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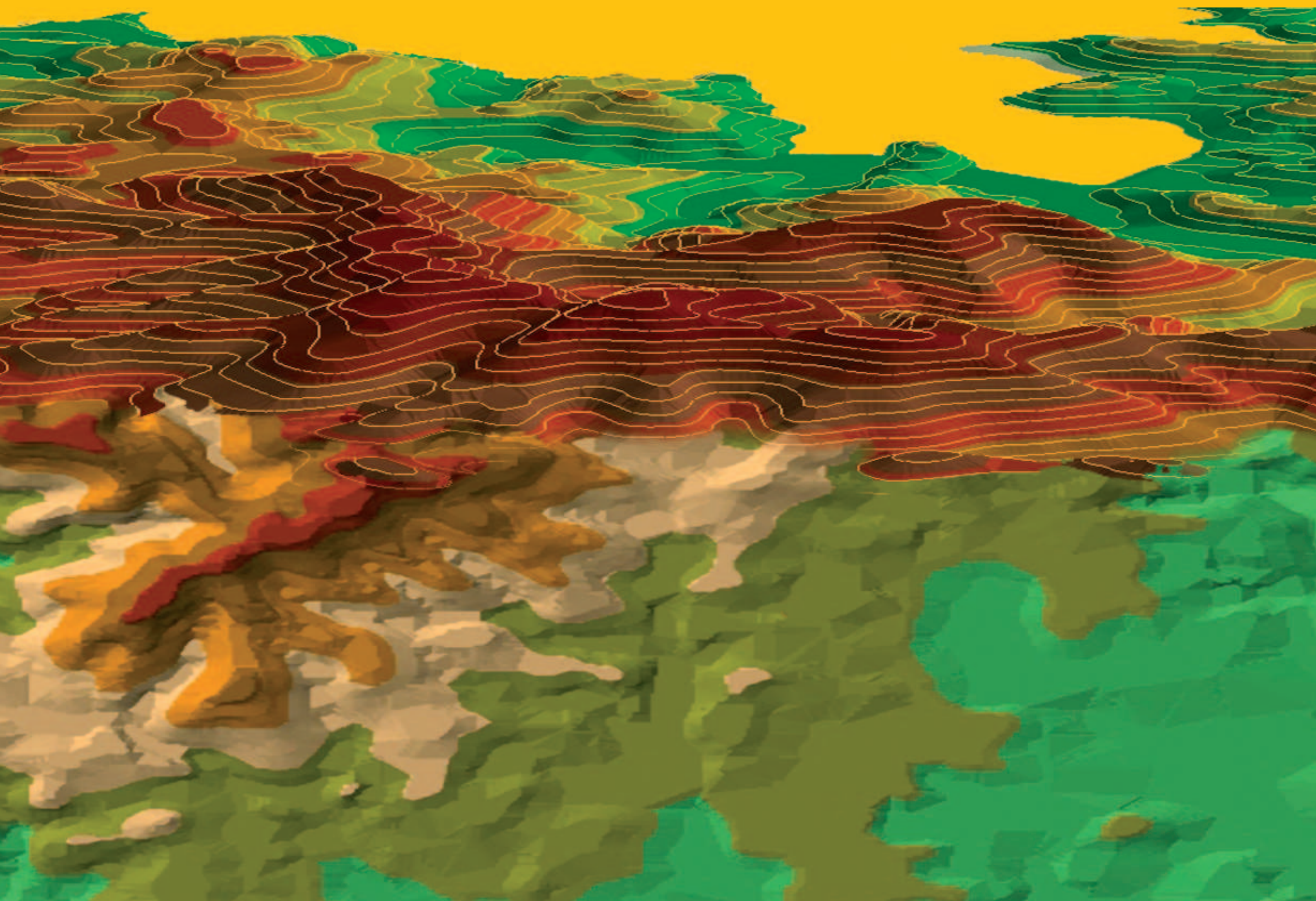

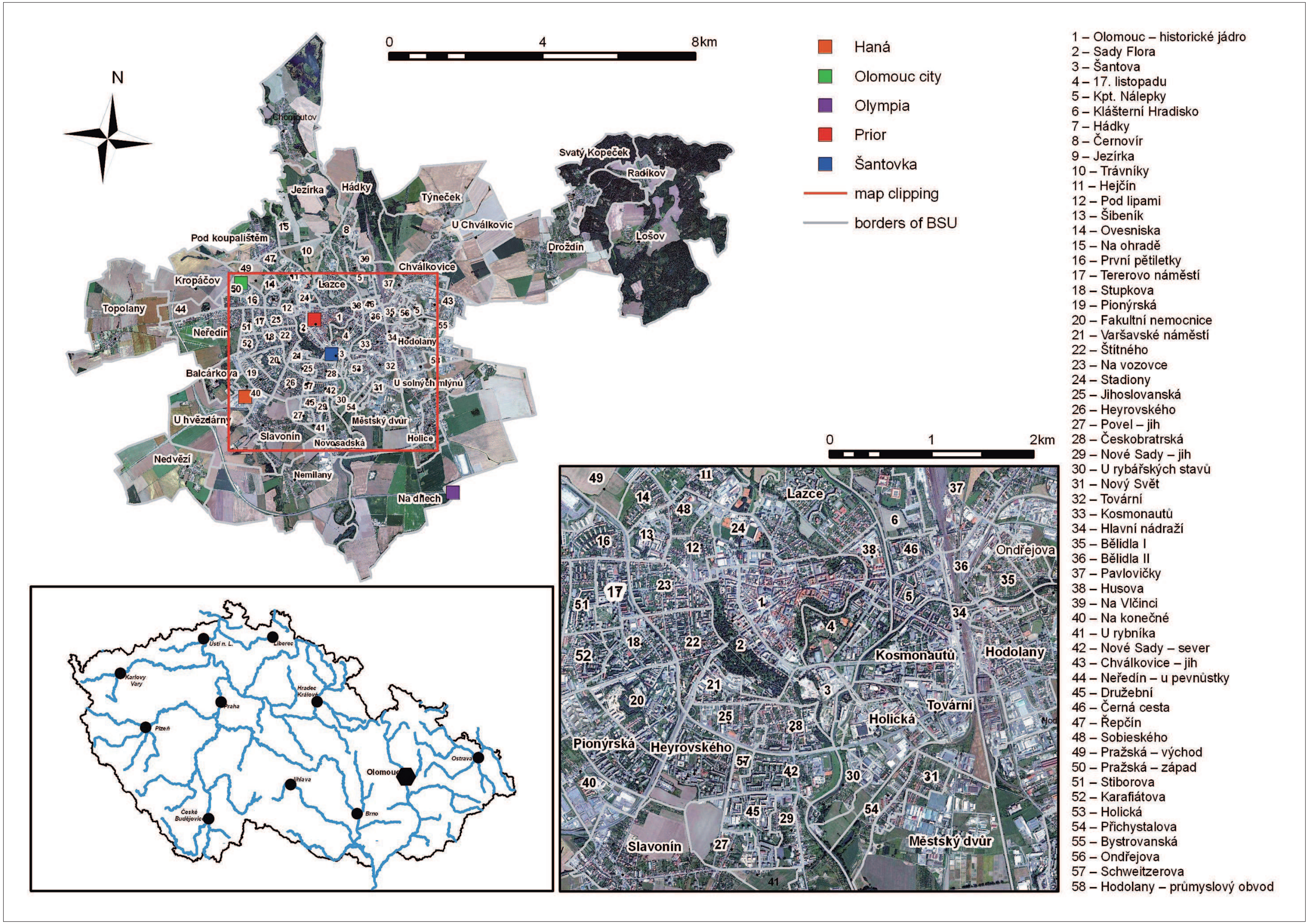

Fig. 1: Localisation of the area of interest and the shopping centres in Olomouc. Source: Národní geoportál INSPIRE, Authors´ design

Illustrations related to the paper by P. Klapka et al.

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Articles:

COARSE BED SEDIMENTS IN A HEADWATER CHANNEL AS INDICATORS OF FLUVIAL PROCESSES AND SLOPE-CHANNEL COUPLING: A CASE STUDY FROM THE CARPATHIAN MOUNTAINS (CZECH REPUBLIC)

Tomáš GALIA, Václav ŠKARPICH

Abstract

The character of riverbed sediments usually reflects fluvial processes and the dynamics of sediment transport in fluvial systems. The approach in this study was based on the measurement of the largest boulders located within a bankfull channel, and on the observation of changes in their size in the longitudinal profile of a headwater stream in the Moravian-Silesian Beskids Mountains. The resulting trends in a particle-size index reflect the character of sediment delivery into channel segments and the recent channel-forming processes. The largest boulders were observed in channel sections with a strong interaction of slope and fluvial processes, and a slight coarsening of sediments was recorded in the incised downstream sections of the longitudinal stream profile. In contrast, the refining of bed sediments was typical of the transitional zone between slope-channel coupled reaches and an alluvial cone characterised by a tendency to material aggradation.

Shrnutí

Hrubá sedimentární frakce pramenného toku jako indikátor fluviálních procesů a vazby mezi svahy a korytem: příkladová studie z karpatského pohoří (Česká republika)

Charakter dnových sedimentů v říčních systémech obvykle odráží probíhající fluviální procesy a dynamiku transportu sedimentů. Naše metodika byla založena na měření největších valounů a balvanů uvnitř aktivního koryta a sledování velikostních změn v rámci podélného profilu beskydského pramenného toku. Výsledné trendy indexu velikosti klastů reflektují charakter donášky sedimentů do korytových segmentů a současné korytotvorné procesy. Největší balvany byly pozorovány v korytových úsecích se silnou interakcí svahových a fluviálních procesů a mírné hrubnutí sedimentů bylo pozorováno v zahlubujících se úsecích dolní části studovaného podélného profilu toku. Naopak zjemňování dnových sedimentů bylo typické pro přechodnou zónu mezi korytovými úseky přimknutými ke svahům a úseky nacházejícími se na proluviálním kuželu, kde se spíše projevovala agradace materiálu.

Key words: *headwater stream, bed sediments, fluvial processes, slope-channel coupling, Moravian-Silesian Beskids Mountains, Czech Republic*

1. Introduction

Steep headwater channels are understood as an integral part of the fluvial network connecting the mountain landscape with lowland streams. They also control sediment delivery into lowland channels with regard to its amount and nature (Chartrand, Whiting, 2000). This implies that the mountain streams function as an open system connecting hill slope and fluvial processes (Owczarek, 2008). Therefore, modern researchers discuss slope-channel coupling processes (e.g. Walling, 1983; Fryirs, Brierley, 1999; Smith, Dragowich, 2008; Fuller, Marden, 2011), or hillslope sediment delivery zones (Owczarek, 2008). The system dynamics are affected by several factors, including climate, the frequency of high-magnitude events such as floods or debris-flows, and the internal dynamics of adjacent slopes (Chiverrell et al., 2009). In addition, human intervention represented by changes in land cover, as well as by the construction of hydraulic structures in channels, affected channel-slope interactions in the past.

Coarse bed sediments play an important role in high-gradient streams as they act as important dissipaters of flow energy affecting the potential sediment transport and erosion processes (Reid, Hickin, 2008). Downstream coarsening of bed sediments was observed in headwater mountain watersheds ($A < 10\ km^2$) with respect to continual sediment supply from adjacent hillslopes or scouring of debris-flows (Brummer, Montgomery, 2003; Wohl, Wilcox, 2005; Vianello, D'Agostino, 2007). Nevertheless, this trend may be disrupted by lithological characteristics of sediment inputs (Golden, Springer, 2006) or human intervention in the channels (Škarpich et al., 2010; Dade et al., 2011). Woody debris stored in the stream channels significantly affects the average size of bed particles, too (e.g. Kaczka, 2003; Montgomery et al., 2003), and it plays an important role in the development of stepped-bed morphologies (Gomi et al., 2003).

In other cases, the refining of bed sediments begins at points where slopes are disconnected from stream channels due to the initial occurrence of floodplain segments, and thus stepped-bed morphology is gradually transformed to plane beds and pool-riffles (Golden, Springer, 2006). The connectivity of coarse sediment flux in river systems was examined by the movement of forms (e.g. bars) or size populations of particles (e.g. cobbles) in gravel-bed channels, while great attention was paid to sediment delivery zones (Hooke, 2003; Hradecký, Děd, 2008; Owczarek, 2008). Other studies deal with variations in median grain sizes of bed sediments (Surian, 2002; Brummer, Montgomery, 2003; Attal and Lavé, 2006; Vianello and D'Agostino, 2007; Škarpich et al., 2010), or changes in the lithology of bed sediments due to sediment supply coming out from the tributaries (Attal, Lavé, 2006).

This paper presents a simple methodology to evaluate slope-channel coupling and fluvial processes in a headwater high-gradient stream of flysch mid-mountain relief (Moravian-Silesian Beskids Mts., Western Carpathians). Our approach is based on a detailed monitoring of the sizes of the largest boulders located in the bankfull channel and its comparison with the mapped zones of the potential sediment delivery, and observed erosion or depositional trends in the channel. Measuring diameters of a small number of the largest boulders in short steps (5 boulders at 10-m longitudinal distances in our case) represents a relatively less time-consuming, yet detailed method to obtain grain-size trends in the coarsest fraction of bed sediments along the longitudinal stream profile, when compared to classic pebble counts (in sensu Wolman, 1954). A cluster analysis verified the correlation between the sizes of the coarsest bed sediments, forms of sediment supply and prevailing processes in the channel-reaches under study.

2. The case study watershed

The study focused on the uppermost part of the Lubina River watershed, covering the northern slopes of the Radhošťská hornatina Mts., one of the culmination parts of the Moravian-Silesian Beskids Mts. In cross-sections investigated upstream, the watershed areas ranged between 0.20–1.11 km^2 with regard to the beginning and the end of the studied stream longitudinal profile. Watershed altitudes vary between 990 m a.s.l. on ridges and 490 m a.s.l. at the end of the longitudinal profile. From the geological point of view, the watershed is built by the Cretaceous flysch nappe structure with alternating sandstones and claystones of different permeability, resulting in both shallow and deep landslide activity (Pánek et al., 2009, 2010, 2011). The highest parts of the watershed consist of massive Godula sandstones and, to a small extent, Ostravice sandstones, followed by predominantly claystone members in the lowest parts: Mazák Member, Lhoty Formation, Veřovice Member and the uppermost part of the Těšín-Hradiště Formation (Menčík, Tyráček, 1985). As illustrated in Fig. 1, the main channel of the stream under study begins in members with dominant claystone lithology. Thus in the first step, resistant sandstones of the Godula Member are transported into initial channel-reaches from the uppermost parts of the watershed by hill slope processes.

A detailed analysis was performed on a 1.03-km-long reach of the profile, which belongs to the Trojanovická brázda Furrow in a geomorphological sense. This reach is underlain mainly by claystone bedrock of the Veřovice Member and the Těšín-Hradiště Formation. The end point of the 1.03-km-long reach was established near the outfalls of two left tributaries (Fig. 1). This location was selected because of a possible sediment delivery of Godula sandstones from the tributaries to the main channel, and the presence of artificial bank stabilization structures. The studied longitudinal profile was not affected by recent human impact except at the 0.43 km point, where some remains of a former small dam were found. The upper part of the Lubina River watershed represents a typical transitional area between steep mountain slopes with mean hill slope gradients of up to 40° and a forefield area with significantly lower gradients of about 5°, which results in a variety of slope and fluvial processes. Generally, the sediment delivery from adjacent steep slopes prevails between 0.0 and 0.4 km. The channel-reaches exhibit a tendency towards incision. Moreover, immediately upstream from the 0.0 km point, a sluice acts as a barrier to sediment transport during high-magnitude floods, playing an important role in such an accelerated erosion trend. Downstream from the 0.4 km point, sediment inputs are mostly represented by bank failures developed in alluvial and proluvial sediment cover. Except for the prevailing erosion trends occurring due to elementary functions of mountain headwater channels, significant aggradation is identified in some reaches between 0.4 and 0.8 km, which are also affected by small woody debris jams. On the other hand, deeply-incised channel-reaches in an alluvial fan are located downstream from the 0.8 km point (Fig. 2).

Annual precipitation in the case study watershed is 1,240 mm according to the 1954–2005 data series coming from the Malá Ráztoka experimental watershed located in the Radhošťská hornatina Mts. During extreme flood events, specific discharges may reach up to 2000–3000 $l.s^{-1}.km^{-2}$ (Bíba et al., 2006). The evaluation of bed-load transport in

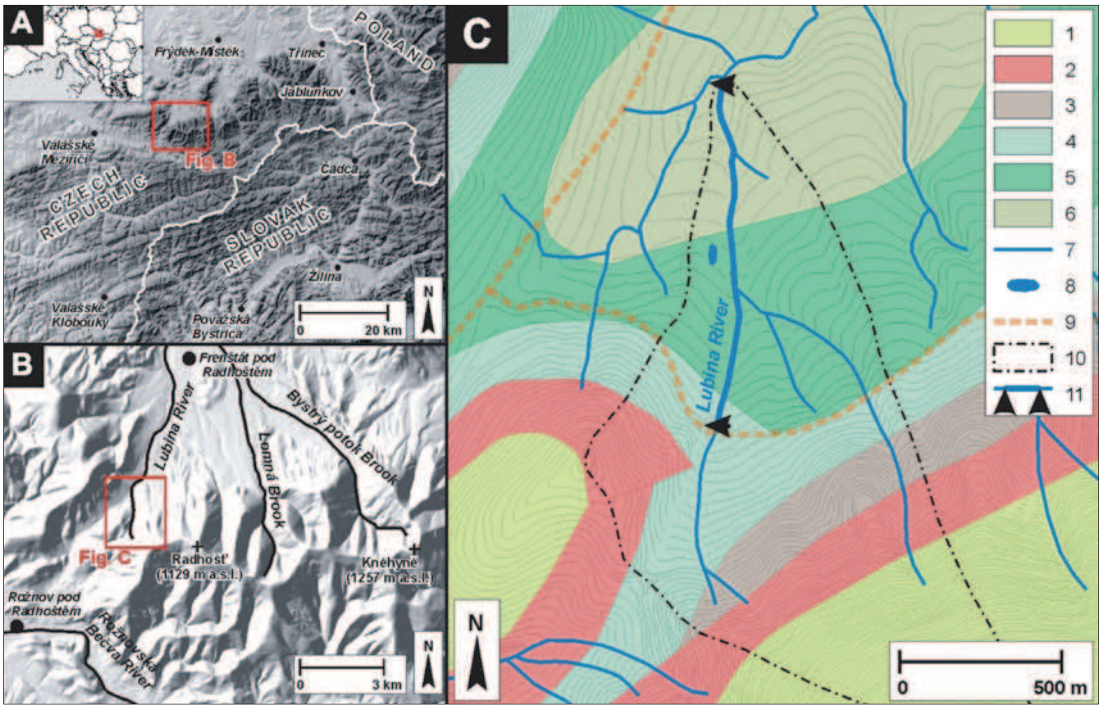

Fig. 1: Study area (Geological conditions: 1 – Godula Formation, 2 – Ostravice sandstones, 3 – Mazák Member, 4 – Lhoty Formation, 5 – Veřovice Member, 6 – Těšín-Hradiště Formation, 7 – stream, 8 – reservoir, 9 – road, 10 – boundaries of the study watershed, 11 – beginning and end of the longitudinal profile)

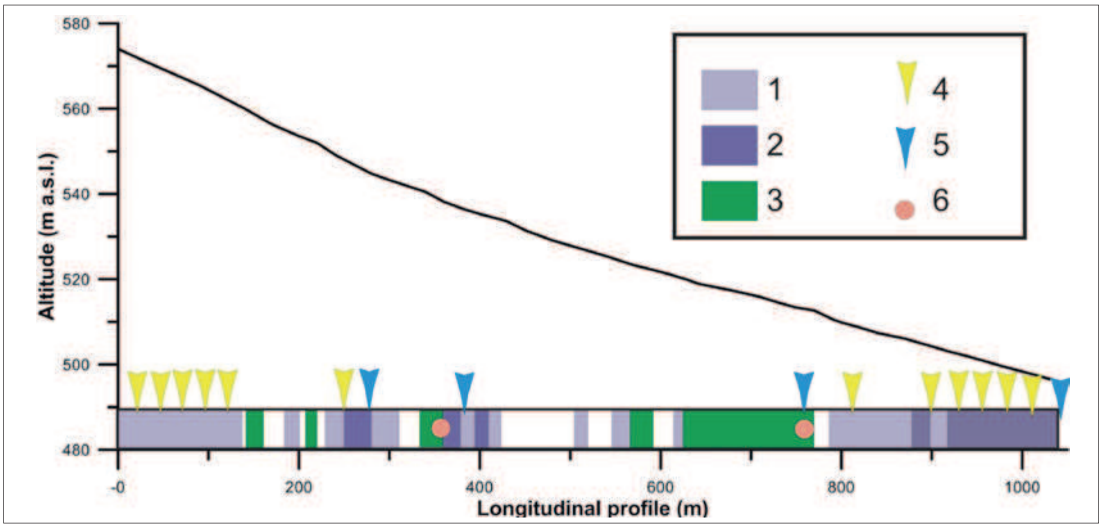

Fig. 2: Scheme of the study longitudinal profile of the Lubina stream; 1 – erosion trends with incision ≤ 0.5 m, 2 – erosion trends with incision > 0.5 m, 3 – aggradation trends, 4 – bank failure, 5 – tributary, 6 – woody debris jam

some upper channel-reaches (c. 0.0–0.5 km of the studied longitudinal profile) clearly demonstrated that a Q_{20} high-magnitude flood event was able to transport almost all bed material in local headwater channels. After the event, large boulders with diameters of up to 0.3–0.4 m were found in post-flood accumulations (Galia, Hradecký, 2011; 2012). Forest cover in the studied area is close to 100%, but the so-called Wallachian colonisation resulted in extensive deforestation of the Moravian-Silesian Beskids Mts. during the 16–17th centuries, and then later reforestation at the turn of the 19th and 20th centuries. The recent forest cover consists of spruce and beech in the upper part of the watershed, while beech is considered to be a dominant species along the studied longitudinal profile.

