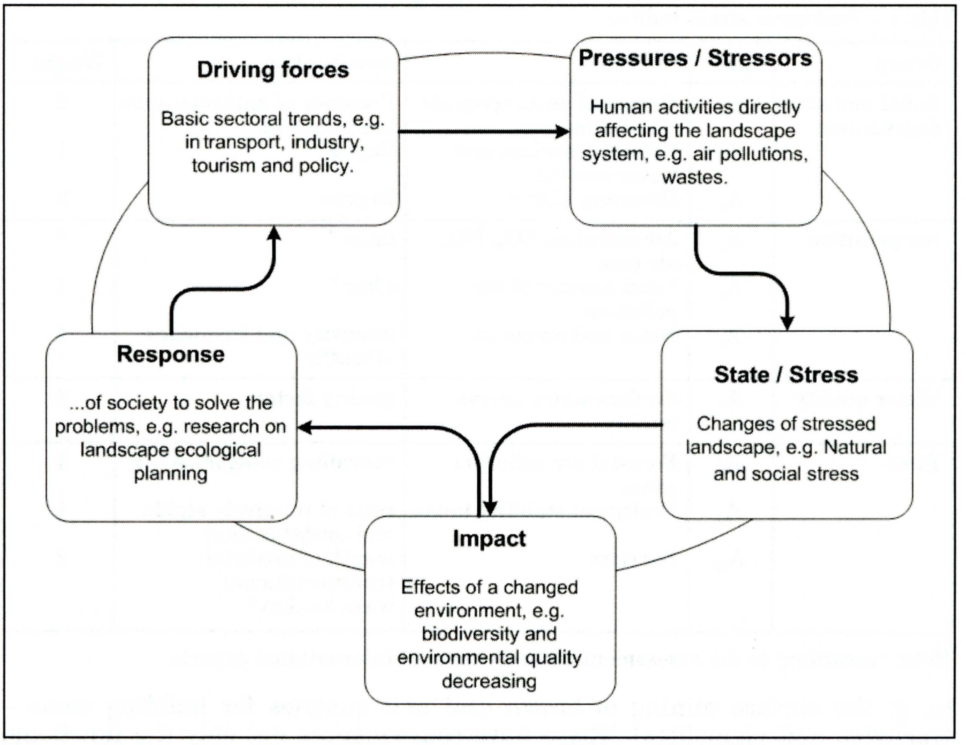

Fig. 3 – The DPSIR scheme "Driving forces – Pressures – State – Impact – Response". Source: Jesinghaus (1999).

The environmental stress in the study area indicates the influence of the stressors that are located both within the area and also in areas beyond its borders. The effects of environmental stressors don't respect administrative boundaries. From the terminological reference the stress follows internationally recognized methodological schemes evolved on the basis of the EEA concept (European Environmental Agency; Jesinghaus 1999). Environmental stress accounting reflects the anthropogenic pressures in the DPSIR scheme ("Driving forces – Pressures – State – Impact – Response", Fig. 3).

A fundamental point of the methodological procedure is to choose the indicators and then to represent these according to their particular features in the natural and human subsystems (Anděl 1993). The accounting process is done in correspondence with similar methods that are based on a set of rating points. The maximum interval of the chosen indicator for a monitored area then is divided into quartiles. Values are assigned to each as follows: in the range of low (quartiles Q1=0), below the average (Q2=1), above-average (Q3=2) and high (Q4=3). These then are multiplied by relevant weights (e. g. 1 or 2). Naturally the hierarchy level is important. In the environmental stress accounting, the variation interval for individual indicators with hierarchy level increases and there can even be different scale of rating points. The following environmental stress assessment is valid for any other territory.