3. Methods

The fluvial-geomorphic mapping provided detailed information on recent channel-forming processes of selected headwater parts of the Lubina stream. Sediment inputs such as hill slope debris scours, bank failures and small tributaries were recorded in the schematized longitudinal profile of the stream with respect to their potential sediment delivery into channel segments. Channel-reaches with trends of recent incision, balance and aggradation were distinguished as representing general stream behaviour under recent local conditions. Incised reaches were later divided into deeply-incised segments (> 0.5 m) and segments displaying minor erosion trends (≤ 0.5 m). Moreover, positions of large woody debris or small woody debris jams were recorded because of their influence on the grain-size distribution and sediment transport.

All three axes (dimensions) of the five largest boulders were measured at 10 ± 1 m intervals of the longitudinal profile except for the 0.44 km point, where the remains of a former dam occur. The measured boulders were mostly found within the bankfull channel; boulders buried in flood accumulations or situated on adjacent hill slopes above the bankfull depth were omitted from further analysis. A total of 515 boulders were evaluated in 103 channel cross-sections between the 0.0 and 1.03 km points. Average grain diameter and particle-size index based on the nominal diameter $D_n = (a \,.\, b \,.\, c)^{1/3}$ were computed for a single channel cross-section, in fact representing grain-size percentiles d_{95}–d_{99} of bed material. All measured boulders were sandstones of the Godula Member that do not occur in the evaluated longitudinal profile as underlying bedrock. This implies that sandstone boulders were first transported by slope processes into initial channels from the uppermost parts of the watershed. This resulted in a bi-modal character of bed sediments in the studied stream. The ratio of resistant sandstone particles usually varied between 55–70% of total pebble counts. Debris flow activity was not identified in the studied watershed.

Bankfull channel geometry was obtained in c. 50-m intervals. Efforts were made to collect data in positions which were not greatly influenced by unusual elements, such as the presence of large woody debris or large bank failures, in order to achieve a general trend of the progress of bankfull parameters. Laser rangefinder and clinometer were used to measure the mean channel gradient for relatively homogenous channel-reaches, the lengths of which usually varied from 10 to 30 meters.

Statistical testing (the Mann-Whitney U test) was applied to reveal significant differences between the coarse bed sediments of the individual sections of the longitudinal profile. Cluster analysis based on the K-means algorithm was conducted to group some samples of the evaluated channel cross-sections. The calculations comprised the values of the particle-size index in the cross-sections and distances of the cross-sections from the beginning of the studied longitudinal profile.

4. Results

The average grain diameter based on the measurement of the *b*-axis and the particle-size index D_n from the evaluation of all three axes of a particle, exhibit a strong correlation ($R^2 = 0.86$) expressed by the linear trend: $D_n = 0.77b + 1.14$, where b is the mean length (m) of the middle axis of the five largest boulders. Later in the study, D_n is used to represent mean values of this index for the five largest boulders in a single evaluated channel cross-section.

Variations in the particle-size index, channel gradient and hydraulic radius within the longitudinal profile are demonstrated in Fig. 3. Proportionality between the channel gradient S and grain size is not significant, even though a weak relationship ($R^2 = 0.26$) exists in the resulting linear trend: $D_n = 77.6S + 12.1$. No relationship occurs between the particle-size index and bankfull geometry, represented by channel width, depth or hydraulic radius ($0.00 < R^2 < 0.01$). On the other hand, Fig. 3 displays a clear trend of sediment refining within the longitudinal profile. The linear relationship takes the following form: $D_n = -8.73L + 27.18$ ($R^2 = 0.53$), where the channel length L (km) is defined as distance from the source of the stream. Plotting drainage area A (km^2) instead of channel length shows a slightly lower dependence ($R^2 = 0.47$) expressed as $D_n = -6.71A + 22.5$.

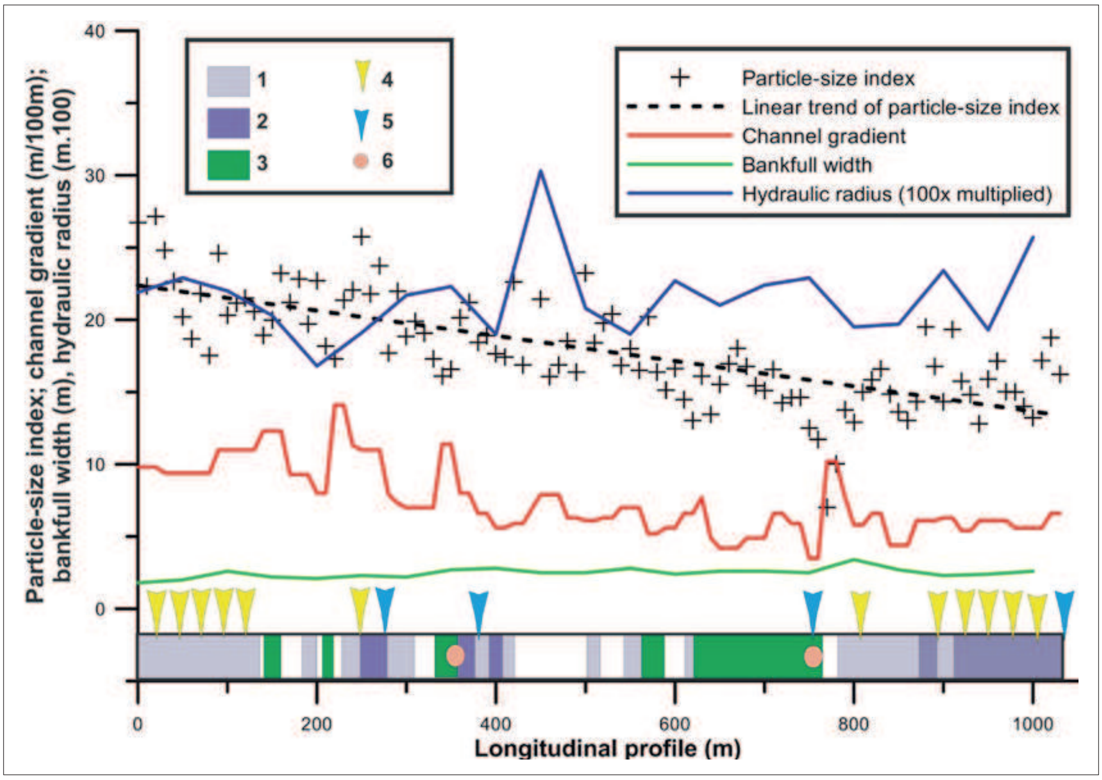

Fig. 3: Variations in the particle-size index, channel gradient and hydraulic radius within the longitudinal profile 1 – erosion trends with incision ≤ 0.5 m, 2 – erosion trends with incision > 0.5 m, 3 – aggradation trends, 4 – bank failure, 5 – tributary, 6 – woody debris jam

The longitudinal profile was later divided into three relatively homogenous sections with respect to sediment delivery and prevailing fluvial processes (Fig. 4). The uppermost section A (0.00–0.37 km) represents a channel – slope coupled system in which coarse material is predominantly delivered from adjacent steep hill slopes. We assume that the intensity of such sediment delivery decreases downstream with the decreasing gradient of adjacent hill slopes. The erosive character of the section is documented by the presence of an incised gully shape of the valley, including a number of bank failures. This phenomenon resulted in significantly higher values of the particle-size index than in the other two sections, as statistically demonstrated by the Mann-Whitney U test statistic ($p < 0.001$). Only a weak relationship exists between the channel length and the particle-size index corresponding to downstream sediment refining ($R^2 = 0.22$): $D_n = -11.41L + 29.37$.

The subsequent section B (0.37–0.79 km) generally lacks the sediment delivery of material from adjacent hill slopes, whereas the channel segment is supplied mostly with coarse material from fan deposits. Upper parts of the section are characterised by a balance between erosion and deposition, with a small number of incised channel-reaches. On the contrary, the reaches between the 0.55–0.75 km often contain large gravel deposits within the channel and these reaches can be understood as recently transport-limited. The downstream refining of coarse bed material is significant for the entire longitudinal profile of section B ($R^2 = 0.53$): $D_n = -18.5L + 37.48$. Grain-size analysis showed no effect of the former small dam (at 0.44 km) on bed sediments. Therefore, remaining parts of the dam can hardly be considered as a recent barrier to coarse sediment flux.

Section C (0.79–1.03 km), as the most downstream part of the longitudinal profile, differs significantly since the channel incises approximately 1–2.5 meters into the valley bottom sediments. Sediment inputs come from bank failures cutting the coarse-grained matrix of fan deposits, inducing a weak tendency towards bed sediment coarsening ($R^2 = 0.06$): $D_n = 6.53L + 5.89$. Values of the particle-size index differ statistically between sections B and C ($p = 0.0097$), depending on the presence of coarser sediments in section C.

Technically speaking, significant refining of bed sediments takes place through the A and B sections up to c. 0.8 km, where this tendency passes to slight coarsening due to the occurrence of the deeply-incised reaches of the C section supplied with coarse-grained material. From the perspective of channel-forming processes and the character of sediment supply, boundaries between the individual sections are not sharp. The discriminating cross-sections

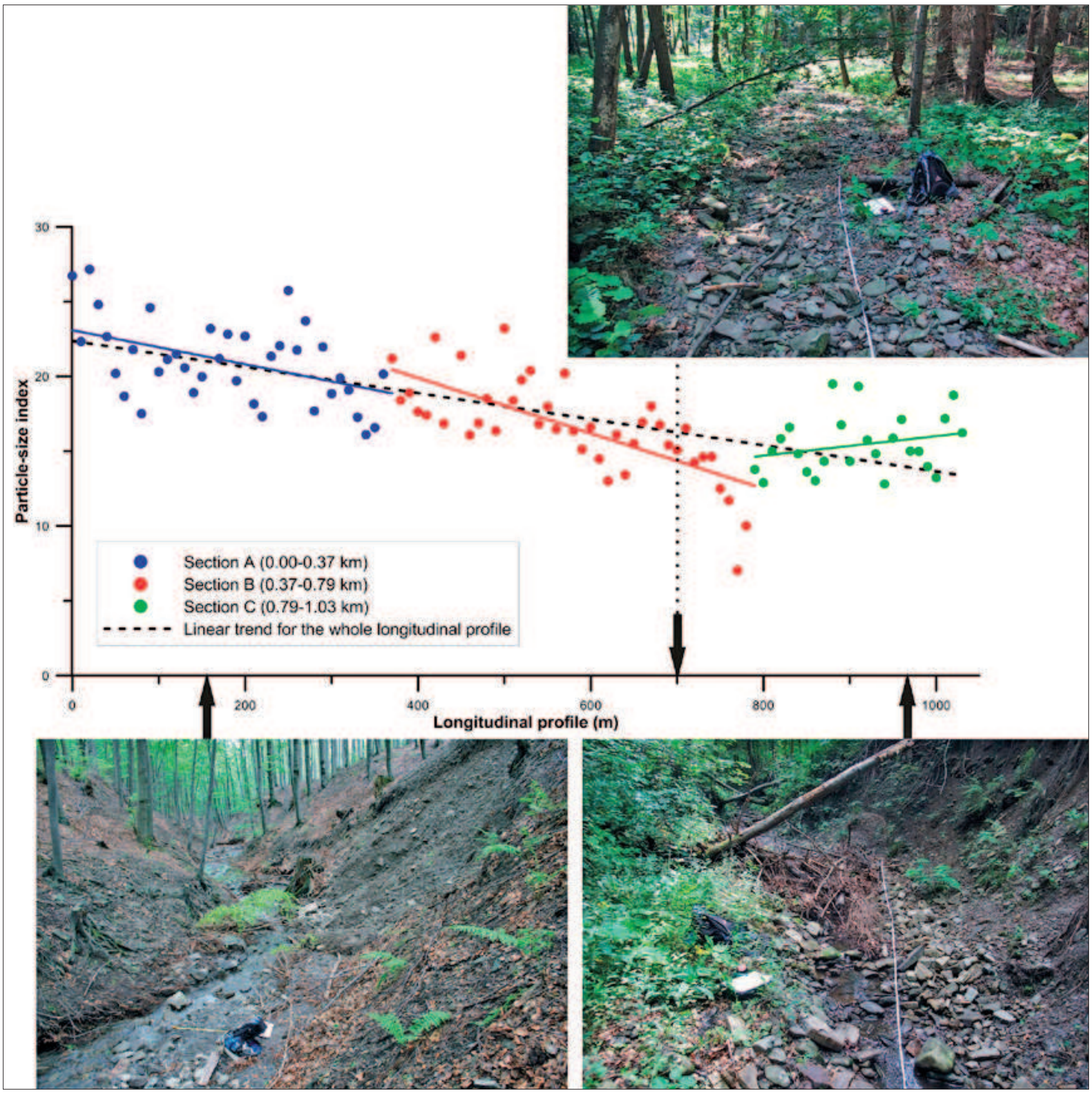

Fig. 4: Resulting trends in the particle-size index within the individual sections of the longitudinal profile; the photographs illustrate channel-reaches typical of the sections

(at 0.37 and 0.79 km) were selected as "middle positions" points in the transitional zones between the prevailing processes. On the contrary, the expected fluvial transport of coarse sediments during high-magnitude floods (e.g. those in 1996, 1997, 2009 and 2010) did not erase differences in grain sizes and trends within the individual sections. This implies that bed-load transport in each section strictly relates to local stream power, and that dis-connectivity in the transport of coarse sediments may exist between the sections. Moreover, active sediment supply takes place in relation to the adjacent landforms, i.e. sediment inputs are triggered from steep hill slopes in section A or from coarse fan deposits in section C during high-magnitude events. In contrast, no influence of the larger right tributary was observed at the 0.35 km point on sizes of the largest boulders, despite the fact that the tributary acts as an important sediment input of Godula sandstone particles for the main channel.

Cluster analysis was used to determine whether a natural grouping existed on the basis of the obtained values of the particle-size index in relation to fluvial processes and sediment supply within the examined longitudinal profile. The best results were achieved by a grouping into six clusters (K1–K6) by the K-Means algorithm (Fig. 5). The K1 and K2 clusters correspond to the A section with high sediment delivery from the adjacent hill slopes. Moreover, the highest values of the particle-size index included in the K1 cluster may have underlined the incision trends due to the upstream presence of a sluice acting as a barrier in the sediment flux, and the related effect of "hungry water" in this channel-reach (c. 0.00–0.05 km). The K3 cluster represents a transition zone between the hill slope delivery of the A section and some transport-balanced or incised cross-sections of the B section. The transport-balanced trend with an inclination towards aggradation is included in the K4 cluster, typical of downstream parts of

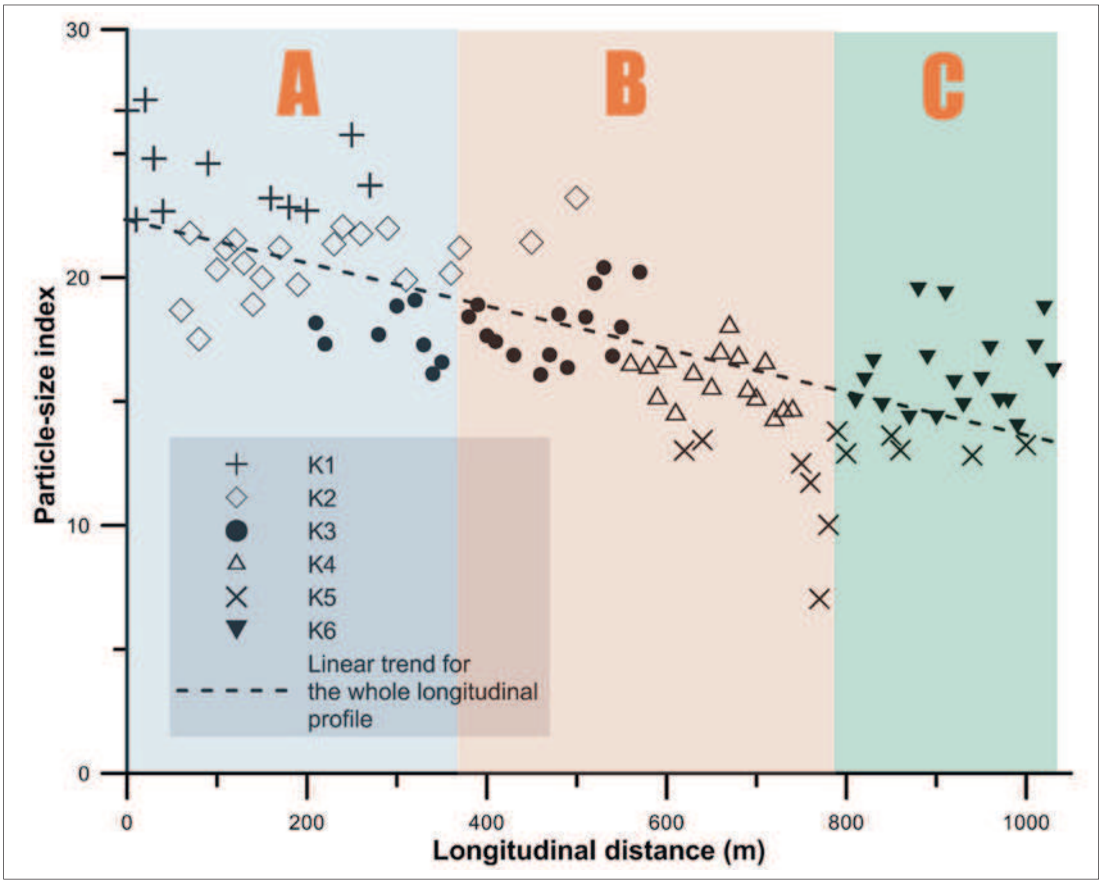

Fig. 5: Grouping of individual channel cross-sections on the basis of a K-means cluster analysis, with the positions of individual sections

the B section. The K5 cluster represents the finest bed sediment connected, in most cases, with the tendency towards aggradation due to the presence of large woody debris or woody jams in the bankfull channel of the transitional zone between the B and C sections. Finally, the K6 cluster strictly delineates the deeply incised channel-reaches of the C section. The coarse character of the bed material derives from the intensive erosion of deposits of the alluvial cone in these channel-reaches.