For the purpose of the ecological stress accounting (EcoS) we first notice the degree of degradation of the relief and soils (Tab. 1). For the northwestern part of Czechia a distinctive anthropogenic topography transformation is typical

Tab. 1 – Ecological stress indices

Group	Index	Indicator	Specification	Weight*
Relief and soils degradation	A_1	Degree of anthropogenic transformation	Presence of anthropogenic landforms in	2
	A_2	Potential aeolian and water erosion	Degree	1
	A_3	Dumping places	Degree	2
Air pollution	A_4	Air pollution SO_2, NO_x, air dust	$\mu g.m^{-3}$	2
	A_5	Local sources of air pollution	$t.km^{-2}$	1
	A_6	Noise and emission	intensity and frequency of traffic	2
Water quality	A_7	Surface water course quality	quality factor	2
Biota	A_8	Forestal air pollution zones	prevailing category A – F	1
	A_9	Ecological stability index	ratio of relatively stable and unstable land	1
	A_{10}	Barriers	length of artificial-transportational ways $km.km^{-2}$	2

Note: *according to the assessment made by team of international experts

(e. g. the surface mining of brown coal and quarries for building stone – trachytes and phonolites). These have consequences not only the functional disturbances of the natural subsystem but also in terms of the devaluation of the total visual landscape's quality (Balej 2004). The presence of illegal and controlled dumping land-fills was evaluated by using a 0–3 rating scale. The potential of water and wind soil erosion was calculated by means of the Universal Soil Loss Equation (USLE) as defined by Wischmeier, Smith (1978). Air quality was monitored on the basis of emission concentrations of solid materials, SO2 and NOx and also by the indicator of the air pollution from local sources (namely from houses heated by solid energy sources). The surface water quality is represented by the indicator of the quality of the water in streams. Ecological stress in the vegetation cover reflects of emission zones of forest areas (the proportion of forest areas with deteriorated health state, that is: the defoliation of treetops measured in %), and the ecological stability index according to Míchal (1992) (ratio of ecologically relatively stable and labile land use types). With respect to the completeness of the information about the stress in the natural subsystem the barrier effect calculation and the presence of noise or odour cannot be omitted. The landscape fragmentation first of all by transportation barriers (Anděl et al 2005) was calculated as the density of transportation lines (railway and roads) with individual stages being moreover weighted by the intensity of traffic (by the number of vehicles or trains passing on them within 24 hours). The ecological stress (EcoS) is given by
where w stands for the weight (1 or 2), n indicates the number of indicators 1 till 10 and An is the indicator of ecological stress.

$$EcoS = \sum_{n=1}^{10} w * A_n$$

Tab. 2 – Social stress indices

Group	Index	Indicator	Specification	Weight*
Population change	B_1 B_2 B_3	Natality Natural increase Index of vitality	5 years average 5 years average preproductive / postproductive	1 1 2
Family relation	B_4 B_5	Divorce rate Incomplete families	5 years average number	1 2
Economic relation	B_6 B_7	Index of education Unemployment	university / elementary 5 years average	2 2
Spatial relation	B_8 B_9 B_{10}	Natives Migrational balance Migrational change	in % 5 years average 5 years average	2 2 1

Note: *according to the assessment made by team of international experts

Social stress (SocS) reflects social aspects which we consider as having a negative effect on o human beings. A set of evaluating indicators should therefore indicate basic population features (Tab. 2). The population movement is evaluated by three indicators – the vitality index (rate of pre-productive and post-productive component), the level of the birth rate and the natural growth. In the case of the municipality scale of the research it is important to work with the last two mentioned indicators and a five-year of averages to eliminate random phenomena. Family disturbance indicates the rate of incomplete to complete families and we set the divorce rate as the number of divorces per 1,000 inhabitants in the given five-year period. We monitor the economic features with the help of the unemployment rate. As in the totalitarian period it did not exist statistically and it is correct to work with this indicator only in the last time horizon rather than to abstract from it. In the environmental stress methodological concept it nevertheless acts as an indicator which for the territories not having gone through the totalitarian era is not substitutable. An important indicator is the educational structure monitored via the index of education calculated as the proportion of inhabitants with university/college to those with basic education. Indicators monitoring the spatial movement of inhabitants form a distinctive group. They testify implicitly about the relationship of the inhabitants to the territory where they live. One of the indicators is the ratio of inhabitants born in the living place, the second is the migration balance indicating attractiveness or on the contrary unattractiveness of the study areas, and the third is the migration turnover testifying about a labile or stable relation to the living place. Both of the last indicators are, with respect to the possible contingency, monitored in a five-year time horizon (Haggett 1975). The social stress (SocS) is given by

$$SocS = \sum_{n=1}^{10} w * B_n$$

where w is for the weight (1 or 2), n indicates the number of indicators 1 till 10 and Bn is the indicator of social stress.