5. Discussion

The trend of downstream bed material coarsening in small headwater channels (Brummer and Montgomery, 2003; Vianello, D´Agostino, 2007) was not confirmed in the studied part of the longitudinal profile for the coarsest fraction. The reported correspondence between the longitudinal stream distance from the source or the increase in the watershed area and the coarsest bed sediments, represented by the mean value of the particle-size index of the largest boulders, reflected:

a) changes in the lithology of the source bedrock, as the generally coarser resistant sandstones of the Godula Member are gradually substituted by finer particles of claystone members; and
b) the role of slope-channel (de)coupling processes related to the intensity and nature of sediment supply. Thus, we can speculate that bed surface organization in the studied profile is responsive to the nature of bedrock lithology and channel-shaping processes. In spite of its calculated weak correlation, the parameter of channel gradient also plays a certain role. This finding is in accordance with Golden and Springer (2006) and Hradecký and Děd (2008), who claim that the median grain size is not a function of the watershed area in small mountain headwater watersheds, namely due to the lithological nature of supplied sediments, the variety of sediment inputs in the longitudinal profile and the limited possibilities of sediment sorting in highly confined channels with small storage capacities.

Vianello and D'Agostino (2007) observed a significant power trend between the channel gradient and the size of bed sediments (d_{50}, d_{90}) in an Alpine torrent. The same authors also documented a good relation between the bankfull width and the size of bed sediments, while the parameter of channel width was mainly dependent on change in watershed area. In contrast, bankfull geometry was recognized as an important independent variable for the size of the largest boulders within the

Lubina River longitudinal profile. The observed range of bankfull widths (1.9–3.4 m) resulted from a variety of channel-forming processes rather than from the direct impact of an increase in drainage areas, and thus channel-forming discharges above the individual cross-sections (0.20–1.11 km^2).

The recorded sizes of the largest boulders correctly reflected the prevailing erosion or depositional trends in the channel and forms of sediment inputs, despite the fact that we expected bed-load transport of coarse material during the recent flood events. Even the automated cluster analysis performed on the basis of particle-size index and channel length was able to distinguish channel-reaches from the perspective of their recent behaviour and sediment supply conditions. Hooke (2003) reported a potentially limited connectivity for coarse sediments in the fluvial system with respect to stream power during floods. A high-magnitude flood (Q_{20}) was able to move boulders of up to 0.4 m in diameter in some upstream channel-reaches (Galia, Hradecký, 2011, 2012). Connectivity in the bed-load transport of this sediment-size fraction is interrupted in downstream parts due to the decreased channel gradient, the presence of a larger space for the deposition of material between the channel and valley slopes, and a more frequent occurrence of woody debris in the channel. In addition, the incision trends are imprinted in the coarsening of bed material in the C-section. That is in line with the observation of Škarpich et al. (2010), who documented bed material coarsening in the incised reaches of torrents in the Moravian-Silesian Beskids Mts. Moreover, relatively many authors discuss a linkage between the incised channels and the coarsening of bed sediments in gravel-bed rivers (e.g. Wyżga, 1993; Kondolf, 1997; Škarpich et al., 2012). Similarly, Owczarek (2008) identified alluvial bars characterised by angular coarse material, which are strictly related to hill slope sediment delivery zones.

6. Conclusion

The evaluation of the largest boulders in a bankfull channel revealed significant trends in stream behaviour and the nature of sediment supply in the longitudinal profile of a mountain headwater stream. The role of slope processes was accentuated by the presence of uniform sandstone lithology of the studied bed particles. This simple method, based on the measurement of the largest boulders in connected cross-sections (five boulders at 10 m intervals, in our case), can be used as a demonstration of the assessment of channel-forming processes, as well as in the observation of (dis)connectivity in coarse sediment transport.

Nevertheless, this approach needs to be tested and verified in a variety of headwater channels, e.g. in torrents impacted by human actions, in high-gradient streams influenced by debris-flow scouring, or in streams with different geological conditions.

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References:

ATTAL, M, LAVÉ, J. (2006): Changes of bedload characteristics along the Marsyandi River (central Nepal): Implications for understanding hillslope sediment supply, sediment load evolution along fluvial networks, and denudation in active orogenic belts. In: Willett, S. D., Hovius, N., Brandon, M. T. and Fisher, D. M. [eds.]: Tectonics, Climate, and Landscape Evolution: GSA Special Papers. Vol. 398, p. 143–171.

BÍBA, M., OCEÁNSKÁ, Z., VÍCHA, Z., JAŘABAČ, M. (2006): Lesnicko-hydrologický výzkum v beskydských experimentálních povodích. Journal of hydrology and hydromechanics, Vol. 54, No. 2, p. 113–122.

BRUMMER, C. J., MONTGOMERY, D. R. (2003): Downstream coarsening in headwater channels. Water Resources Research, Vol. 39, No. 10, p. 1–14.

CHARTRAND, S. M., WHITING, P. J. (2000): Alluvial architecture in the headwater streams with special emphasis on step-pool topografy. Earth Surface Process and Landforms, Vol. 25, p. 583–600.

CHIVERRELL, R. C., FOSTER, G. C., MARSHALL, P., HARVEY, A. M., THOMAS, G. S. P. (2009): Coupling relationships: Hillslope–fluvial linkages in the Hodder catchment, NW England. Geomorphology, Vol. 109, p. 222–235.

DADE, W. B., RENSHAW, C. E., MAGILLIGAN, F. J. (2011): Sediment transport constraints on river response to regulation. Geomorphology, Vol. 126, p. 245–251.

FRYIRS, K. BRIERLEY, G. J. (1999): Slope channel decoupling in Wolumla catchment, South Coast, New South Wales, Australia: the changing nature of sediment sources since European settlement. Catena, Vol. 35, p. 41–63.

FULLER, I. C., MARDEN, M. (2011): Slope-channel coupling in steepland terrain: A field-based conceptual model from the Tarndale gully and fan, Waipaoa catchment, New Zealand. Geomorphology, Vol. 128, p. 105–115.

GALIA, T., HRADECKÝ, J. (2011): Bedload transport and morphological effects of high-magnitude floods in small headwater streams – Moravskoslezské Beskydy Mts. (Czech Republic). Journal of hydrology and hydromechanics, Vol. 59, No. 4, p. 238–250.

GALIA, T., HRADECKÝ, J. (2012): Critical conditions for beginning of coarse sediment transport in torrents of Moravskoslezské Beskydy Mts. (Western Carpathians). Carpathian journal of Earth and environmental sciences, Vol. 7, No. 4, p. 5–14.

GOLDEN, A. R., SPRINGER, G. S. (2006): Hydraulic geometry, median grain size, and stream power in small mountain streams. Geomorphology, Vol. 78, p. 64–76.

GOMI, T., SIDLE, R. C., WOODSMITH, R. D., BRYANT, M. D. (2003): Characteristics of channel steps and reach morphology in headwater streams, southeast Alaska. Geomorphology, Vol. 51, p. 225–242.

HOOKE, J. M. (2003): Coarse sediment connectivity in river channel systems: a conceptual framework and methodology. Geomorphology, Vol. 56, p. 79–94.

HRADECKÝ, J., DĚD, M. (2008): Současné trendy v zrnitostním složení sedimentů štěrkových lavic toků Moravskoslezských Beskyd – příkladová studie Sihelský potok. Geologické výzkumy na Moravě a ve Slezsku v roce 2007, p. 19–23.

KACZKA, R. J. (2003): Coarse woody debris dams in mountains streams in Central Europe, structure and distribution. Studia Geomorphologica Carpatho – Balcanica, Vol. 37, p. 111–127.

KONDOLF, G. M. (1997): Hungry water: effects of dams and gravel mining on river channels. Environmental Management, Vol. 21, p. 533–551.

MENČÍK, E., TYRÁČEK, J. (1985): Beskydy a Podbeskydská pahorkatina (Přehledná geologická mapa 1:100 000). Ústřední ústav geologický, Praha.

MONTGOMERY, D. R., COLLINS, B. D., BUFFINGTON, J. M., ABBE, T. B. (2003): Geomorphic effects of wood in rivers. In: Gregory, S., Boyer, K., Gurnell, A. M. [eds.]: The Ecology and Management of Wood in World Rivers, p. 21–47. American Fisheries Society Symposium 37.

OWCZAREK, P. (2008): Hillslope deposits in gravel-bed revers and their effects on the evolution of alluvial channel forms: A case study from the Sudetes and Carpathian Mountains. Geomorphology, Vol. 98, p. 111–125.

PÁNEK T., HRADECKÝ J., ŠILHÁN, K. (2009): Geomorphic evidence of ancient catastrophic flow type landslides in the mid-mountain ridges of the Western Flysch Carpathian Mountains (Czech Republic). International Journal of Sediment Research, Vol. 24, p. 88–98.

PÁNEK, T., HRADECKÝ, J., MINÁR, J., ŠILHÁN, K. (2010): Recurrent landslides predisposed by fault-induced weathering of flysch in the Western Carpathians. In: Calcaterra, D., Parise, M. [eds.]: Weathering as a Predisposing Factor to Slope Movements. 248 pp.

PÁNEK, T., TÁBOŘÍK, P., KLIMEŠ, J., KOMÁRKOVÁ, V., HRADECKÝ, J., ŠŤASTNÝ, M. (2011): Deep-seated gravitational slope deformations in the highest parts of the Czech Flysch Carpathians: Evolutionary model based on kinematic analysis, electrical imaging and trenching. Geomorphology, Vol. 129, p. 92–112.

REID, D. E., HICKIN, E. J. (2008): Flow resistance in steep mountain streams. Earth Surf. Process. Landforms, Vol. 33, p. 2211–2240.

SMITH, H. G., DRAGOVICH, D. (2008): Sediment budget analysis of slope–channel coupling and in-channel sediment storage in an upland catchment, southeastern Australia. Geomorphology, Vol. 101, p. 643–654.

SURIAN, N. (2002): Downstream variation in grain size along an Alpine river: analysis of controls and processes. Geomorphology, Vol. 43, p. 137–149.

ŠKARPICH, V., GALIA, T., HRADECKÝ, J., PEČ, J. (2010): Identifikace (dis)konektivit vodních toků za využití makrogranulometrické analýzy korytových sedimentů (Moravskoslezské Beskydy). Geologické výzkumy na Moravě a ve Slezsku v roce 2010, p. 199–204.

ŠKARPICH, V., GALIA, T., HRADECKÝ, J. (2012): Podmínky akumulace a transportu sedimentů v člověkem ovlivněných korytech Beskydských toků: příkladová studie soutoku řeky Morávky a Mohelnice. Geologické výzkumy na Moravě a ve Slezsku v roce 2012, p. 53–58.

VIANELLO, A., D´AGOSTINO, V. (2007): Bankfull width and morphological units in an Alpine stream of the Dolomites (Northern Italy). Geomorphology, Vol. 83, p. 266–281.

WALLING, D. E. (1983): The sediment delivery problem. Journal of Hydrology, Vol. 65, p. 209–237.

WOHL E. E., WILCOX, A. (2005): Channel geometry of mountain rivers in New Zealand. Journal of Hydrology, Vol. 300, p. 252–266.

WOLMAN, M. G. (1954): A method of sampling coarse river-bed material. Transactions American Geophysical Union, Vol. 35, No. 6, p. 951–956.

WYŻGA, B. (1993): River response to channel regulation: Case study of the Baba River, Carpathians, Poland. Earth surface processes and landforms, Vol. 18, p. 541–556.

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THE FOOTFALL OF SHOPPING CENTRES IN OLOMOUC (CZECH REPUBLIC): AN APPLICATION OF THE GRAVITY MODEL

Pavel KLAPKA, Martin ERLEBACH, Ondřej KRÁL, Michal LEHNERT, Tomáš MIČKA

Abstract

The issue of the footfall of large retail facilities in the city of Olomouc is treated in this article from the perspective of spatial interaction modelling. A production-constrained gravity model is applied to reveal spatial patterns of shopping travel intensities in the city. Three problems are addressed: the existing pattern and intensities of flows to the shopping centres; the prediction of possible future changes in these patterns and intensities; and inferences about hypothetical sizes of shopping centres according to some defined conditions.

Shrnutí

Návštěvnost obchodních center v Olomouci (Česká republika): aplikace gravitačního modelu

Článek se zabývá problematikou návštěvnosti velkých maloobchodních zařízení ve městě Olomouci z pohledu modelování prostorových interakcí. K odhalení prostorových vzorů a intenzit cest za nákupy ve struktuře města slouží produkčně omezený gravitační model. Zabýváme se třemi problémy: stávajícím vzorem a intensitami toků do nákupních center, predikcí možných budoucích změn těchto toků a jejich intensit a odvozením hypotetické velikosti nákupních center podle definovaných podmínek.

Key words: *footfall, spatial interaction, gravity model, shopping centre, Olomouc, Czech Republic*

1. Introduction

The first modern shopping centres started to appear in Czech cities during the second half of the 1990s. They were usually built on the city outskirts in “green” fields; with the advent of the millennium, industrial brownfields within larger city centres started to be adopted for retail facilities. Thus, the spatial location of shopping centres affects in a relatively significant way the organisation of urban space and the behaviours of city inhabitants and visitors (Berry, 1967; Birkin, Clarke, Clarke, 2002, for more on the issue in the Czech Republic, see Szczyrba, 2010). However, the intra-urban retail-based flows of persons are not easy to capture since there are no statistical data on such movements and/or the footfall[1] of shopping centres is either a subject of trade secrets or it can be uncovered by a demanding questionnaire survey, sometimes disapproved of by the management of the shopping centres (for example in Moravia, see Kunc et al., 2011).

A useful possibility to tackle the problems of acquiring the necessary data is to resort to spatial interaction modelling, that is able not only to represent with a greater or lesser accuracy the actual flows, but also able to anticipate the future development of intra-urban retail movements. The article sets the following general objective. We attempt to model the present and future intra-urban flows induced and attracted by shopping centres in the city of Olomouc, and use them to describe and analyze the modelled footfall of these shopping centres. We will make use of the gravity model to fulfil this objective. We also hope that this article will contribute to a renaissance of the application of quantitative methods, particularly spatial interaction modelling of the current state of retail facilities and prognosis of their development (see Johnston, 2008).

Before we formulate the research questions, the basic geographical background of the issue under consideration should be provided (Fig. 1 – see cover

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[1] The Oxford Dictionaries defines ‘footfall’ as “the number of people entering a shop or shopping area in a given time” (http://oxforddictionaries.com/definition/english/footfall)

p. 2). The city of Olomouc is a mezzo-regional centre in central Moravia and has 100,000 inhabitants. Currently there are four general shopping centres in Olomouc. A shopping centre for our purpose is understood as a group of retail shops including a hypermarket or a supermarket, restaurants and other businesses (we are not taking into account specialised hobby or furniture centres). The oldest one, Prior, is located in the medieval core of the city and was completed in 1982; presently it is under reconstruction. The remaining three shopping centres were constructed during the first half of the 2000s (Obchodní centrum Haná opened in 2002, Olympia in 2004 and Olomouc City in 2005), all in peripheral locations (Olympia closely outside the city cadastre). In February 2012, construction of a fifth shopping centre - Galerie Šantovka – was launched in close vicinity to the historical core of Olomouc. It is to be opened in the autumn of 2013.

Respecting the assumption that we examine intra-urban interactions, not taking into account the hinterland of the city of Olomouc, this starting situation raises the following research questions (the last one being rather theoretical) to which we attempt to seek answers in this contribution:

1. What is the current modelled footfall of the existing shopping centres?, and what spatial patterns do the intra-urban retail-based flows follow?;
2. How will the completion of the Galerie Šantovka shopping centre affect the footfall of the already existing shopping centres?, and how will the spatial patterns of intra-urban retail-based flows change?; and
3. What would have to be the hypothetical size of the existing shopping centres so that their modelled footfall would equal that of the Galerie Šantovka shopping centre?

2. Spatial interaction modelling

The theoretical background and historical development of spatial interaction modelling is comprehensively discussed in the research literature, for example by Sheppard (1978), Senior (1979), Haynes, Fotheringham (1984), Fotheringham, O'Kelly (1989), Pooler (1994), Fotheringham, Brunsdon, Charlton (2000), and Wilson (2010), but we provide a basic insight into spatial interaction modelling approaches. In our argumentation, we aim only at cornerstone references specific for the issue (modelling of retail) and the territory (Czech Republic) dealt with in the paper. The modelling of different flows and movements in human geography and regional science was inspired by physical relations (Newton's law of universal gravitation), and appeared already by the end of the 19th century (Ravenstein, 1885). Models of spatial interactions were further developed by Reilly (1931), who defined the law of retail gravitation. The 1940s saw the development of the approach called social physics (e.g. Zipf, 1947; Stewart, 1948) with an equivalence of demographic force to gravitation force. This conception of spatial interaction modelling led to the formulation of gravity models in their simple "Newtonian" variant (e.g. Isard, 1960; Haggett, 1965; Chojnicki [ed.], 1977). In the Czech lands and Slovakia, such a simple approach was applied by several researchers, e.g. Řehák (2004), Halás (2005), Hubáčková and Krejčí (2007), Řehák, Halás, Klapka (2009) or Halás and Klapka (2010).

While the preceding discussion dwelled on Newtonian physics, most of the following enhancements pursue findings from probability theory or information theory, and employ optimisation procedures with reference to objective functions. An early advance in the theoretical base of spatial interaction modelling was reached in studies published by Wilson (1967, 1974), who was inspired by the second law of thermodynamics and defined a "family" of spatial interaction models that were based on entropy maximisation. Such models seek a most probable situation (i.e. the interaction pattern of origin-destination flows) in a system consisting of equal categories by identifying a macrostate consisting of the largest number of microstates (see Fotheringham, Brunsdon, Charlton, 2000:218). The introduction of a system of constraints into the above-mentioned situation produces four types of spatial interaction models (Wilson, 1974). Slightly different ways of deriving the family of spatial interaction models were proposed by Alonso (1978) on the basis of the theory of movement, and by Tobler (1983).

Apart from entropy maximisation, a more general approach based on information minimisation was put forward by Snickars, Weibull (1977) and later applied for example by Plane (1982). It seeks a most probable situation in the system consisting of unequal categories by identifying a minimum information gain (Fotheringham, O'Kelly, 1989:19) as conceived by information theory.

So far the bases for the models have come from physics. In order to address criticisms levelled at such models, particularly that they are still not taking into account the nature of human behaviour, a framework using more behavioural spatial approaches was put forward by Fotheringham, 1986 (see also Fotheringham, O'Kelly, (1989); Fotheringham, Brunsdon, Charlton, (2000)). These models are based on the issue of discrete spatial choice by individuals with respect to the potential alternatives, and on the hierarchical processing of information. Some of the advanced bases of spatial interaction models, namely those employing entropy maximisation, were theoretically discussed in Czech and Slovak geography by Paulov (1991) and Hlavička (1993), and applied by Bezák (2000).

Recent developments have brought several new impulses to the theory and context of spatial interaction modelling, with inspirations from economic, ecological, mathematical or behavioural concepts (see more in Wilson, 2010). Openshaw (1998) and particularly Fischer (1998, 2009), or Fischer, Reismann (2002), introduce discussion of the neural network modelling of unconstrained and singly constrained spatial interactions, which dwells on the previous bases of the families of spatial interaction models. Chen (2009) uses a new cross-correlation function in the traditional model that incorporates a time dimension into the modelling. The changing role of distance in the age of the Internet is handled for instance by Blum, Goldfarb (2006).