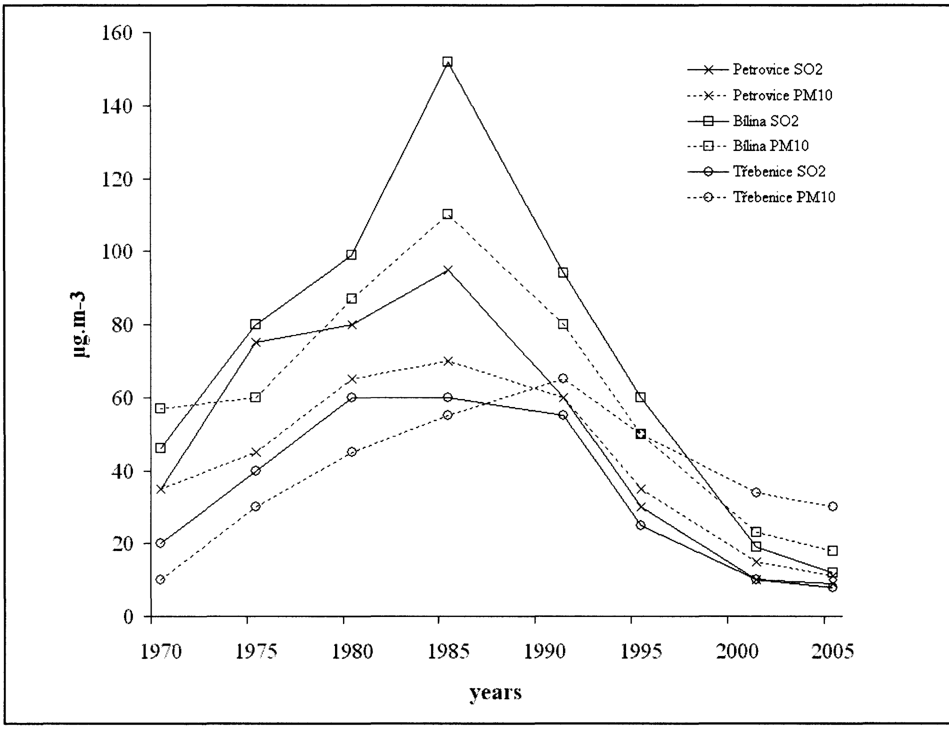

Fig. 4 – Average SO_2 and PM_{10} (particles smaller than 10 µm) concentrations in the study areas (µg.m^{-3} per year). Source: data of CHMI.

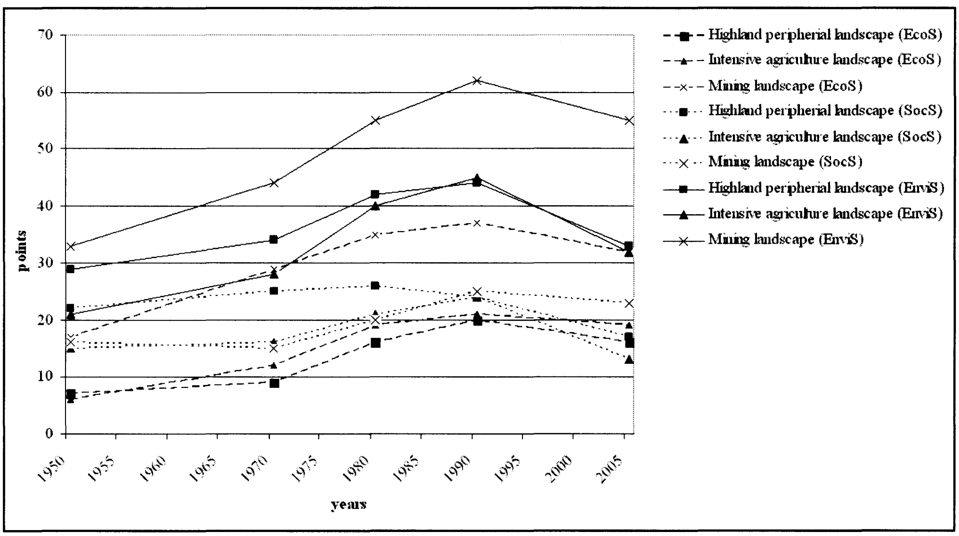

Fig. 5 – The development of the ecological (EcoS), social (SocS) and environmental (EnviS) stresses in the study areas in the period of 1950–2005

Results

The “strongest” stressing factor, from the point of view of the influences rate on other components of the natural subsystem, are stressors causing ‘stress’ in the air and which consequently and synergistically have an effect on the whole natural subsystem. Figure 4 shows the development of the A4 indicator, which was changed in the most dynamic way.

The ecological stress development confirms dynamic changes in the impact of the most prominent stressors especially where power stations produce multiplicative stressing effects on landscape components (Fig. 5). The high increase of the ecological stress until 1990 is connected to both air pollution and also the increasing deterioration of forest growth. Also affected are an increase in anthropogenic soil and relief transformation and a decrease in the quality of surface streams. On the other hand, there has been a markedly and even dynamic decrease in ecological stress after 1990 in all the study areas but this is compensated by stressing effects of increased traffic intensity. There also has been the affects of intensified noise and transport emissions, the expanding landscape fragmentation, the non-decreasing degree of the anthropogenic relief and soil transformation and a non-improving state in health of the forest growths. The amplitude of the ecological stress changes has reached, in this second half of the 20th century, its maximum values in Třebenice area (more than 300 %), in Petrovice area (almost 300 %) and in Bílina area (more than 200 %). Among these three study areas Bílina is worse hit in that this area exceeds others as a distinctively impaired natural subsystem. It reaches the highest values in all monitored indicators of the ecological stress.

Environmental stress (EnviS) is the sum of stress in two subsystems (social and natural):

$$EnviS = \sum_{n=1}^{10} w * B_n + \sum_{n=1}^{10} w * A_n$$

where w is the weight (1 or 2), n indicates the number of indicators from 1 till 10 and An and Bn are indicators of ecological and social stress respectively.

While some partial indicators may act in different ways and even include opposite directions (such as registering positive immigration in the social subsystem but negative in relation to the natural one), in general such variability does not pose a significant problem.[1]

The totalitarian period (the German occupation and the period of communism between1939–1990) is a final phase in the Czechia industrial society. For the northwestern part of Czechia this means a break with existing development practices and opening up to a dynamic growth of the ecological and social stresses. This turning point then also is, besides the intensive increase in anthropogenic stressors, connected to strong migration movements. The latter refers to the transfer of Germans to “new” settlements on the borderland. This relocation of the German population here and movement of people from the Czech interior have resulted in changes both quantitative and qualitative in character. The insufficient occupancy for

[1] The relation of indicators in both subsystems has been analysed by correlation coefficients and will be further analysed in a future research.

emigrating population between 1930 and 1950 had resulted in a population deficit for Petrovice area of approx. 72 %, for Bílina area 30 % and for Třebenice area 25 %. Other significant indicators include nationality, age categories and changes in economic development. This new settlement has certain distinguishing albeit negative specifics: a higher ethnic heterogeneity, an unfavorable educational structure and a distinctive social pathology (i. e. delinquencies, drug addiction, steep divorce rates). On the one hand these settlement gravity towns have grown dynamically but on the other there has been a "collapse" of the structure in the smaller settlements. Also there have been a number of settlements that have been abandoned in the post-war non-settlement period, such as the territory of the Czech-German borderland. In Petrovice area two-thirds of the settlements have disappeared. However, because of the brown coal mining in the Bílina area, the town of Bílina still remains as one out of eight settlements. Here new 'in-coming settlers' now live and have lost their historical connections to their landscape. In 1990 the proportion of natives in Petrovice area reached only 25 %. From the aspect of view of migration there are strong labile tendencies (resulting in a high migration turnover). In the totalitarian period a constant high negative migration balance resulted in the younger generations moving into larger towns. This had an effect on the life expectancy index with pronounced family disturbances noted as well as a rise in the number of 'incomplete' families. Throughout the totalitarian period the social stress factors continuously increased to reach a peak towards the end of the period (with gross accelerations in the 1980s).