A number of relatively recent works is concerned with the joint problem of intervening opportunity, spatial discrete choice and probability of choice. For instance, Akwawua and Pooler (2001) introduced spatial dominance effects that combine the size and distance of destinations into the intervening opportunity scheme. Drezner, Drezner (2007) discuss a p-median problem dealing with the customers´ choice of destinations.

The application of spatial interaction models in retailing studies goes back to works published by Reilly (1931), who defined the relation between two competing centres and an intervening location based on retail commuting. His work was extended by Converse (1949) and Huff (1964). Converse (1949) defined mathematically the breaking point between the influences of competing centres, and Huff (1964) expressed a theoretical probability of customer choice from shopping centres. He proposed a model that is able to estimate footfall in a particular shopping centre taking into account the selling areas of shopping centres and the time distance between customers and shopping centres. Fotheringham (1985, 2012 – first published in 1989) considers the estimation of shopping trips and their spatial distribution as a classic spatial interaction modelling task.

Spatial interaction models have been recently applied in various forms to a wider area of retail research, for instance by Lee, Pace (2005) who modelled the spatial distribution of retail turnover between shopping centres. Schenk et al. (2007) dealt with the modelling of consumer behaviour in terms of grocery shopping on a regional level in the functional region of Umeå, Sweden. Suárez-Vega et al. (2007) defined the attraction function between a shopping facility and customers. Li, Liu (2012) assessed the performance of shopping malls based on their location by employing a modified version of Huff´s model. Scott, He (2012) introduced a time-geographical approach to the shopping destination choice model. Rasouli, Timmermans (2013) enriched the problem with the issue of uncertainty in shopping behaviour, which affects the application and form of spatial interaction models.

Spatial interaction models generally show that the volume of spatial interaction increases with scale (i.e. either quantitative or qualitative "importance" "size", or "mass") of locations, and decreases with the distance separating them. To put it another way, the interaction (T_{ij}) between two location i and j is a function of the measure v of propulsiveness of i, the measure w of attractiveness of j, and the measure d of distance between i and j:

$$T_{ij} = f\,(\mu v_i;\ \alpha w_j;\ \beta d_{ij}) \quad [1]$$

where μ, α, β are parameters reflecting the relation of variables v, w and d to the interaction patterns. The greatest importance is granted to the variable and parameter responsible for the formulation of the friction of distance and its expression in the models. The spatial separation between two spatial locations is expressed in the form of distance decay curves that have various forms and usually a non-linear shape (e.g. Taylor, 1971, 1983; Johnston, 1973; Wilson, 1974, or Sheppard, 1978). Negative Pareto and negative exponential functions with various values of parameters have been applied most frequently to express the spatial separation between two locations. The role of distance and the distance decay function is discussed for instance by Taylor (1971), Cliff et al. (1974), Wilson (1974), Fotheringham (1981), and De Vries et al. (2009).

3. Method

3.1 The form of the model

The family of spatial interaction models (or in our case gravity models) consists basically of four variants: unconstrained case, production-constrained case, attraction-constrained case and production-attraction (or doubly) constrained case (Wilson, 1974; Fotheringham, O'Kelly, 1989). For our purpose, when we investigate the footfall of shopping centres, the production-constrained variant of the model provides the greatest advantage (see, for example, the numerous applications listed in Fotheringham, 1986; Fotheringham, O'Kelly, 1989, or Wilson, 2010). To put it short at first, the model seeks a spatial pattern for the allocation of retail flows (shopping trips) from residential zones to shopping centres, assuming that we have a prior knowledge of a number of these outgoing flows. This knowledge acts as a production constraint and can be expressed as follows:

$$O_i = \sum_j T_{ij} \quad [2]$$

where O_i stands for the total of outgoing flows from i.

Taking into account this constraint [2], the model can be formally expressed as:

$$T_{ij} = A_i O_i w_j d_{ij}^{-\beta} \quad [3]$$

where:

T_{ij} expresses the volume of interaction between i and j; A_i plays the role of a balance parameter; O_i expresses the number of outflows from origins; w_j plays the role of a proxy variable expressing the attractiveness of destinations; d_{ij} marks a distance between i and j; and β is a parameter of the model controlling the shape of the distance decay function.

The balance parameter A_i ensures that on the demand (i.e. production) side of the model, the number of total outflows from origins is exactly reproduced by the model and allocated to destinations; in our case, that the number of outgoing shopping trips from the residential zones is totally distributed among the shopping centres on the supply (i.e. attraction) side of the model. The balance parameter is expressed as follows, using the above symbols:

$$A_i = (\textstyle\sum_j w_j d_{ij}^{-\beta})^{-1} \quad [4]$$

If a mathematical expression should be used, the balance parameter A_i ensures that the constraint given by equation [2], for this purpose written preferably in reverse order as

$$\sum_j T_{ij}^{*} = O_i$$

is fulfilled in the matrix of estimated flows, the asterisk denoting then, that in this case, T_{ij} stands for the estimated flow between i and j.

3.2 Variables entering the model

In this section, we will specify the character of the data entering the model. The origins i are related to the basic settlement units – BSUs (see Figs. 1 (cover p. 2) or 2) – which are the smallest spatial zones for the used data gathered from the 2001 census. These are the numbers of independent households (see Tab. 2), since we assume that shopping trips are usually made for the whole household. Another approximation should be made with respect to the location of basic settlement

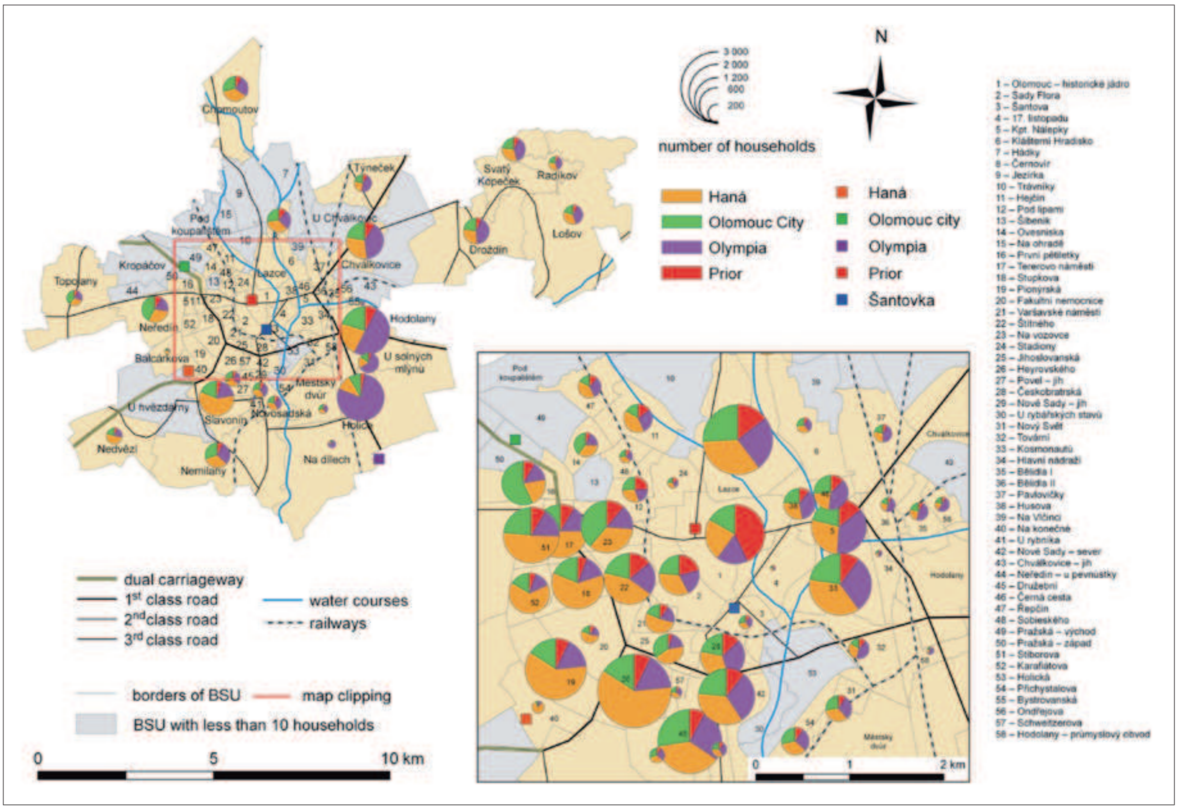

Fig. 2: Modelled footfall of the four currently existing shopping centres
Sources: 2001 Population census, Authors´ elaboration

units. They are of areal character and if we calculate distances (d_{ij}) between origins and destinations, we have to deploy a point pattern for both variables, in our case based on the public transport stops (see below for the nature of the distance measure used). While this nature is inherent to shopping centres, we have used the geographic centres of built-up areas within each areal unit and the nearest public transport stop to the centres, in order to acquire a point pattern of origins (see e.g. Fig. 2). Out of 82 basic settlement units in the city of Olomouc, sixteen (see e.g. Fig. 2 – grey colour) have less than 10 (in seven cases zero) independent households and these have been excluded from the analysis. Thus, 66 basic settlement units were finally entered into the interaction and spatial separation matrices.

Four (and later five) shopping centres are destinations j, thus constituting the columns of the interaction and spatial separation matrices. Since we have no prior knowledge of ingoing flows to the shopping centres, we have to express their attractiveness by a proxy variable w.

Our case should rather be called a pseudo-production-constrained variant, regarding the character of the data, where we know the number of flows originating in the spatial zones (in this case the BSUs), while the attractiveness of the shopping centres has to be expressed by a proxy variable. In this respect, we have made use of the selling areas of the shopping centres (Tab. 1).

Shopping centre	Selling area (m^2)
Obchodní centrum Haná	37,500
Olympia	30,000
Olomouc City	24,500
Prior	5,000
Galerie Šantovka	46,500*

Tab. 1: Selling areas of shopping centres
*Note: *planned selling area*
Source: Internet pages of retail chains, Szczyrba, 2010

The last variable entering the model is the distance between origins and destinations. We have tested three types of distance (Euclidian distance, time distance by automobile, and time distance by public transport), and the results provided by the time distance by public transport are presented in this article. Although the presentation of all results is not possible due to size constraints, our choice needs to be justified. The Euclidian distance has served the principal methodological purpose as a common basis for comparisons of the results provided by both types of time distances. Finally, we have resorted to the time distance by public transport as we have preferred the transport mode that is accessible virtually to anyone and that provides a more stable expression of distance based on timetables. The last issue to be discussed is the distance decay function. We have used the negative power function and tested four values of the β parameter expressing the resistance of distance to the interactions. Haynes, Fotheringham (1984) claim that the β parameter is often empirically found between (− 0.5 and − 2.0), and Fotheringham, Brunsdon, Charlton (2000:232) suggest a power function with the value of the β parameter = (− 1) for the assessment of competing alternatives in a spatial choice problem such as this. In accord with these findings, we have set the β parameter to (− 1).

4. Results of the modelling

In the following discussion, we aim particularly at textual presentation of the general results regarding the modelled flow and predicted footfall of the shopping centres. The fine network of modelled intra-urban flows between the shopping centres and basic settlement units is not commented upon since it can be sufficiently understood from Figs. 2, 3, 4, and Tab. 4 providing necessary data and their spatial representation.

4.1 Starting situation

Detailed results provided by the production-constrained gravity model for the existing four shopping centres (Prior, Olympia, Haná and City) are presented in Fig. 2 and Tabs. 2 and 4 recording the modelled situation. Fig. 2 and Tab. 4 show the current

Shopping centre	No. of households per m^2	Percentage out of total selling area	Percentage of attracted households out of total
Obchodní centrum Haná	0.45	38.7	39.2
Olympia	0.39	31.0	26.5
Olomouc City	0.42	25.2	23.2
Prior	0.97	5.1	11.1

Tab. 2: General modelled situation (4 shopping centres)
Sources: Internet pages of retail chains, Szczyrba 2010, Authors´ calculations

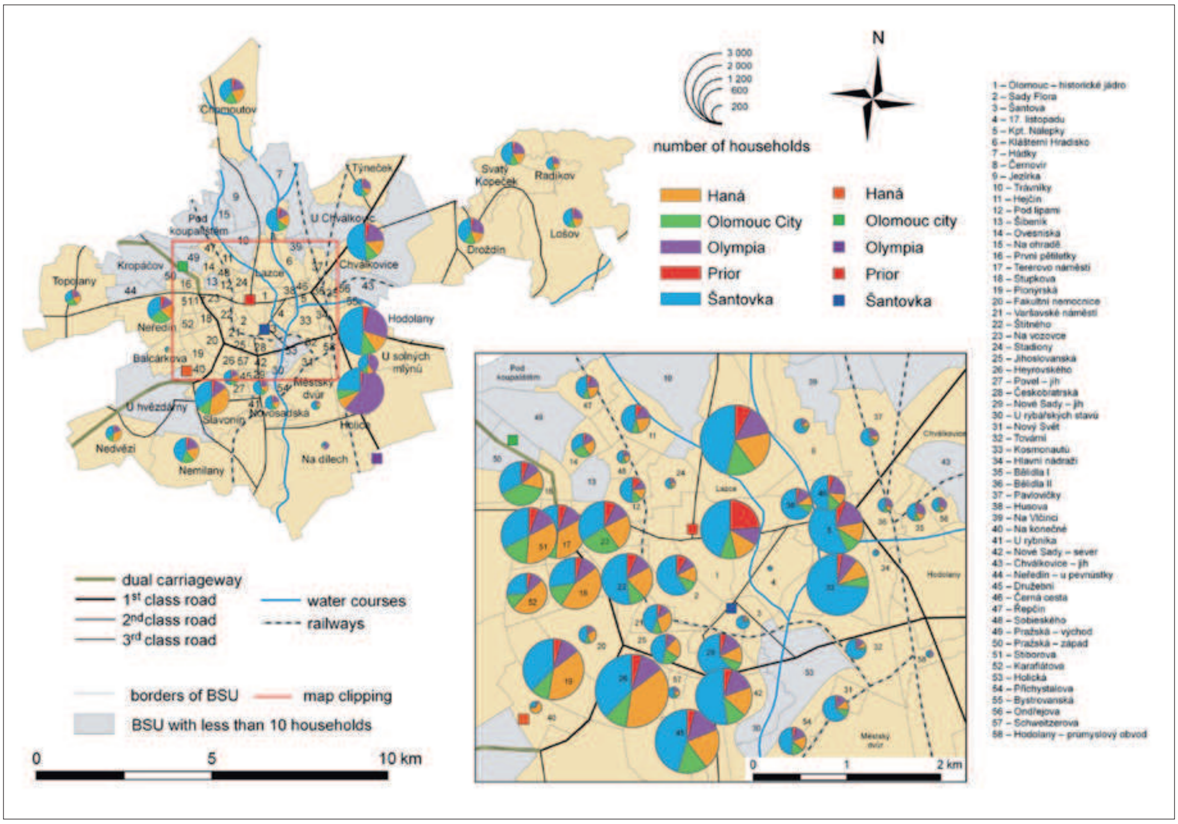

Fig. 3: Modelled footfall of the five future shopping centres
Sources: 2001 population census, Authors' elaboration

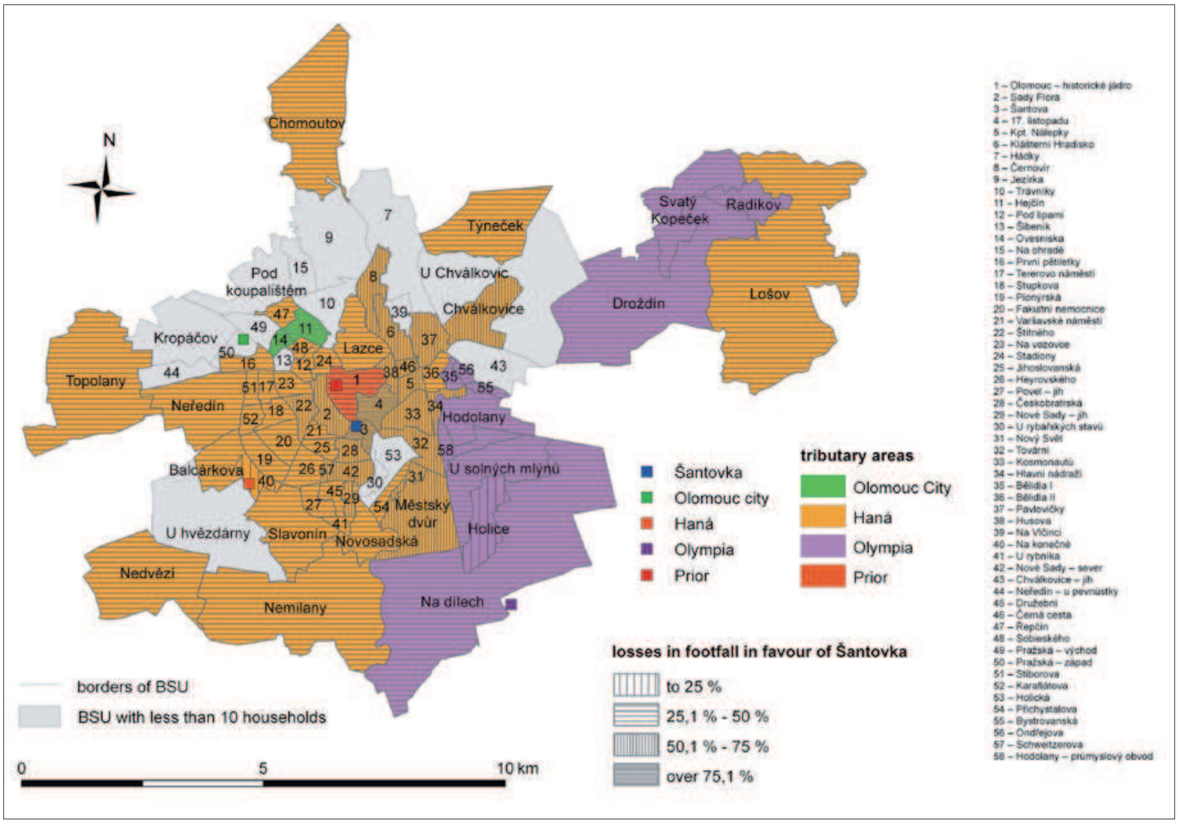

Fig. 4: Construction of the Galerie Šantovka and its influence on the footfall spatial pattern
Sources: 2001 Population census, Authors´elaboration

modelled relations of households within each BSU to the existing shopping centres, or, in other words, the modelled distribution of households among the shopping centres, which can be understood herein as the expression of modelled spatial shopping preferences of the Olomouc city population.

In general, the model shows that out of 43,603 households in Olomouc, the highest percentage is attracted by the Obchodní centrum Haná (39.2% of households) followed by Olympia (26.5%), Olomouc City (23.2%) and Prior (11.1%) – see Tab. 2. This general pattern correlates with the total selling area share of the shopping centres (Tab. 2), though this relation is not linear, since the location of the shopping centres and the time distance between BSUs and the shopping centres play an important role in this respect.

However, if we take into account the number of attracted households per one square metre (Tab. 2), the most successful facility is Prior (0.97 households/m^2), given its position in the centre. The lowest number is recorded for Olympia (0.39 households/m^2), which is located outside the city cadastre. Nevertheless, the remaining two shopping centres (Haná and City) do not significantly differ from the Olympia in the number of households per square metre and thus we identify two types of shopping centres: newly-constructed suburban facilities and traditional centrally-located facilities.

4.2 Situation after the completion of the Galerie Šantovka

Detailed results of the modelled prediction concerning the situation after the opening of the Galerie Šantovka are presented in Figs. 3, 4 and Tabs. 3 and 4. Fig. 3 and Tab. 4 show a prediction of the spatial distribution of households among the future five shopping centres, and thus can be understood as a modelled prediction of the future spatial shopping preferences of residents in the city of Olomouc.

These preferences are assumed to turn dramatically in favour of the newly-constructed Galerie Šantovka, since it will attract 44.9% out of 43,603 households in Olomouc. The present leader, Obchodní centrum Haná, will attract 22.1% of households, and will be followed by Olympia (14.3%), Olomouc City (12.8%) and Prior (5.9%) – see Tab. 3. The correlation between the share of the shopping centres in the total selling area and the percentage of attracted households is slightly lower than in the case of the original four shopping centres, but still significant. This lower value is caused by the specific conditions of the Galerie Šantovka – it will be the largest shopping centre in Olomouc and it will be located in the centre, which will change the existing spatial patterns.

The number of attracted households per one square meter (Tab. 3) illustrates the position of Prior (0.51 households/m^2) in spite of the fact that this facility experiences the highest decrease in this parameter. The three suburban shopping centres (Olympia, Olomouc City and Obchodní centrum Haná) have comparable numbers, thus showing their affinity to the newly-constructed facility type. The Galerie Šantovka (0.42 households/m^2) represents the third facility type: a relatively centrally-located revitalised brownfield. The lower number of attracted households per one square meter as compared with Prior indicates a more spacious conception of the 21st century shopping centre as opposed to the 1970s concept of the socialist shopping facility.

Following the completion of the Galerie Šantovka, all existing shopping centres are expected to lose more than one half of the attracted households according to the production-constrained gravity model (Obchodní centrum Haná 56.6%, Olomouc City 55.1%, Olympia 53.9% and Prior 53.1%). The spatial distribution of this phenomenon is presented in Fig. 4, together with the original tributary areas of the four existing centres delineated according to the first (highest) outflow from each BSU. These tributary areas show the present importance of the Obchodní Centrum Haná shopping centre and its favourable location within the public transport network. It is the only shopping centre with a tram connection, considerably increasing its accessibility (it is useful to remember that time

Shopping centre	No. of households per m^2	Percentage out of total selling area	Percentage of attracted households out of total
Galerie Šantovka*	0.42	32.4	44.9
Obchodní centrum Haná	0.26	26.1	22.1
Olympia	0.21	20.9	14.3
Olomouc City	0.23	17.1	12.8
Prior	0.51	3.5	5.9

Tab. 3: General modelled situation (5 shopping centres)
*Note: *data for the planned selling area*
Sources: Internet pages of retail chains, Szczyrba 2010, Authors´ calculations

Name of BSU	Households	Prior		Olympia		Haná		City		Galerie Šantovka	No. in maps
		A	B	A	B	A	B	A	B	B	
17, listopadu	14	3.1	0.6	3.5	0.7	4.0	0.8	3.4	0.7	11.3	4
Balcárkova	18	1.3	0.8	3.2	1.9	10.4	6.3	3.1	1.9	7.1	–
Bělidla I	183	13.4	7.2	86.0	46.5	44.3	23.9	39.3	21.3	84.1	35
Bělidla II	118	8.6	4.7	55.5	30.0	28.5	15.4	25.4	13.7	54.2	36
Bystrovanská	14	1.1	0.6	7.3	4.1	2.8	1.5	2.8	1.6	6.3	55
Černá cesta	672	83.2	41.1	266.1	131.5	151.2	74.7	171.6	84.8	339.8	46
Černovír	312	33.3	16.0	82.6	39.7	111.0	53.3	85.1	40.9	162.2	8
Českobratrská	1,121	145.0	55.7	366.3	140.7	362.5	139.2	247.1	94.9	690.5	28
Droždín	381	24.5	14.2	161.3	93.5	105.9	61.4	89.3	51.7	160.2	–
Družební	2,337	178.3	97.5	623.9	341.4	891.3	487.7	643.6	352.2	1,058.3	45
Fakultní nemocnice	175	15.5	8.5	32.4	17.8	93.2	51.1	33.8	18.5	79.1	20
Hejčín	457	67.5	36.6	129.7	70.2	184.2	99.8	75.6	41.0	209.4	11
Heyrovského	3,062	220.4	137.5	495.9	309.5	1,859.7	1,160.5	486.0	303.3	1,151.2	26
Hlavní nádraží	23	2.6	0.8	9.3	2.6	6.0	1.7	5.0	1.4	16.4	34
Hodolany	1,353	103.1	53.0	674.9	347.0	299.4	153.9	275.6	141.7	657.4	–
Hodolany průmyslový obvod	29	1.7	0.9	16.7	9.3	6.1	3.4	4.5	2.5	12.9	58
Holice	1,252	31.2	23.6	984.1	742.8	129.5	97.7	107.2	80.9	307.0	–
Husova	559	57.3	19.7	202.4	69.6	165.4	56.9	133.8	46.0	366.8	38
Chomoutov	356	27.6	16.6	95.8	57.7	130.0	78.3	102.5	61.8	141.6	–
Chválkovice	777	66.5	32.6	308.3	151.1	229.1	112.3	173.1	84.8	396.3	–
Jihoslovanská	501	23.8	12.6	88.5	47.0	214.0	113.7	174.7	92.8	234.9	25
Karafiátova	929	47.2	34.8	121.3	89.6	606.5	447.9	154.1	113.8	243.0	52
Klášterní Hradisko	123	10.3	3.7	36.6	13.2	42.6	15.3	33.6	12.1	78.7	6
Kosmonautů	2,179	217.6	57.5	652.9	172.4	816.2	215.5	492.2	130.0	1,603.6	33
Kpt. Nálepky	1,703	243.4	104.5	625.8	268.7	476.1	204.4	357.7	153.6	971.8	5
Lazce	2,779	400.3	216.1	700.6	378.2	955.4	515.7	722.7	390.1	1,278.9	–
Lošov	210	15.5	8.9	79.8	46.1	70.4	40.7	44.3	25.6	88.7	–
Městský dvůr	48	3.6	1.6	15.1	6.6	16.1	7.0	13.2	5.8	27.0	–
Na dílech	30	0.9	0.7	22.4	16.4	4.2	3.1	2.4	1.8	8.0	–
Na konečné	81	2.4	1.9	6.1	4.8	66.5	52.1	5.9	4.6	17.6	40
Na vozovce	1,530	170.2	112.2	232.1	153.0	531.9	350.6	595.8	392.6	521.6	23
Nedvězí	144	8.9	5.8	29.4	19.0	75.9	49.1	29.8	19.3	50.8	–
Nemilany	355	24.6	13.8	106.0	59.6	117.8	66.2	106.6	59.9	155.5	–
Neředín	394	33.9	21.6	72.7	46.2	121.2	77.1	166.2	105.7	143.4	–
Nové Sady-jih	123	12.0	5.8	38.9	18.8	41.7	20.1	30.5	14.7	63.6	29
Nové Sady-sever	1,800	189.6	90.8	541.7	259.4	646.4	309.5	422.3	202.2	938.1	42

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Tab. 4: Modelled footfall of the shopping centres with respect to the number of households in basic settlement units
Note: A – situation with 4 shopping centres, B – situation with 5 shopping centres
Sources: 2001 Population census, Authors´ calculations

Tab. 4: continuance from previous page

Name of BSU	Households	Prior		Olympia		Haná		City		Galerie Šantovka	No. in maps
		A	B	A	B	A	B	A	B	B	
Novosadská	112	10.5	5.4	36.4	18.8	39.4	20.4	25.7	13.3	54.1	–
Nový svět	384	33.3	12.2	115.2	42.2	129.1	47.3	106.4	39.0	243.2	31
Olomouc-historické jádro	1,988	854.1	474.7	341.6	189.9	457.5	254.3	334.8	186.1	883.0	1
Ondřejova	119	9.2	5.1	62.5	34.4	23.4	12.9	23.9	13.2	53.4	56
Ovesniska	318	20.7	13.7	60.0	39.9	110.7	73.6	126.6	84.2	106.5	14
Pavlovičky	176	13.2	5.5	74.7	31.2	49.6	20.7	38.4	16.0	102.6	37
Pionýrská	2,101	151.2	94.4	340.3	212.3	1,276.0	796.3	333.5	208.1	789.9	19
Pod lipami	357	88.1	44.4	72.1	36.3	104.3	52.6	92.5	46.6	177.0	12
Povel-jih	129	10.2	5.3	36.8	19.1	42.5	22.2	39.5	20.6	61.8	27
První pětiletky	1,097	91.1	61.1	153.1	102.6	227.8	152.7	625.0	419.1	361.5	16
Přichystalova	419	39.8	20.3	114.9	58.7	143.6	73.4	120.7	61.7	204.8	54
Radíkov	102	7.3	4.1	37.7	21.3	33.0	18.6	24.0	13.5	44.4	–
Řepčín	289	33.7	18.8	89.0	49.6	115.9	64.5	50.5	28.1	128.0	47
Sady Flora	910	192.1	77.7	192.1	77.7	308.7	124.9	217.2	87.9	541.9	2
Schweitzerova	70	5.8	2.9	18.9	9.3	27.4	13.5	17.9	8.8	35.4	57
Slavonín	675	30.9	19.9	121.3	77.9	394.1	253.1	128.7	82.7	241.4	–
Sobieského	94	11.5	6.4	22.0	12.2	35.7	19.8	24.8	13.8	41.8	48
Stadiony	61	10.7	5.6	14.6	7.7	20.1	10.5	15.5	8.1	29.1	24
Stiborova	1,774	150.3	101.2	300.7	202.5	902.0	607.4	420.9	283.5	579.4	51
Stupkova	1,528	90.7	65.8	213.9	155.0	935.7	678.2	287.7	208.5	420.5	18
Svatý Kopeček	305	23.2	12.6	116.1	63.0	94.6	51.4	71.1	38.6	139.5	–
Šantova	98	10.6	2.1	28.2	5.6	31.7	6.3	27.6	5.5	78.4	3
Štítného	1,482	207.1	99.4	310.6	149.1	647.2	310.7	317.1	152.2	770.5	22
Tererovo náměstí	1,616	137.9	92.6	264.7	177.9	827.3	555.9	386.1	259.4	530.2	17
Topolany	135	10.2	6.8	29.9	19.8	41.8	27.8	53.1	35.2	45.4	–
Tovární	236	27.0	7.2	100.4	26.6	71.2	18.9	37.4	9.9	173.4	32
Týneček	172	15.4	7.8	74.6	37.9	43.3	22.0	38.7	19.6	84.8	–
U rybníka	15	1.2	0.6	4.5	2.4	5.3	2.8	4.0	2.1	7.1	41
U solných mlýnů	226	10.9	6.6	138.4	84.8	41.9	25.7	34.8	21.3	87.6	–
Varšavské náměstí	473	47.0	26.0	89.7	49.6	246.7	136.4	89.6	49.5	211.5	21
Total	**43,603**	**4,834**	**2,567**	**11,550**	**6,222**	**17,045**	**9,643**	**10,173**	**5,606**	**19,565**	–

distances entering the model were public transport time distances, which made the content of Fig. 4 somewhat unexpected; results based on Euclidean distance or automobile time distance would provide considerably different tributary areas of the shopping centres).

4.3 Hypothetical size of the existing shopping centres

The gravity model is also able to infer a hypothetical situation that provides an answer to the third research question raised in the introduction. Table 5 presents theoretical selling areas of the existing shopping centres that would generate the same footfall (i.e. attraction for the households) as the Galerie Šantovka with its 46,500 m^2 of planned selling area. Here we assume that the known demand level is preserved in the computation and that only its spatial distribution is altered. A note should be made here that for each estimated selling area of individual shopping centres, the model takes into account the influence of the remaining shopping centres and the Galerie Šantovka itself, and their current (planned) selling areas. Thus, each row in Tab. 5 represents a different situation.

The Prior shopping centre would need the greatest expansion of its selling area as compared with its current size. An 8.5-times larger selling area would attract the same footfall as the model predicts for the Galerie Šantovka. In absolute figures, Olympia would have to extend its selling area by 71,600 m^2 to equal the footfall of the Galerie Šantovka. On the other hand, the Obchodní centrum Haná proves its relative competitiveness (shown in Figs. 3 and 4) also in both figures presented in Tab. 5.

If we venture to take our conjectures even further, we are able to outline the most interesting situations in the respective spatial contexts (see Figs. 5, 6a, b and 7a, b). This time they should be considered as highly hypothetical, with no spatial and municipal planning connotations and ambitions, as they appear mostly infeasible and sometimes even impossible. We present them as one of the interesting results available through spatial interaction modelling.

Shopping centre	Current area (m^2)	Theoretical area (m^2)	Difference (m^2)	Multiple
Haná	37,500	93,500	56,000	2.5
Olympia	30,000	101,600	71,600	3.4
Olomouc city	24,500	95,000	70,500	3.9
Prior	5,000	42,500	37,500	8.5

Tab. 5: Hypothetical size of the existing shopping centres matching the footfall of the planned Galerie Šantovka
Note: Planned area of Galerie Šantovka is 46,500 m^2
Source: Authors´ calculations

Fig. 5: Example of a hypothetical expansion of the shopping centre (Olympia) with no or little spatial conflicts expected
Source: Národní geoportál INSPIRE, Authors´ elaboration

Fig. 5 presents a hypothetical expansion of Olympia while keeping its current height (i.e. number of floors). This expansion would face little or no spatial conflicts since the Olympia is located at the outskirts of the city of Olomouc with sufficient development areas in its vicinity (mostly arable land). In this case, the expansion of the shopping centre appears generally possible -- but not taking into account numerous other factors, such as broader economic conditions, etc.

On the contrary, the hypothetical expansion of Prior appears impossible in all respects. Fig. 6a, b present two options of the horizontal expansion of Prior while keeping its current height and following the course of important communications. In the first case (Fig. 6a), the UNESCO site of the Holy Trinity Column, the gothic church of St. Moritz and parts of the blocks of medieval and early modern houses, would have

Figs. 6a, b: Examples of a hypothetical horizontal expansion of the shopping centre (Prior) with severe spatial conflicts in the city structure
Source: Národní geoportál INSPIRE, Authors´ elaboration

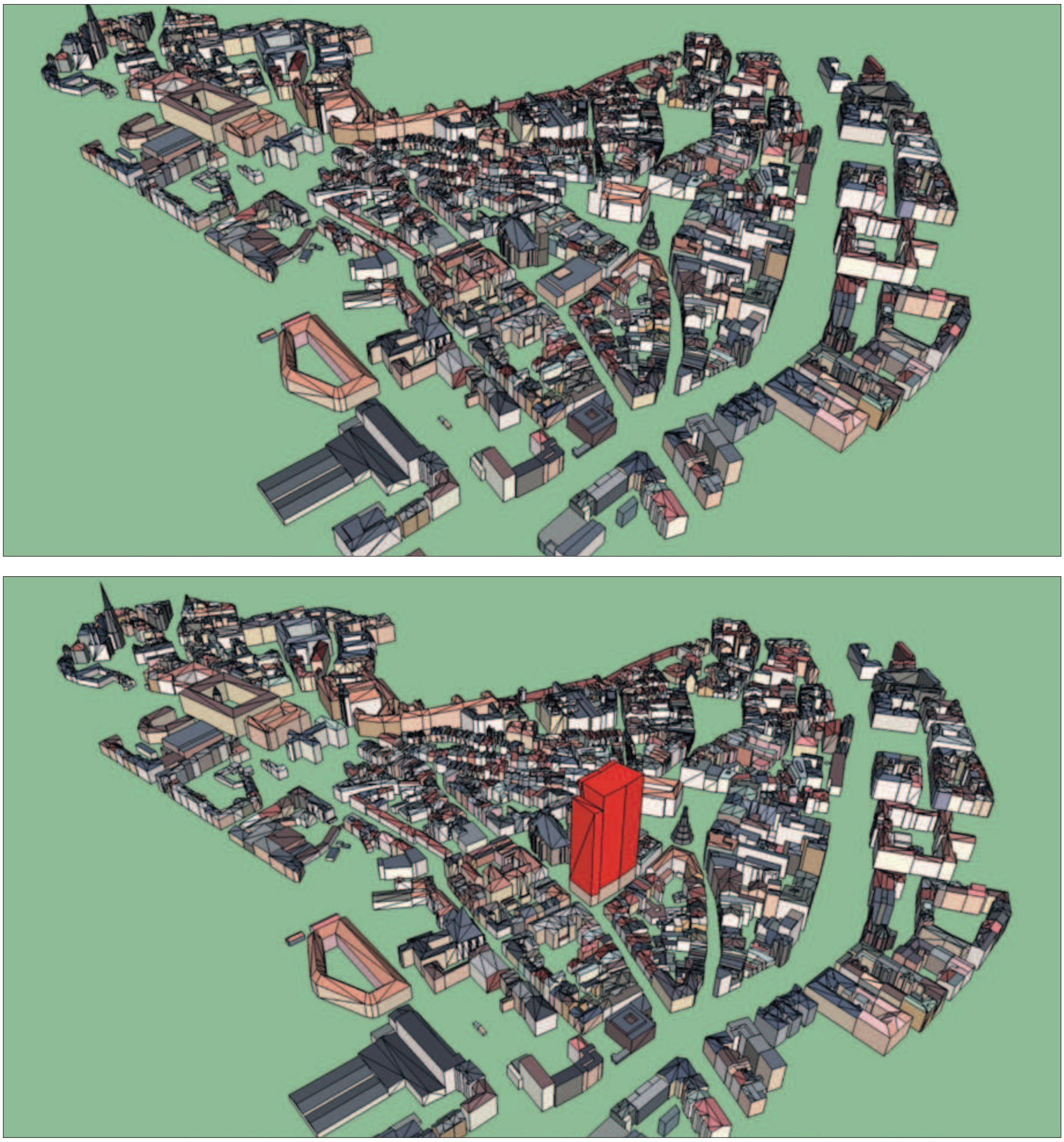
to be destroyed. In the second case (Fig. 6b), the whole large block of predominantly medieval and early modern houses would have to give way to the expansion of Prior.

Another hypothetical possibility would be to keep the current floor projection of Prior and to propose a vertical expansion of the shopping centre. The results of this step (see Figs. 7a, b) would severely disturb not only the townscape of the historical core of Olomouc but also the skyline of the whole city and its surroundings. For comparison, the spire of St. Wenceslas Cathedral (near the upper left corner of Figs. 7a, b) reaches a height of 102 m.

5. Conclusion

The application of the production-constrained gravity model has provided sufficient data for the description, prediction and inference of spatial phenomena related to the issue of the shopping centres' footfall in the city of Olomouc, and helped to answer the research questions raised at the outset.

However, reading these results, one has to be aware of two constraints setting the research framework. One of them is the spatial context which excluded the surroundings of the city of Olomouc, which somewhat decreased the total intensity of interactions and the



Figs. 7a, b: Example of a hypothetical vertical expansion of the shopping centre (Prior) with severe conflicts in the townscape
Source: Authors´ elaboration

modelled footfall of the shopping centres. Secondly, the distance between origins and destinations applied in the model had certain effects on the spatial patterns.

Apart from these disadvantages, inherent to spatial interaction models, the gravity model option applied in our study confirmed the crucial role of location in similar research tasks (i.e. location of shopping centres). Several notions on the location of shopping centres in Olomouc should be presented here. We only hint at some of the related issues hereinafter because they would deserve further detailed individual studies. We rather point out the identifying role of the gravity model. *Firstly*, the importance of location should be considered more as a relative rather than an absolute measure, since the relative locations of the competing shopping centres, the concentration of households, and the place within the public transport network, have acted as mutually dependent factors creating the modelled spatial patterns.

Secondly, within this relatively conceived system of locations, their central positions within the city have brought the greatest advantages for such retail facilities, which is documented on the examples of Prior (both in the present and predicted states) and Galerie Šantovka (in the predicted state). In spite of having the smallest selling area, Prior would experience the smallest relative decrease in footfall upon completion of the Galerie Šantovka. In contrast, the suburban retail facilities, particularly those with poor public transport connections (Olomouc City and Olympia), are assumed to experience more significant losses in their footfall.

Thirdly, the primitive typology of retail facilities (traditional centrally-located, suburban newly-constructed, and revitalised brownfield) and the respective modelled results argue in favour of the revitalisation of disused industrial areas within or near the city centre, and their active use as for example in retail facilities, as well as arguments against the occupation of suburban agricultural land. However, it is fair to admit that the assessment of the location of shopping centres has to take into account more factors, such as economy and transport. As shown above, the gravity model can particularly contribute to the assessment of the latter. Shopping centres in the city centre are very intensive in terms of individual transport; however, they are easily accessible by public transport, too. On the other hand, the location of suburban shopping centres is more favourable for individual and logistic transport, while access by public transport is less convenient.