In the post-industrial period social stress again decreased and regressed to the levels noted at the beginning of totalitarianism (Fig. 5). These changes are apparent from research in the development tendencies of study areas. Here different geographic conditions, the population, social and natural features are brought in. A crucial point in social stress development is then the year 1990. This was when the areas being studied here neared almost identical levels (about 25 points). The social stress in Třebenice and Bílina areas then dramatically accelerated in this second half after a period of stagnation in the first half of the totalitarian period. This was due to decreases in the vitality index, a lowering of the natural growth index and a loss of migration through unattractive migrating prospects. On the contrary, in the Petrovice area the social stress remained very high from the beginning of the totalitarian period; there was a distinctive increase in the first half of the totalitarian period (the loss of the migration through factors of un-attractiveness) after which a phase of stagnation followed. In the post-industrial period the social stress in the areas studied develops in quite different ways. In the Třebenice area there is a decreases due to a positive migration balance and an advancement in natural growth and surprisingly too in the educational structures. In the Petrovice area similar tendencies are evident. Here there is a dynamically expanding rate of natives that guarantees/consolidates the wholes area's social stability. The situation in the Bílina area however is different; here the positive changes of indicators assert themselves with great difficulties.

Correlation analysis showed mutual cohesion of some indicators (e. g. natives or migration balance). It also revealed the existence of negative correlations in cases where groups of social stress were indicated nationwide or within Central European tendencies (e. g. population decline, divorce rate, increasing of the rate of single-parent families). Local specifics are not reflected such as spatial movement or economical relations. This is

Tab. 3 – The present-day typology of the study areas from the point of view of anthropogenic stressors effects and the environmental, ecological and social stresses (1950–2005)

Indicator Geolocation	Mining–urban regionallyexposed	Recreational semiperiphery	Agricultural periphery
Location (m above sea level) The level of EcoS The level of SocS The level of EnviS	basin (195–215) high high EcoS>SocS Bílina	mountainous (450–750) low relatively low EcoS>SocS Petrovice	lowland (170–260) relatively low Low EcoS=SocS Třebenice

documented through correlation indexes between groups. Natality, for example, has a high correlation with one-parent families (0.754) and a negative one with the natives ratio (-0.654) and the index of education (-0.717). Inside these groups more or less expected correlations can be found, e.g. natives' ratio and migration balances (0.735). In the frames of the ecological stress it is shown that individual indicators of the ecological stress intensify synergistically (a positive correlation index). Low values of correlation indexes with the group of "biota" indicators document a different character of this component within the natural subsystem. The developmental inertia of qualitative parameters is stronger in this case. Also, dynamics and variability are less intensive.

On the basis of the ecological, social and environmental stresses development, in the combination with the geographic-location factors a very simplified typology can be drawn (Tab. 3): the first type – regionally exposed areas with the prevailing mining and urban functions of the landscape are characterized by a high ecological and social stress, whereas the ecological stress exceeds the social stress significantly; the second type – the semi-periphery with the recreational function – has a low level of stress where social stress dominates over ecological stress. This then can be differentiated from the third type on the periphery that carries an agricultural function and where the ecological and social stresses reach balanced values. The results verify the occurrence of the given types as representatives of larger territorial units of the northwestern part of Czechia. The first type represents polycentric core basin areas under the Ore Mountains with the dominating energy industry and mining function. The second type exemplifies the Ore Mountains plateaus, from the greater part a marginal territory abandoned and after the transfer of the German population permanently under-settled with weakened historical relations to the landscape. The 3rd type is typical for intensively agriculturally managed territory with fertile soils suitable for plant production.

Discussion and conclusions

Prognoses suggest that by the year 2010 the emission concentrations will decrease to 10 µg m-3. In the next years still a slight decrease can be expected for the ecological stress and then rather stagnation. There may be even a minor increase. In the connection with the presupposed escalation of the electric power output or more precisely opening of heat power station blocks in the next years there can arise possible changes in the concentrations of sulphur dioxide or nitrogen oxides. The growing traffic intensity will

Tab. 4 – Main driving forces in the northwestern part of Czechia

	Year	Driving forces	EcoS	SocS	EnviS (intensity)
Totalitarian period	1945	transfer of Germans, disruption of historical relations, traditions and customs, break off across-the-border cooperation	high landscape permeability, finely grained mosaic of patches	loss of the relations of man with the landscape	xx
	1948	central planning, the end of private property, 1st collectivisation wave, depletion of settlement structure, new colonisation	landscape unification – collective openfields	high migration turnover	xxx
	1970	chemical industry development, 2nd collectivisation wave, development of quarry coal and bulding stone mining	growing air and river pollution	negative migration balance	xxxx
	1980	development of second dwelling, power engineering, construction of prefab housing estates, dynamical decrease of surface water quality	culmination of air and surface stream pollution, forestdecline, monoculture planting	effort to steady population – "death grant", prefab housing estates	xxxxx
Postindustrial period	1990	market economy, privatization and restitution, building of sewage processing plants, gasification, rehabilitation of landscape	improvement of air and surface streams quality	lowering of migration turnover, increase of natives	xxxxxx
	2005	building of transport infrastructure, tourism develoment, suburbanisation and urbanisation trends, reclaiming works, damping of surface mining	noise and traffic emissions, damaged forest growths, anthropogenic dagradation of soil and relief, barriers	positive migration balance, strengthening of identity of man with a landscape	xxx

definitely contribute to increased toxic levels. The variability of emission concentrations of solid polluting particles in the air, namely in rural areas and during winter months, is dependent on the in which real use of ecologically-more-friendly fuels in households. The air emissions of the polluting agents possess many additional effects on the other components of the natural subsystem. Also insulation intensity is decreased through the higher degree dust particles present in the air (PM10). It has been noted that in topoclimatic conditions the air circulation has declined. The influence of the precipitations acidity on the chemical soil characteristics belongs among the most prominent impacts on other landscape components. Due to the acid rainfalls, the pH factor of soils in the northwestern Czechia has dropped by an approximate average of 0.5 degree during the 1971–1981. It is hard to anticipate whether there will be improving tendencies within the indicators that relate to anthropogenic soil and relief transformations. It is expected that the health state of the forest growths will stagnate in direct relation to the soil pollution. Also, the global climatic changes will affect the planted spruce tree monocultures in lower locations and these will suffer from more distinctive damage. Increasingly, however, there is a tendency to respond to the intensity of the line stressors. Since the 1980s a twofold (in some cases even more) increase in the carrying capacity of the communications by vehicles has occurred. This increase has an unambiguous stress effect that results in higher landscape fragmentation and also alongside intensified communications and increased traffic. The noise and emissions from the transport will thus increase.

Driving forces are a decisive factor in the environmental stress development (Tab. 4). The determining driving forces in the first phase of the totalitarian period were the transfer of the German population and the following non-settlement. It caused a break of continuity in the landscape trajectory and also the relationship between humans and the landscape. The second phase (after 1948) was distinguished by the abolition of private property, the collectivization and by negative developmental trends in the settlement structure. The environmental stress was increased namely by landscape "unification", homogenization (both of the function and the structure) and by a high migration turnover (lability of settlement). New settlers from the Czech interior were often unsuccessful in "growing together" with their place of living. The question is: Is a landscape a scene we are looking at, or a world we are living in? (Wylie 2007). The third phase of the totalitarian era (after 1970) is distinguished by a high pressure on the natural subsystem (the development of the quarry coal mining, energy and chemical industries). As the ecological stress increases dynamically, this has a consequent effect attached to the loss of the landscape attractiveness. Also, this results in "changing the polarity" balance of the migration to a negative. This tendency culminated in the threat of an ecological disaster in the 80s: the culmination of air and water pollution and, forests in decline etc. The disturbance of the natural subsystem shows itself negatively on the state of health of the population. The emigration of the inhabitants is regulated politically and in the form of so-called stability bonuses commonly known as: "death grants".