Finally, we can see that the modelling of spatial interactions and the application of gravity models is able to contribute to the resolution of research tasks, particularly when statistical data on the examined issue are lacking, in our case, when we strive to reveal the spatial patterns of shopping centre footfall.

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References:

AKWAWUA, S., POOLER, J. A. (2001): The development of intervening opportunities model with spatial dominance effects. Journal of Geographical Systems, Vol. 3, No. 1, p. 69–86.

ALONSO, W. (1978): A theory of movement. In: Hansen N. M. [ed.]: Human Settlement Systems: International Perspectives on Structure, Change and Public Policy. Ballinger, Cambridge (Mass.), p. 197–211.

BERRY, B. J. L. (1967): Geography of market centres and retail distribution. Prentice Hall, Englewood Cliffs, 146 pp.

BEZÁK, A. (2000): Interregional migration in Slovakia: some tests of spatial interaction models. Geografický časopis, Vol. 52, No. 1, p. 15–32.

BIRKIN, M., CLARKE, G. P., CLARKE, M. (2002): Retail Geography and Intelligent Network Planning. Wiley, Chichester, 284 pp.

BLUM, B. S., GOLDFARB, A. (2006): Does the internet defy the law of gravity? Journal of International Economics Vol. 70, No. 2, p. 384–405.

CHEN, Y. (2009): Urban gravity model based on cross-correlation function and Fourier analyses of spatio-temporal process. Chaos, Solitons and Fractals, Vol. 41, No. 2, p. 603–614.

CHOJNICKI, Z. [ed.] (1977): Metody ilościowe i modele w geografii. PAN, Warszawa, 232 pp.

CLIFF, A. D., MARTIN, R. L., ORD, J. K. (1974): Evaluating the friction of distance parameter in gravity models. Regional Studies, Vol. 8, No. 3–4, p. 281–286.

CONVERSE, P. D. (1949): New laws of retail gravitation. Journal of Marketing, Vol. 14, No. 3, p. 379–384.

DE VRIES, J. J., NIJKAMP, P., RIETVELD, P. (2009): Exponential or power distance-decay for commuting? An alternative specification. Environment and planning A, Vol. 41, No. 2, p. 461–480.

DREZNER, T., DREZNER, M. (2007): The gravity p-median model. European Journal of Operational Research, Vol. 179, No. 3, p. 1239–1251.

FISCHER, M. M. (1998): Computational neural networks - a new paradigm for spatial analysis. Environment and Planning A, Vol. 30, No. 10, p. 1873–1892.

FISCHER, M. M., REISMANN, M. (2002): A methodology for neural spatial interaction modelling. Geographical Analysis, Vol. 34, No. 3, p. 207–228.

FISCHER, M. M. (2009): Principles of neural spatial interaction modelling. In: Sonis, M. [ed.]: Reassessment of Theories of Regional Science. Springer, Heidelberg, p. 199–214.

FOTHERINGHAM, A. S. (1981): Spatial structure and distance-decay parameters. Annals of the Association of American Geographers, Vol. 71, No. 3, p. 425–436.

FOTHERINGHAM, A. S. (1985): Spatial competition and agglomeration in urban modelling. Environment and Planning A, Vol. 17, No. 2, p. 213–230.

FOTHERINGHAM, A. S. (1986): Modelling hierarchical destination choice. Environment and Planning A, Vol. 18, No. 3, p. 401–418.

FOTHERIGHAM, A. S. (2012): Customer store choice and retail competition. In: Pellegrini, L., Reddy, S. K. [eds.]: Retail and marketing channels: economic and marketing perspectives on producer-distributor relationships. Routledge, Oxon, p. 234–257.

FOTHERINGHAM, A. S., BRUNSDON, C., CHARLTON, M. (2000): Quantitative geography: perspectives on spatial data analysis. Sage, London, 270 pp.

FOTHERINGHAM, A. S., O´KELLY, M. E. (1989): Spatial interaction models: formulations and applications. Kluwer, London, 244 pp.

HAGGETT, P. (1965): Locational Analysis in Human Geography. Arnold, London, 339 pp.

HALÁS, M. (2005): Dopravný potenciál regiónov Slovenska. Geografie, Vol. 110, No. 4, p. 257–270.

HALÁS, M., KLAPKA, P. (2010): Regionalizace Česka z hlediska modelování prostorových interakcí. Geografie, Vol. 115, No. 2, p. 144–160.

HAYNES, K. E., FOTHERINGHAM, A. S. (1984): Gravity and spatial interaction models. Sage, London, 88 pp.

HLAVIČKA, V. (1993): Teoretická východiska a souvislosti konstrukce gravitačních modelů. Geografie, Vol. 98, No. 1, p. 34–43.

HUBÁČKOVÁ, V., KREJČÍ, T. (2007): Regionální vliv Slovácka pohledem Reillyho modelu. In X. mezinárodní kolokvium o regionálních vědách. 1. vyd. Brno, Ekonomicko-správní fakulta MU, p. 220–227.

HUFF, D. L. (1964): Defining and estimating a trading area. Journal of Marketing Vol. 28, No. 3, p. 34–38.

ISARD, W. (1960): Methods of regional analysis: and introduction to regional science. MIT, Cambridge (Mass.), 784 pp.

JOHNSTON, R. J. (1973): On frictions of distance and regression coefficients. Area, Vol. 5, No. 3, p. 187–191.

JOHNSTON, R. J. (2008): Quantitative Human Geography: Are We Turning Full Circle? Geographical Analysis, Vol. 40, No. 3, p. 332–335.

KUNC, J., FRANTÁL, B., SZCZYRBA, Z., TONEV, P., TOUŠEK, V. (2011): Shopping centres and shopping behaviour: selected relations and socio-geographical implications (The Vaňkovka Gallery Brno, Czech Republic example). Acta Universitatis Palackianae Olomucensis – Geographica, Vol. 42, No. 1, p. 5–17.

LEE, M.-L., PACE, R. K. (2005): Spatial Distribution of Retail Sales. The Journal of Real Estate Finance and Economics, Vol. 31, No. 1, p. 53–69.

LI, Y., LIU, L. (2012): Assessing the impact of retail location on store performance: a comparison of Wal-Mart and Kmart stores in Cincinnati. Applied Geography, Vol. 32, No. 2, p. 591–600.

OPENSHAW, S. (1998): Neural network, genetic, and fuzzy logic models of spatial interaction. Environment and Planning A, Vol. 30, No. 10, p. 1857–1872.

Oxford Dictionaries, 2013 [on line]. Accessible at: http://oxforddictionaries.com/definition/english/footfall.

PAULOV, J. (1991): The zone-size-dependent entropy formula and spatial interaction modelling: a note on some implications. Environment and Planning A, Vol. 23, No. 4, p. 557–570.

PLANE, D. A. (1982): An information theoretic approach to the estimation of migration flows. Journal of Regional Science, Vol. 22, No. 4, p. 441–456.

POOLER, J. (1994): An Extended Family of Spatial Interaction Models. Progress in Human Geography, Vol. 18, No. 1, p. 7–39.

RASOULI, S, TIMMERMANS, H. (2013): Assessment of model uncertainty in destinations and travel forecasts of models of complex spatial shopping behaviour. Journal of Retailing and Consumer Services, Vol. 20, No. 2, p. 139–146.

RAVENSTEIN, E. G. (1885): The laws of migration. Journal of Royal Statistical Society, Vol. 48, p. 167–235.

ŘEHÁK, S. (2004): Geografický potenciál pohraničí. In: Jeřábek, M., Dokoupil, J., Havlíček, T. [eds.]: České pohraničí – bariéra nebo prostor zprostředkování? Academia, Praha, p. 67–74.

ŘEHÁK, S., HALÁS, M., KLAPKA, P. (2009): Několik poznámek k možnostem aplikace Reillyho modelu. Geographia Moravica, Vol. 1, p. 47–58.

REILLY, W. J. (1931): The law of retail gravitation. Knickerbocker Press, New York, 75 pp.

SCHENK, T. A., LÖFFLER, G., RAUH, J. (2007): Agent-based simulation of consumer behaviour in grocery shopping on a regional level. Journal of Business Research, Vol. 60, No. 8, p. 894–903.

SCOTT, D. M., HE, S. Y. (2012): Modelling constrained destination choice for shopping: a GIS-based, time-geographic approach. Journal of Transport Geography, Vol. 23, p. 60–71.

SENIOR, M. L. (1979): From gravity modelling to entropy maximising: a pedagogic guide. Progress in Human Geography, Vol. 3, No. 2, p. 174–210.

SHEPPARD, E. S. (1978): Theoretical underpinning of the gravity hypothesis. Geographical Analysis Vol. 10, No, 4, p. 386–402.

SNICKARS, F., WEIBULL, J. W. (1977): A minimum information principle. Regional Science and Urban Economics, Vol. 7, No. 1–2, p. 137–168.

STEWART, J. Q. (1948): Demographic gravitation: evidence and applications. Sociometry, Vol. 11, No. 1/2, p. 31–58.

SUÁREZ-VEGA, R., SANTOS-PEŃATE, D. R., DORTA-GONZÁLEZ, P. (2007): The follower location problem with attraction thresholds. Papers in Regional Science, Vol. 86, No. 1, p. 123–137.

SZCZYRBA, Z. (2010): Development of retail geographical structure in the Czech Republic: a contribution to the study of urban environment changes. Acta Universitatis Palackianae Olomucensis – Geographica, Vol. 41, No. 2, p. 5–20.

TAYLOR, P. J. (1971): Distance transformation and distance decay function. Geographical Analysis Vol. 3, No. 3, p. 221–238.

TAYLOR, P. J. (1983): Distance Decay in Spatial Interactions. CATMOG 2. Geo Books, Norwich, p. 35.

TOBLER, W. (1983): An alternative formulation for spatial-interaction modelling. Environment and Planning A, Vol. 15, No. 5, p. 693–703.

WILSON, A. (2010): Entropy in Urban and Regional Modelling: Retrospect and Prospect. Geographical Analysis, Vol. 42, No. 4, p. 364–394.

WILSON, A. G. (1967): Statistical theory of spatial distribution models. Transportation Research, Vol. 1, p. 253–269.

WILSON, A. G. (1974): Urban and regional models in geography and planning. Wiley, London, 418 pp.

ZIPF, G. K. (1947): The hypothesis of the “minimum equation” as a unifying social principle: with attempted synthesis. American Sociological Review, Vol. 12, No. 6, p. 627–650.

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THE SOIL TEMPERATURE REGIME IN THE URBAN AND SUBURBAN LANDSCAPES OF OLOMOUC, CZECH REPUBLIC

Michal LEHNERT

Abstract

The soil temperature regime is a relevant part of comprehensive topoclimatic research. Soil temperature data series measured at selected stations of the metropolitan station system of Olomouc in 2010–2011 were analysed. The focus was on the identification of geofactors influencing the soil temperature regime in the area of interest. The possibility of soil temperature simulation using knowledge of local specifics of the soil temperature regime was verified. The results indicate that the variability of the soil temperature regime was, apart from physical and chemical properties of soil, determined predominately by the character of the relief and the occurrence of related atmospheric inversions. The impact of the urban landscape on the soil temperature regime was not demonstrated. Average daily soil temperature was simulated with satisfying results, based on a model adjusted for a period without snow cover. The results represent a basis for further research on geofactors influencing the soil temperature regime in Olomouc and its surroundings.

Shrnutí

Režim teploty půdy v městské a příměstské krajině Olomouce, Česká republika

Režim teploty půdy je důležitá součást komplexního topoklimatického výzkumu. Na základě dat z účelové staniční sítě byla analyzována teplota půdy v letech 2010–2011. Cílem bylo identifikovat hlavní geofaktory ovlivňující režim teploty půdy v zájmovém území. Ověřována byla také možnost využití znalostí místních specifik režimu teploty půdy pro simulaci půdní teploty. Ukázalo se, že variabilita teploty půdy byla kromě fyzikálně-chemických vlastností půdy podmíněna zejména charakterem reliéfu a souvisejícím výskytem inverzí. Samotný vliv města na teplotu půdy se prokázat nepodařilo. Na základě upraveného modelu byla s dobrou přesností simulována průměrná denní teplota půdy v teplém půlroce. Získané poznatky představují základ pro studium vlivu jednotlivých geofaktorů na režim teploty půdy v Olomouci a okolí.

Keywords: *soil temperature regime, soil temperature simulation, Olomouc and its surroundings, Czech Republic*

1. Introduction

Thermal and temperature soil characteristics are part of fundamental physical properties in soil science. Since the first modern research conducted by De Vries (1952), a number of publications thoroughly describing heat transfer in soils have been published. Nevertheless, the current state of knowledge is only used with difficulties from the climatological point of view, as geographical space varies significantly (soil properties, topography, weather conditions, etc.). Consequently, the spatial and temporal distribution of soil temperature and predictions of soil temperatures are considerably underdeveloped in comparison with other fields of study in climatology. Some local climatic effects may, however, be affected by the soil temperature regime (Vysoudil, 2009). For instance, the soil temperature regime might affect air temperature and relative air humidity regimes near the ground. This could lead to local radiation inversions.

Permanent long-term soil temperature measurements in the Czech Republic are made mainly by a professional meteorological station. Data analyses and assessments are usually limited to descriptions of the soil temperature regime on a macroclimatic level (Bedrna, Gašparovič, 1980; Coufal et al., 1993; Tolasz et al., 2007). As a result, detailed analyses on a local climate level, which would include a dense grid of sites, are made only rarely (Pokladníková et al., 2006; Tesař et al., 2008; Lehnert, 2010; Hora, 2011).

The approach taken in this study is based on the description of particular geofactors and their influence on the soil temperature regime. According to Hanks (1992), geofactors shaping the soil temperature regime can be distinguished:

1. as those influencing the amount of heat available on the soil surface; and
2. those influencing the dissipation of available heat.

Research on factors influencing dissipation of available heat has strong roots in soil science and therefore there are many reports describing the influence of particle size, soil moisture content, humus (or organic matter) content and porosity, on heat flows in the soils (see Hanks, 1992; Geiger et al., 2003; Horton, Hochster, 2011). On the other hand, a systematic description of the factors the amount of heat available on the soil surface is clearly missing. Nevertheless, geofactors influencing the amount of heat available on the soil surface can be considered to include relief (Elizbarashvili, 2007; Kim et al., 2000), vegetation (Green et al., 1984), soil cover colour (Oke, Hannell, 1966), the complex relation of air temperature and air humidity in terms of water vapour condensation in soil pores (Hofmann, 1955), climatic conditions in general (Elizbarasvilli, 2007), and/or the influence of the urban environment (Tang et al., 2011).

Since recognition of the influences of all geofactors is a demanding task at a level to meet acceptable accuracy in the space-time continuum, most relevant studies were published during the last two decades when computerized spatial statistics tools became available. The results of Balland and Arp (2005), who managed to generalize the influence of geofactors on soil thermal conductivity over a wide range of conditions, encouraged the development of soil temperature regime models applicable in various geographic conditions. Meanwhile, Kang et al. (2000) presented a hybrid soil temperature regime model based on the influence of topography, active surface characteristics and air temperature on soil temperature, which has excellent accuracy for the investigated area.

Despite the fact that the above-mentioned models have brought the most satisfactory results, they cannot be considered comprehensive or widely applicable to various geographic situations at this time. For instance, almost none of the existing models take into account the variety of local climate dynamics. Knowledge of the influence of the spatial variations in climatic factors on the soil temperature regime is very poor.

This situation emphasizes the level of uncertainty in soil temperature regime simulations. Furthermore, Kutílek (1990) demonstrated a free correlation of "hydrotope" and "pedotope", which (to some extent) presents a limitation on the soil temperature regime simulation on a local scale.

The particular aim of this study is to identify the geofactors determining the soil temperature regime in Olomouc and in its surrounding areas. At the same time, the paper aims to create a basis for a simple but comprehensive approach to soil temperature regime simulation in the area under investigation. Therefore, the paper presents both a description of the soil temperature regime, analysing the influence of the geofactors, and an experimental attempt to demonstrate the applicability of knowledge of the spatial variability of local soil temperature, for soil temperature simulation in the investigated area.

2. Data and methods

The soil temperature analysis was primarily based on data obtained from the six stations included in the metropolitan station network of Olomouc (MESSO), see Tab. 1. The analyzed soil temperatures were measured at a depth of 0.2 m in 2010 and 2011. The specified stations measured, among other variables, air temperature at a height of 1.5 m and precipitation intensity. Moreover, the BYST, DDHL and ENVE stations measured global radiation. The global radiation data measured at the ENVE station was used for the nearby BOT_PF, DOMI and LETO stations. There were no soil temperatures measured at ENVE; therefore the station is grey-tinged in Table 1. More detailed information about the MESSO stations was presented by Vysoudil et al. (2012).

The data were recorded at 10-minute intervals and processed according to the procedures of Nosek (1972). Daily, monthly and annual maximum and minimum soil temperatures were determined. Average soil temperatures were calculated as an arithmetic mean of all corresponding values measured at 10-minute intervals. Air temperature data, which were used for comparative analyses and for the soil temperature simulation, were treated similarly. For selected days, hourly sums of precipitation and hourly averages of global radiation were also calculated. Snow cover depth was measured at the Olomouc-Holice station of the Czech Hydrometeorological Institute (for more details see Vysoudil et al., 2012).

Besides the previously-mentioned analyses of meteorological characteristics, some soil properties were also specified. More precisely, soil texture (due to technical reasons, the smallest measured grain that includes fine silt and clay was limited to ≤ 0.063 mm) and soil humus content were determined. Soil samples

Site	Location (ϕ)	Location (λ)	Altitude (m a.s.l.)	Site position	Topography	Soil type
BOT_PF	49° 36´ 01´´	–17° 15´ 27´´	211	urban	flat land	Urbic Anthrosol
BYST	49° 32´ 33´´	–17° 11´ 16´´	218	rural	flat land	Luvic Chernozem
DDHL	49° 39´ 36´´	–17° 24´ 33´´	307	rural	valley	Haplic Gleysol
DOMI	49° 35´ 49´´	–17° 15´ 03´´	220	urban	flat land	Urbic Anthrosol
KOPE	49° 37´ 39´´	–17° 20´ 20´´	362	suburban	slope	Stagnic Luvisol
LETO	49° 35´ 29´´	–17° 12´ 35´´	258	suburban	flat land	Urbic Anthrosol
ENVE	49° 35´ 30´´	–17° 15´ 46´´	230	urban	(roof)	–

Tab. 1: Characteristics of the MESSO stations included in the study

were taken repeatedly from a soil borehole on 13 October 2011 in line with the methodology published by Zbíral, Honsa and Malý (1997).

In the following stage of this study, a simple empirical model published by Zheng et al. (1993) was used. The model is based on a daily average soil temperature simulation using air temperature data. The elemental version of this model was adopted as a tool for the experimental quantification of local differences in soil temperature simulation. The Zheng et al. (1993) model was chosen because of its accuracy, simplicity and flexibility, validated by Kang et al. (2000).

The above-quoted model is based on the so-called 'regional' regression equation (Zheng et al., 1993). The regional regression equation uses the correlation between the average daily soil temperature and the 11-day moving average of air temperature. Consequently, data obtained from the regional equation calculations were incorporated into one of the empirically-developed formulas. In this study, we used a simple version of the model, which is applicable only to the period without snow cover:

$$F(J) = [A(J) - A(J-1)]\, M_2 + E(J-1),$$

in which $F(J)$ is the simulated average soil temperature for day J; $A(J)$ is the measured average air temperature for day J; $A(J-1)$ is the measured average soil temperature on the day preceding the day J; M_2 is an empirically given constant 0.2, and $E(J-1)$ is the soil temperature on the previous day estimated solely from the regional regression equation. The author's intention was to experimentally express spatial variations of soil temperature on a local level. Therefore, a LGF variable (Local Geographical Factors) was added to the formula (see below). LGF is assumed to quantify the specific influence of geofactors on the soil temperature of the monitored stations.

It is important to mention some differences in the initial data series of this study and the research carried out by Zheng et al. (1993). In our research, the soil temperature was measured at a depth of 20 cm, whereas Zheng et al. (1993) measured at a depth of 10 cm. We chose the depth of 20 cm because it is widely used in meteorological stations. Since the influence of snow cover could have concealed some required information, the calculations of soil temperature simulation in this paper are based only on the data series obtained during the period from May to October.

3. Soil temperature regime

There were significant differences between the annual soil temperature regimes in 2010 and 2011 (Figs. 1 and 2, Tabs. 2 and 3). Regardless of these differences,

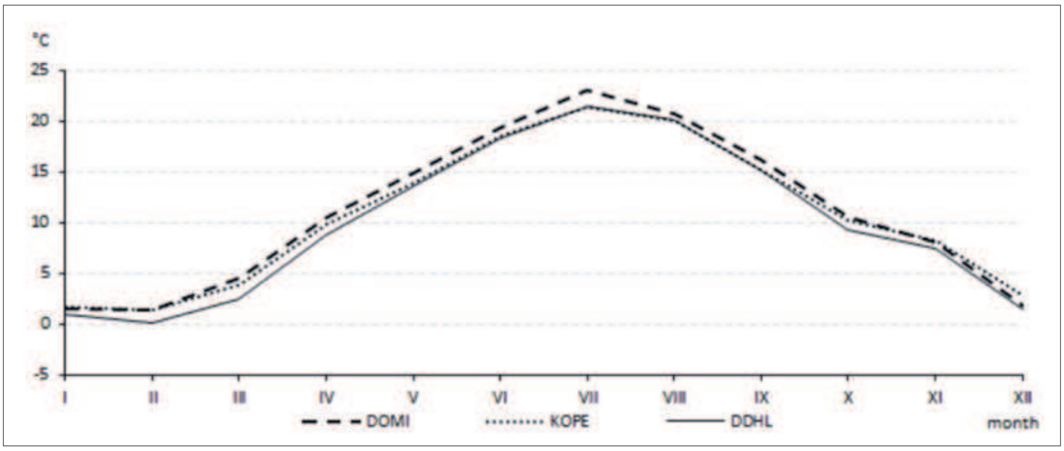

Fig. 1: Average soil temperatures at selected MESSO stations, 2010

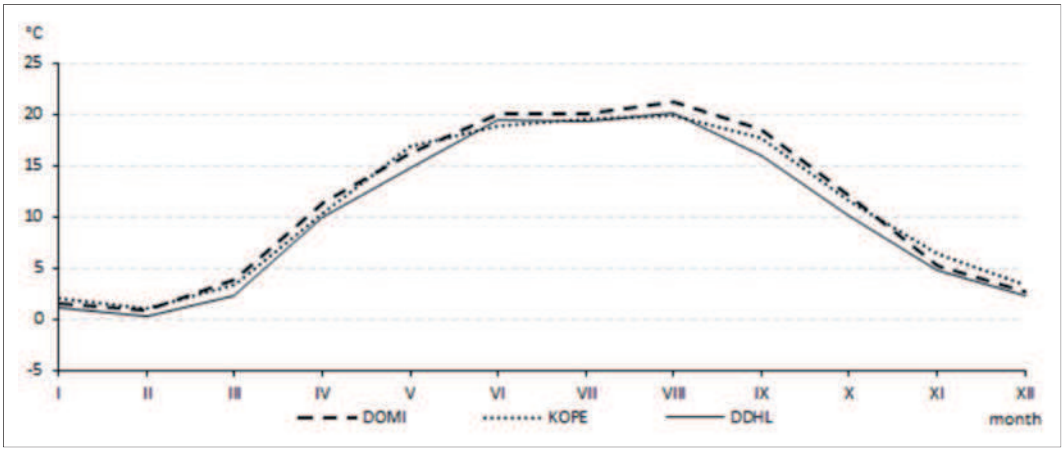

Fig. 2: Average soil temperatures at selected MESSO stations, 2011

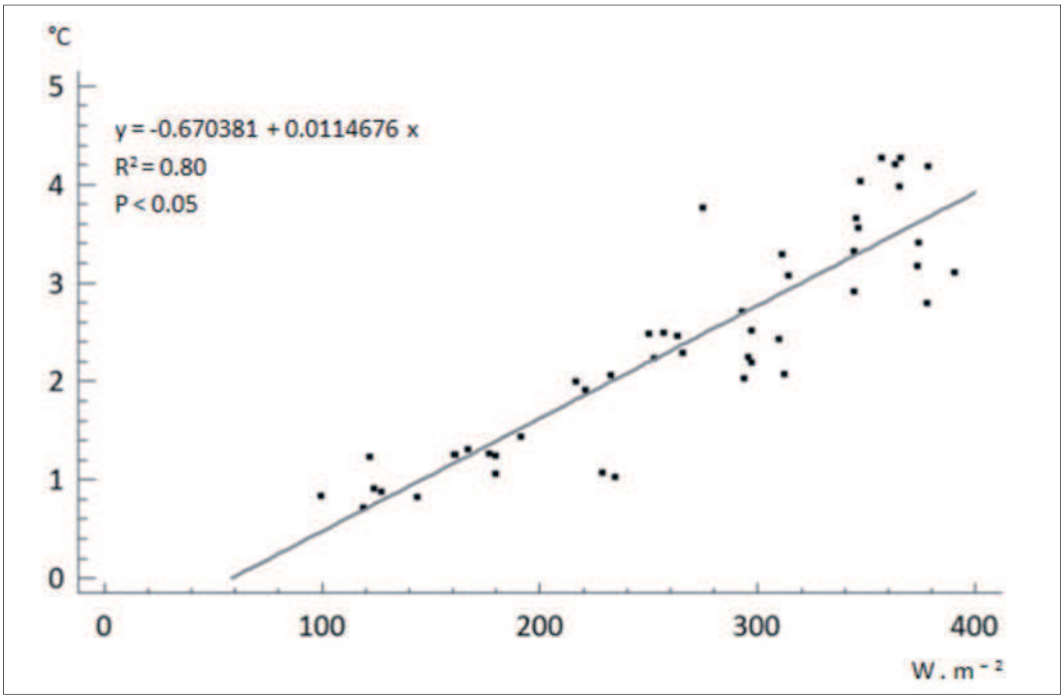

Fig. 3: Daily soil temperature amplitude and average daily global radiation intensity, MESSO 2010–2011

Station	Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Avg
BOT_PF	2010	1.4	1.3	4.4	10.0	14.2	18.7	21.9	19.8	15.2	9.7	8.0	1.8	10.5
	2011	1.5	1.0	3.9	10.0	14.3	19.0	18.8	19.7	16.6	10.8	5.0	2.8	10.3
BYST	2010	1.2	0.7	3.7	9.7	14.3	18.7	21.8	20.4	15.8	10.5	8.4	2.1	10.6
	2011	0.9	0.9	3.7	10.5	15.2	18.6	17.7	18.5	16.6	11.3	5.7	3.2	10.2
DOMI	2010	1.6	1.4	4.5	10.5	14.8	19.4	23.1	20.7	16.2	10.5	8.0	1.9	11.0
	2011	1.5	0.9	3.9	11.4	16.2	20.1	20.0	21.2	18.6	12.0	5.2	2.7	11.1
DDHL	2010	0.9	0.1	2.5	8.8	13.7	18.3	21.4	20.1	15.1	9.3	7.4	1.4	9.9
	2011	1.1	0.3	2.3	10.0	14.8	19.4	19.3	20.2	16.0	10.2	4.7	2.2	10.0
KOPE	2010	1.7	1.3	3.9	9.8	13.9	18.6	21.4	20.1	15.1	10.2	8.3	2.8	10.6
	2011	2.0	1.0	3.4	10.3	16.8	18.9	19.5	19.9	17.7	11.6	6.3	3.4	10.9
LETO	2010	1.1	0.7	3.8	9.5	13.5	17.2	21.9	20.3	15.3	10.0	8.0	5.4	10.6
	2011	0.6	0.6	3.4	10.3	15.4	19.6	19.6	20.3	17.9	11.6	1.2	2.8	10.3

Tab. 2: Average soil temperatures at selected MESSO stations, 2010–2011

Station	Maximum temperature		Minimum temperature	
	[°C]	Date	[°C]	Date
BOT_PF	23.3	17.7.2010	0.1	26.2.2011
BYST	22.2	18.7.2010	0.4	28.2.2011
DDHL	23.9	26.8.2011	– 0.7	26.2.2011
DOMI	24.8	26.8.2011	0.1	27.2.2011
KOPE	23.3	26.8.2011	0.3	4.3.2011
LETO	23.0	25.8.2011	– 0.1	26.2.2011

Tab. 3: Maximum, minimum soil temperature at the selected MESSO stations, 2010–2011

neither 2010 nor 2011 were considerably warmer or colder than each other. In 2010, maximum soil temperatures were recorded by most MESSO stations at the end of July while maximum soil temperatures in 2011 were recorded at the end of August. Mean annual soil temperatures recorded at the BOT_PF, BYST and LETO stations were higher in 2010, in contrast to temperatures measured at the DOMI, DDHL and KOPE stations. The highest average soil temperature was measured at DOMI station both in 2010 and 2011. Another significant feature was a later soil temperature increase measured at the DDHL station in the spring of both years.

Apart from the average, minimum and maximum daily and annual temperatures, the daily soil temperature amplitude was observed. The daily soil temperature amplitude increased principally with global radiation intensity in the course of the year. The correlation of global radiation intensity and average soil temperature is illustrated on the radiation weather days in Fig. 3. On days when the weather conditions failed to meet the definition of radiation weather days (wind velocity ≤ 4 $m.s^{-1}$, proportion of sky covered by clouds ≤ 2/8), weather influencing factors were taken into consideration.

4. Factors influencing the soil temperature regime

It follows from the above that global radiation is a determining geofactor influencing the soil temperature regime. However, a detailed analysis of Figures 4 and 5 reveals some other notable relations. It should be noted that the maximum and minimum daily soil

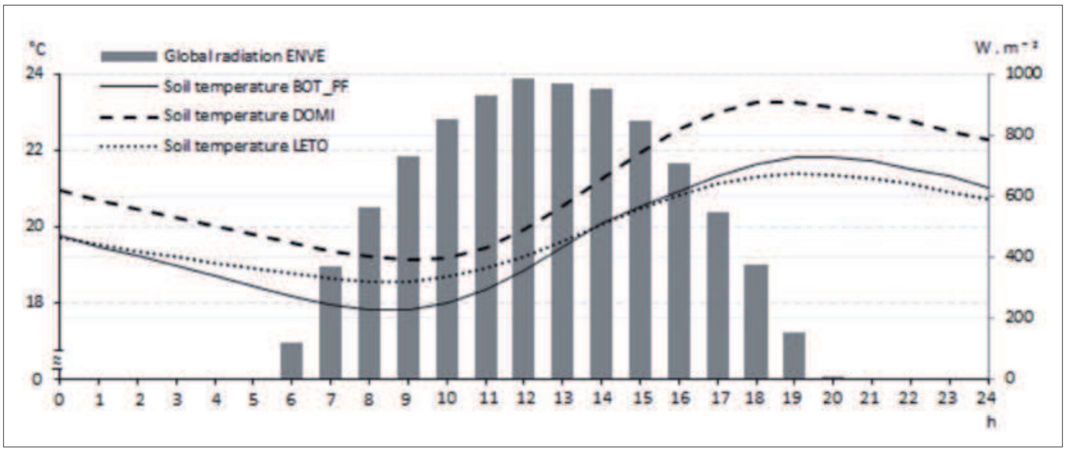

Fig. 4: Soil temperature and global radiation on the selected MESSO stations, 8 July, 2010

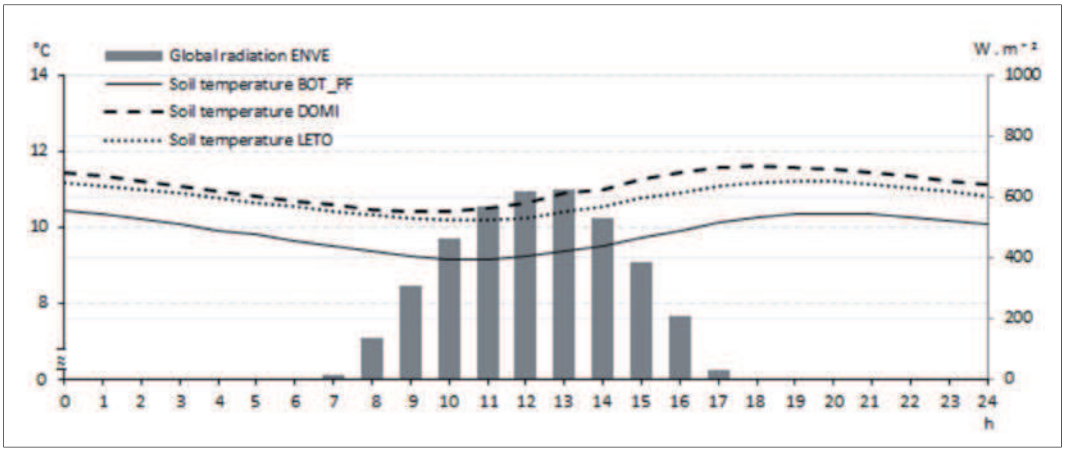

Fig. 5: Soil temperature and global radiation on the selected MESSO stations, 12 October, 2010

temperatures were recorded at each station on different dates and that there were significant differences in the daily soil temperature amplitude between the involved stations. The reasons depended on the interaction of global radiation heat with other geofactors.

With respect to the fact that global radiation plays a key role in the formation of the soil temperature regime, it is crucial to deal with the influence of factors that might reduce global radiation intensity on a local scale. In Olomouc and the surrounding areas, the spatial variability of global radiation was influenced particularly by low cloudiness related to atmospheric temperature inversion. For instance, the soil temperature regime had an entirely different character at the highest altitude for the KOPE station compared with all other MESSO stations during the third ten-day interval in December 2010 (Fig. 6). The occurrence of air temperature inversion was corroborated by air temperature analyses. Another example of the impact of air temperature inversion on the soil temperature regime is the local climate of the V-shaped Bystřice River valley, where the DDHL station is located. Vysoudil (2008) confirmed that atmospheric temperature inversions reduced the intensity of global radiation on the Bystřice River valley bottom, and it was reconfirmed by an unpublished global radiation analysis by the author for the years 2010 and 2011. Therefore, the soil temperature regime at the DDHL station was characterised by a sudden soil temperature decrease at the end of the summer period and by a delayed soil temperature increase at the end of the winter period. Nonetheless, it should be noted that the soil temperature regime of DDHL was also conditioned by the valley shape.

Undoubtedly, the low cloudiness associated with air temperature inversion was not the only category of cloudiness shaping the local differences in global radiation intensity. Nevertheless, the local differences in cloudiness based on frontal circulation must be subject to further investigation. On days with the predominating influence of frontal circulation, the times of maximum and minimum temperature occurrence were shifting by minutes or even hours (Lehnert, 2010).

When cloudiness induced precipitation, the soil temperature suddenly decreased (Fig. 7). The phenomenon could have been caused by two different mechanisms – by water convection or by evaporation. The first one assumes decreased soil temperature due to infiltration of colder water into the soil. The second one counts on increased loss of latent heat from the soil due to increased evaporation.

Relief was another significant geofactor affecting the soil temperature regime. The influence of slope aspect was not taken into account because the data used were measured at the meteorological stations. Despite this, it is unrealistic to avoid the effect of shading of the meteorological stations by the surrounding relief, which significantly affected the soil temperature regime at the DDHL station in particular. For example, during the sunrise on 30 October 2010, non-zero values of global radiation were detected on the DDHL station with an hour lag at the ENVE station (Lehnert, 2012). Consequently, shorter daily durations of global radiation at the DDHL station were detected. These changes had an impact on the minimum daily soil temperature data and also on the average soil temperature value at the DDHL station. On the other hand, according to Lehnert (2012), the effect of altitude was not substantial in the study area.

Global radiation is partly transformed into heat energy on the ground. The efficiency of this process is given by properties of the active surface. In spite of the fact that the active surface at all of the studied

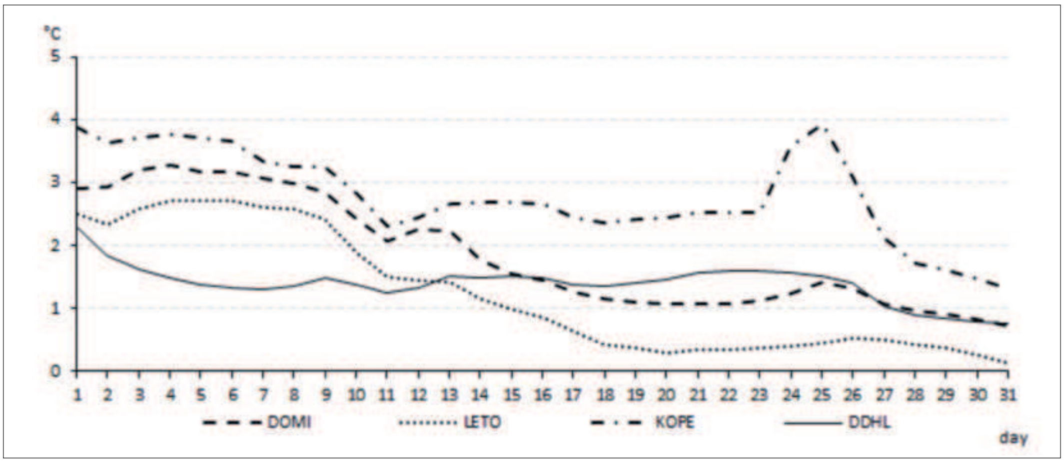

Fig. 6: Average soil temperature, Olomouc and surroundings, December 2010

MESSO stations was maintained lawn, properties of this active surface for all stations were not identical. It was discovered that even seemingly insignificant differences in grass quality (sward height and density) might have an influence on soil temperature (see Lehnert, 2012).

With respect to land cover type, the presence of snow had a major influence on the soil temperature regime. With snow cover present, there was almost no response of soil temperature to global radiation intensity; the course of soil temperature during these days was flat. Therefore, the spatial and temporal variations in snow cover have an impact on the spatial variation of the soil temperature regime (for more details, see Lehnert, 2012). Even a snow cover of less than 5 cm might have changed the soil temperature regime dramatically. Another effect of snow cover becomes important upon the start of snow melting. For instance, soil temperature remained steady or decreased almost imperceptibly at first, and then rose sharply during the thaw at the end of January 2010, which could be due to a sudden and intense emission of latent heat from the saturated soil.

As mentioned above, soil properties represent an important group of geofactors affecting the soil temperature regime. Therefore, we analyzed relations between the average daily soil temperature amplitude and the humus content, and between the average daily soil temperature amplitude and the size of particles. While the role of humus content was ambiguous, there seemed to be a positive correlation between the average daily soil temperature amplitude and the proportion of sand fraction in fine earth (though without statistical significance due to few input data points). This implies that coarse soils have higher average daily soil temperature amplitude than fine soils (Fig. 8). The effect of soil type by itself was particularly obvious in gleysol at the DDHL station, where both the second highest absolute temperature and the lowest annual temperature were detected.