The predominant driving forces in the post-industrial period are connected with the market economy and necessarily also with applying ecological disposals. The air quality and water in surface-streams is markedly improving, limits are being placed on coal mining and there is evidence of the landscape being reclaimed. Improvement to the quality of the environment is also attracting tourism which boosts the migration balance from a negative to a positive orientation. Slowly the identity of humankind with the landscape is strengthened.

Between the totalitarian and the post-industrial periods we can find essential changes of the environmental stress development. While the totalitarian era is characterized by the dynamic increase of the ecological stress and by a certain shift ("delay") of the social stress, in the post-industrial period we identify a decrease of the ecological stress and again with a definite shift also of the social stress. This fact together with the twofold higher amplitude of changes in the ecological stress as compared to the social one thus undoubtedly testifies about a higher dynamic of the natural subsystem and about a higher persistence of the social subsystem. Regarding the indicators used in the research, those proposed by the authors and then refined by the team of international experts, this conclusion indicates taht the higher "vulnerability" of the natural subsystem, the greater the complexity of the social subsystem. Notwithstanding, it has to be mentioned that using another set of indicators (according to data accessibility and relevancy), this conclusion may not be valid generally. An important role is undoubtedly played by a greater merging of social items and where certain negative trends now can be neutralized by opposite tendencies. It is shown that for e.g. air or water quality changes, heading toward a positive development, can be carried out in a relatively shorter time horizon, whereas in the social subsystem changes can be reached only in a relatively long time horizon. Differences surface within individual components of the natural subsystem. It turns out that abiotic elements likewise are subject to developmental changes more quickly than biotic ones. The stress caused by polluted air decreases far more dynamically than the stress induced for e.g. by the deterioration of forest growths or soil acidification. Other argument is the unimproved health of forests in the Ore Mountains even after a rapid decrease of emissions concentrations.

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Shrnutí

VÝVOJ ENVIRONMENTÁLNÍHO STRESU V SEVEROZÁPADNÍ ČÁSTI ČESKA: NOVÉ PŘÍSTUPY A METODY

Článek se věnuje metodice hodnocení krajiny z pohledu environmentální geografie. Zabývá se teoretickým vstupem do problematiky, multikriteriální soustavou reprezentativních indikátorů, které odráží kvalitu jednotlivých složek přírodního a sociálního subsystému. Evnironmentální stres (environmental stress) představuje průnik působení stresorů na systém kulturní krajiny. Lze jej chápat jako reflexi negativního antropogenního vlivu v časoprostorové dimenzi. Samotný proces hodnocení environmentálního stresu vychází z monitorování negativních vlivů na přírodní subsystém krajiny (reliéf, ovzduší, voda, půda, biota) a na humánní (sociální) subsystém krajiny (demografické a ekonomické parametry). Metodiku lze aplikovat na libovolné území i v širších prostorových a funkčních souvislostech. Oproti jiným metodikám, které hodnotí antropogenní tlak na krajinu prostřednictvím zastoupení jednotlivých kategorií využití území, navrhovaný postup umožňuje zachytit i hybné síly případně stresory, ležící mimo studované území, ovšem s výrazným vlivem na jeho charakter či kvalitu.

Na třech modelových územích, které se vyznačují zčásti odlišným vývojem a zejména různými geografickými předpoklady, dokumentujeme změny ve využití území v různých typech krajin severozápadní části česko-německého pohraničí od poloviny 20. století (obr. 1). Důvodů pro volbu zmíněné oblasti bylo několik. Severozápadní Čechy byly v minulosti určitým „barometrem", který avizoval zásadní změny ve vývoji českých zemí a většinou stanul na čele těchto změn. Ať už se jednalo o proces industrializace a urbanizace, která zde probíhala v těsné vazbě na saská města v polovině 19. století, či otázky spojené s ekologickými problémy. Ekologický stres zesílil v 50. letech minulého století a o 30 let později dosáhl jako v jediném území Česka až kritických hodnot. Zasaženy a poškozeny byly všechny přírodní složky prostředí. Negativní dopad se projevoval a projevuje i dodnes na zdraví a psychice obyvatelstva.

Negativní působení člověka na krajinu, tedy změny v působení antropogenních stresorů vyvolávajících ekologický či sociální stres v krajině, lze obecně časově seskupit do různých charakteristických období lidských dějin. Můžeme rozlišit tři základní vývojové etapy ve vývoji společnosti: preindustriální, industriální (ukončena totalitní fází) a postindustriální.

Ve vývoji stresu sledujeme mezi totalitním a postindustriálním obdobím kardinální změny ve vývoji environmentálního stresu. Zatímco totalitní období se vyznačuje dynamickým nárůstem ekologického stresu a s určitým posunem („opožděním") i stresu sociálního, v postindustriálním období sledujeme pokles úrovně ekologického stresu a opět s určitým posunem i stresu sociálního. Tato skutečnost spolu s amplitudou změn (ta je u ekologického stresu v porovnáním se sociálním stresem dvojnásobná) nepochybně vypovídá o vyšší dynamice změn ekologického subsystémů a o vyšší setrvačnosti vývojových trendů subsystému

sociálního. Tento fakt, uvažujeme-li indikátory využité v rámci výzkumu, které byly navrženy autory a zpřesněny mezinárodní expertní komisí, může svědčit o vyšší „zranitelnosti" ekologického subsystému a o větší komplexnosti a vývojové složitosti subsytému sociálního. Nepochybně důležitou roli hraje velká propojenost sociálních prvků navzájem, kdy určité negativní trendy mohou být negovány protichůdnými tendencemi. Ukazuje se, že např. u ovzduší či vod lze provést relativně v kratším časovém horizontu změnu směřující k pozitivnímu vývoji, zatímco u sociálního subsystému lze dosáhnout změn až v relativně dlouhém časovém horizontu. Jistá diferenciace je i u jednotlivých elementů ekologického subsystému. Ukazuje se, že rovněž i abiotické prvky podléhají vývojovým změnám rychleji než biotické. Stres způsobený znečištěným ovzduším klesá daleko dynamičtěji, než stres „měřený" např. znehodnocením lesních porostů či půdy. Příkladem je špatný stav lesů v Krušných horách i po razantním poklesu imisních koncentrací.

Obr. 1 – Geografická poloha Bílinska, Petrovicka a Třebenicka v severozápadní části Česka
Obr. 2 – Obecné schéma působení stresorů a výskytu stresu v krajinném systému. V obrázku shora: hybné síly, stresory, přírodní subsystém (reliéf a půdy, ovzduší, biota, vodstvo), sociální subsystém (rodinné vztahy, ekonomické rysy, prostorová mobilita, populační změna), krajinný systém.
Obr. 3 – Schéma DPSIR „Hybné síly – Tlak – Stav – Impakt – Odezva". V obrázku shora: hybné síly (hlavní odvětvové trendy, např. v dopravě, průmyslu, cestovním ruchu a státní správě), tlaky/stresory (lidské aktivity přímo ovlivňující systém krajiny, např. znečištění ovzduší, odpady), stav/stres (změny stresu v krajině, např. přírodní a sociální stres), impakt (efekty změněného prostředí, např. pokles biodiverziy a environmentální kvality), odezva (společnosti k řešení problémů, např. výzkum krajinně ekologického plánování).
Obr. 4 – Průměrné roční koncentrace SO_2 and PM_{10} v modelových územích ($\mu g.m^{-3}$).
Obr. 5 – Vývoj ekologického (EcoS), sociálního (SocS) a environmentálního (EnviS) stresu v modelových územích v období 1950–2005. V legendě shora: horská periferní krajina, intenzivní zemědělská krajina, těžební krajina.

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