5. Geofactors as a variable in soil temperature regime calculation

In the first part of this research project with the preliminary results described above, some important geofactors influencing the soil temperature regime are

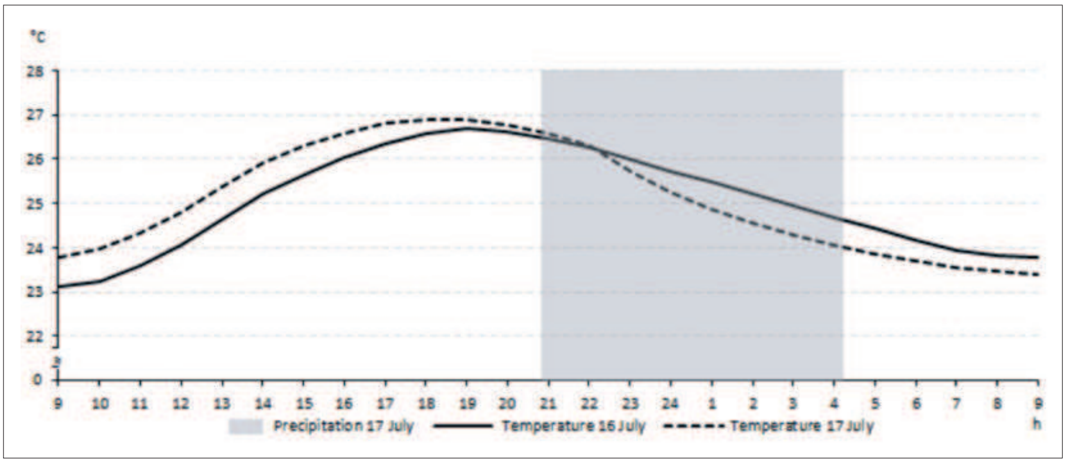

Fig. 7: Diurnal soil temperature regime and distribution of precipitation, BOT_PF, 16 and 17 July 2010

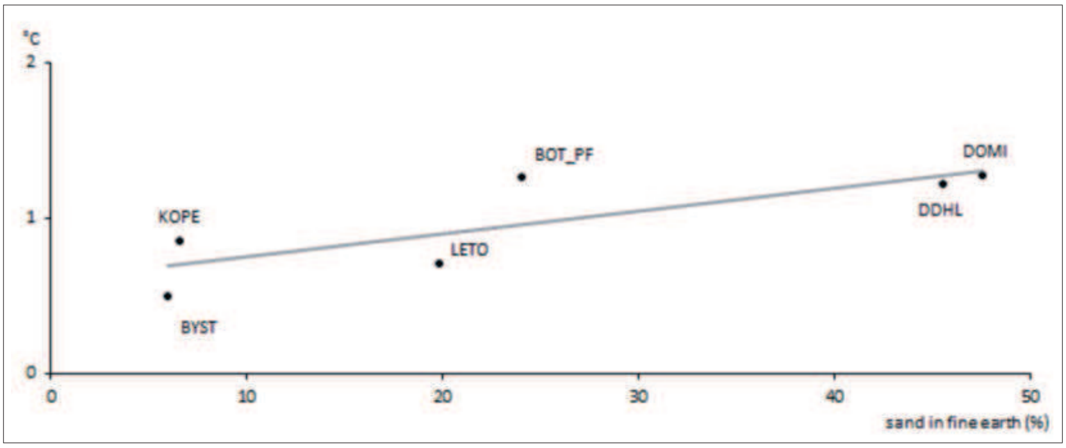

Fig. 8: Relation between the average diurnal soil temperature amplitude and the percentage of sand in fine earth, MESSO, 2010–2011

identified as well as their interactions. At the same time, for further research it is necessary to verify the feasibility of the approach presented here for soil temperature simulation. Therefore, we experimentally used a variable to quantify local soil temperature specifics in the soil temperature simulation.

The basic version of the Zheng et al. (1993) model calculated for Olomouc and its surrounding areas showed satisfactory results (Fig. 9). Subsequently, an implicit LGF variable was included to quantify the local specifics (in the sense of the influence of possible geofactors on the soil temperature) at each station. Thus, $F(J)$ can be expressed as

$$F(J) = [A(J) - A(J-1)]\ M_2 + E(J-1) \pm LGF$$

where

$$[+\ LGF \text{ for } A(J) < A(J_{11avg});\ -\ LGF \text{ for } A(J) > A(J_{11avg})]$$

and $A(J_{11avg})$ is the running average counted for the previous 11 days. The LGF was based on a comparative analysis of soil temperature regime and air temperature regime. At this time, the LGF variable that was used and the method used to establish it are not of essential importance, since the introduced procedure represents only the innovated approach principle.

The model with the LGF variable showed slightly better results than the original model (Fig. 10, Tab. 4). Consequently, an adjusted version of the model based on the 2010 data series was calculated for the year 2011, with the result that the R2 value decreased by only 0.05. To summarize, the model presented here might cover the spatial variability of soil temperatures with good results for Olomouc and its surrounding areas. Nevertheless, the LGF variable should be established empirically to obtain a better more applicable outcome of the research. However, the empirical determination of LGF requires long-lasting and more detailed measurements.

6. Conclusion and discussion

The analyses of MESSO soil temperature data series from 2010 and 2011 present essential information about the soil temperature regime in Olomouc and its surrounding areas. Based on analyses of the influence of meteorological factors, relief was identified as the most substantial geofactor determining the spatial variation of the soil temperature regime in Olomouc and the surrounding areas. The impact of relief on the soil temperature regime was associated primarily with atmospheric inversion, with the exception of the DDHL station where shading had an important role as well.

Station	A	B	C	D	E
DDHL	1.2	1.4	– 0.4	1.8	1.0
DOMI	1.2	1.5	– 0.3	1.8	1.0
BOT_PF	1.3	– 0.2	– 1.1	0.9	1.3
LETO	1.4	0.9	– 1.1	2.0	1.0
KOPE	1.6	1.5	– 1.0	2.5	1.2
BYST	1.2	1.4	– 0.6	2.0	0.9
Avg	1.3	1.1	– 0.8	1.8	1.1

Tab. 4: Results of experimental average daily soil temperature simulation accuracy at MESSO: A) Average error for the original model; B) Average correction for days with increasing air temperature; C) Average correction for days with decreasing air temperature; D) Absolute value of correction; E) Average error for LGF compacted model

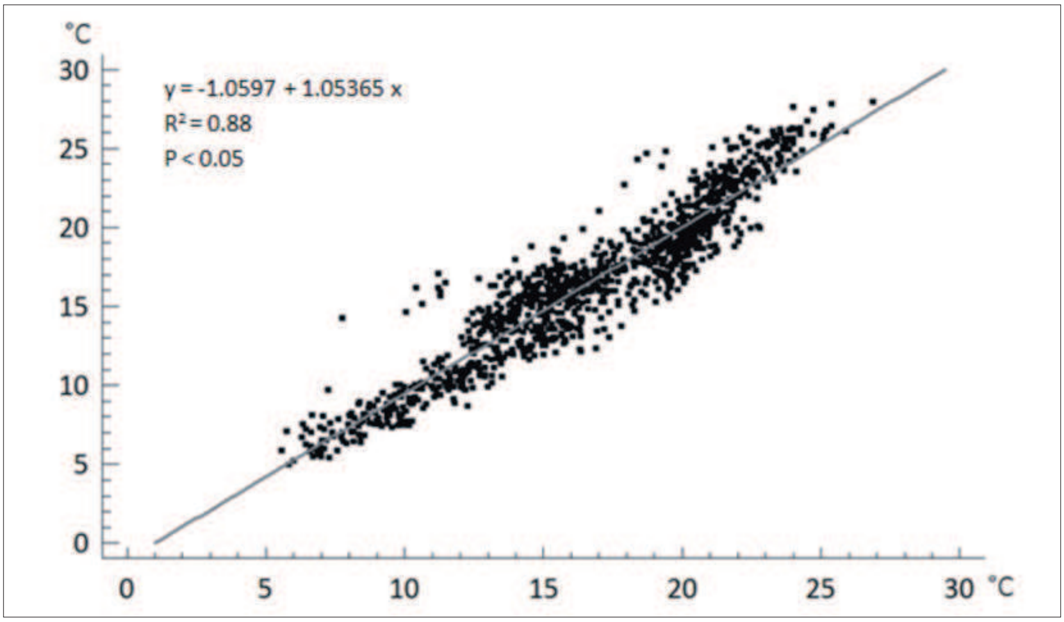

Fig. 9: Correlation between the measured and simulated average daily soil temperatures for the original model

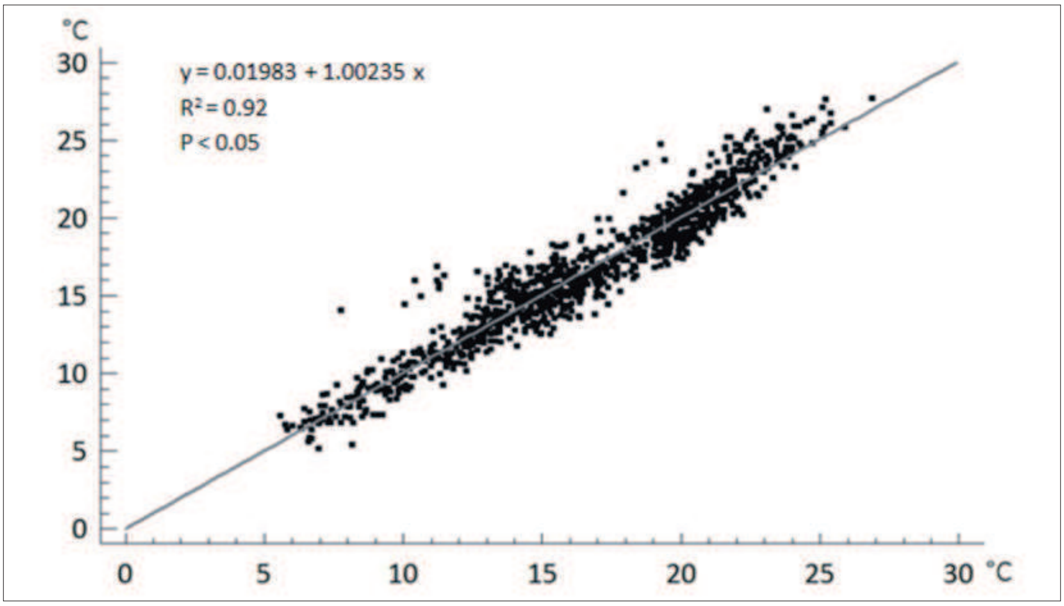

Fig. 10: Correlation between the measured and simulated average daily soil temperatures for the LGF modified model

Global radiation, as the most determinant factor influencing the soil temperature regime, was reduced by low cloudiness locally associated with air temperature inversion. Furthermore, the influence of the remaining cloudiness in terms of its spatial variation must be specified. Apart from the cloudiness itself, the instant impact of precipitation on soil temperature was confirmed. Therefore, the spatial and temporal variation of precipitation falling onto the Earth's surface may sharpen the spatial differences of soil temperature. Even a thin snow cover smoothed the soil temperature regime radically. For this reason, precise snow cover measurements should be made in further studies of soil temperature regime.

Since many authors have confirmed that soil properties have a significant influence on the soil temperature regime, the relation between the sand content in fine earth and daily soil temperature amplitude, as well as the relation between the soil humus content and daily soil temperature amplitude, were investigated. It was shown that there were no statistically significant relations between the values. Soils with a higher sand content in fine earth, however, seemed to have higher daily soil temperature amplitude. Moreover, the DDHL station with gleysol showed the second highest maximum temperature but also the lowest average annual temperatures. This is in agreement with Abu-Hamdeh et al. (2000) who found higher thermal conductivities in sandy soils than in clay loam soils. A further and more detailed analysis of physical and chemical soil properties would be useful to avoid confusion in the interpretation of the influences of local climate factors on the soil temperature regime.

The model developed by Zheng et al. (1993) can be considered a satisfactory tool for further attempts at interpretation and simulation of the spatial variability of soil temperature on a local scale. However, future attempts to interpret the variability of the soil temperature regime must be focused on a smaller area such as a pedotope. Then, the variability of the soil temperature regime at the regional level could be assessed, for example, by using methods of regional typology.

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References:

ABU-HAMDEH, N. H., REEDER, R. C. (2000): Soil Thermal Conductivity: Effects of Density, Moisture, Salt Concentration and Organic Matter. Soil science society of America Journal, Vol. 64, No. 4, p. 1290–1296.

BALLAND, V., ARP, P. A. (2005): Modeling soil thermal conductivities over a wide range of conditions. Journal of Environmental Engineering and Science, Vol. 4, p. 549–558.

BEDRNA, Z., GAŠPAROVIČ, J. (1980): Typy teplotného režimu pôd ČSSR. Geografický časopis, Vol. 38, No. 1, p. 60–77.

COUFAL, V., KOTT, I., MOŽNÝ., M. (1993): Národní klimatický program ČR: Teplota půdy v chladné části roku v období 1961–1991 na území České republiky. Český hydrometeorologický ústav, Praha, 37 pp.

DE VRIES, D. A. (1952): Het Wärmtegeleidingsvermogen van grond. In: Geiger, R., Aron, R. H., Todhunter, P.: The Climate Near the Ground. Rowman & Littlefield publishers, Inc., Lanham, p. 142–144.

ELIZBARASHVILI, E. S. et al. (2007): Specific Features of Soil Temperature Regimes in Georgia. Eurasian Soil Science, Vol. 40, No. 7, p. 761–765.

GEIGER, R., ARON, R. H., TODHUNTER, P. (2003): The Climate Near the Ground. Rowman & Littlefield publishers, Inc., Lanham, 584 pp.

GREEN, F. H. W., HARDING, R. J, OLIVER, H. R. (1984): The relationship of soil temperature to vegetation height. Journal of Climatology, Vol. 4, p. 229–240.

HANKS, R. J. (1992): Applied Soil Physics: Soil Water and Temperature Applications. Springer-Verlag, New York, 176 pp.

HOFMANN, G. (1955): Die Thermodynamik der Taubildung. In: Geiger, R., Aron, R. H., Todhunter, P. (2003): The Climate Near the Ground. Rowman & Littlefield publishers, Inc., Lanham, p. 124.

HORA, P. (2011): Vztah teploty půdy a různých půdních druhů. In: Středová, H., Rožnovský, J., Litschmann, T. [eds.]: Mikroklima a mezoklima krajinných struktur a antropogenních prostředí. Skalní mlýn 2 – 4. 2. 2011.

HORTON, R. HOCHSTER T. (2012): Soil thermal properties. In: Huan, P. M., Li, Y. Sumner, M. E [eds.]: Handbook of soil sciences: properties and processes. 2nd edition. Taylor & Francis Group, Boca Raton, p. 9.1–9.23.

KANG, S., KIM, S., LEE, OH. D. (2000): Predicting spatial and temporal patterns of soil temperature based on topography, surface cover and air temperature. Forest Ecology and Management, Vol. 136, p. 173–184.

KUTÍLEK, M. (1990): Hypotermické režimy půd. In: Němeček, J., Smolíková, L., Kutílek, M.: Pedologie a paleo-pedologie. Academia, Praha, p. 86–99.

LEHNERT, M. (2010): Příspěvek ke studiu místního klimatu na území Přírodního parku údolí Bystřice: Režim teploty půdy a vzduchu. Bakalářská práce. Univerzita Palackého v Olomouci, Olomouc, 85 pp.

LEHNERT, M. (2012): Režim teploty půdy v městské a příměstské krajině (Olomouc a okolí). Diplomová práce. Univerzita Palackého v Olomouci, Olomouc, 104 pp.

NOSEK, M. (1972): Metody v klimatologii. Academia, Praha, 434 pp.

OKE, T. R., HANNELL, F. G. (1966): Variation of temperatures within a soil. Weather, Vol. 21, p. 21–28.

POKLADNÍKOVÁ, H., ROŽNOVSKÝ, J., DUFKOVÁ, J. (2006): Promrzání půdy na stanicích Pohořelice, Vizovice a Bystřice nad Pernštejnem. Meteorologické zprávy, Vol. 59, No. 5, p. 135–140.

TESAŘ, M., ŠÍR, M., KREJČA, M., VÁCHA, J. (2008): Influence of vegetation cover on air and soil temperatures in the Šumava Mts. (Czech Republic). [on line]. IOP Conference Series: Earth and Environmental [cit. 6. 1. 2013]. Available at URL: http://iopscience.iop.org/1755-1315/4/1/012029/.

TOLASZ, R. et al. (2007): Atlas podnebí Česka. ČHMÚ v koedici s Univerzitou Palackého v Olomouci, Praha, Olomouc, 255 pp.

VYSOUDIL, M. et al. (2012): Podnebí Olomouce. Univerzita Palackého v Olomouci, Olomouc, 212 pp.

VYSOUDIL, M. (2008): Surface Atmosphere Layer Temperature Regime (Case Study of the Nature Park Bystřice River Valley, The Nízký Jeseník Highland, Czech Republic). Moravian Geographical Reports, Vol. 16, No. 3, p. 41–56.

VYSOUDIL, M. (2009): Klasifikace místních klimatických efektů. Geografický časopis, Vol. 61, No. 3, p. 229–241.

ZBÍRAL, J., HONSA, I., MALÝ, S. (1997): Analýza půd III: jednotné pracovní postupy. ÚKZUZ, Brno, 150 pp.

ZHENG. D., HUNT, R. E., RUNNING, S. W. (1993): A daily soil temperature model based on air temperature and precipitation for continental applications. Climate Research, Vol. 2, p. 183–191.

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CHANGES IN MIGRATION TO RURAL REGIONS IN THE CZECH REPUBLIC: POSITION AND PERSPECTIVES

Marie NOVOTNÁ, Jiří PREIS, Jan KOPP, Michael BARTOŠ

Abstract

Migration trends in the Czech Republic after 1990 are discussed in this paper. To evaluate the migration trends, the databases of immigrants and emigrants from the Czech Statistical Office from 1990 to 2010, are used. While migration from rural areas to urban areas prevailed in the past, after 1990 the direction changed: the population in rural areas with good natural and socio-cultural environments has been increasing due to migration. Small municipalities have a positive migration balance. We can conclude that these trends could be influenced primarily by social and environmental problems in cities, the increase in automobile use and the development of communication technologies, the migration of pensioners who settle in second homes, and the changing residential preferences of people and entrepreneurs.

Shrnutí

Migrační změny v rurálních regionech České republiky: stav a perspektivy

Článek hodnotí migrační trendy ve venkovských oblastech v České republice po roce 1990. K hodnocení byla použita databáze přistěhovalých a vystěhovalých Českého statistického úřadu za období 1990–2010. Zatímco v minulosti převažovala migrace z venkovských oblastí do měst, po roce 1990 se směr migrace změnil: počet obyvatel ve venkovských oblastech s dobrým přírodním a příznivým socio-kulturním prostředím roste díky migraci. Malé obce mají kladné migrační saldo. Lze předpokládat, že tyto trendy by mohly být ovlivněny především sociálními a ekologickými problémy ve městech, zvýšením motorizace a rozšířením komunikačních technologií, stěhováním důchodců do objektů druhého bydlení a změnami preferencí bydlení.

Keywords: *counterurbanization, migration, rural areas, Šumava area, Třeboň area, West Inner Periphery, Czech Republic*

1. Introduction

Rural areas constitute 73–82% of the Czech Republic land area (depending on specified criteria) and about 26–29% of the total population live in these regions. Their position and challenges are primarily evaluated and classified based on comparison with the main economic hubs (Hanousek et al., 2007). Common characteristics of such areas are lower levels of economic activity and depopulation. The potential for development can be the quality of the environment and that could bring many benefits. If these regions keep and protect their environment, they could encourage people living in large centres and other urban areas to move and to live there on a long-term basis. Our research project is focused on people migrating to rural areas due to the attraction of a better quality environment (both natural and social). This kind of population mobility is called "amenity migration", common in the Anglo-Saxon literature (Moss, 1994; Glorioso, 1999). The goal of amenity migrants is to attain a better quality of life by living in places with higher quality of natural, social or cultural environments.

This paper evaluates the following issues:

- if migration trends in the Czech Republic have changed since the year 2000; whether migration streams have altered; and whether people do migrate into rural areas;
- then we analyse migration streams and trends in detail in three case study areas with high quality environments. These case studies are the Šumava area, including the foothills (A), the Třeboňsko area (B), and the "West Inner Periphery" area (C), which is demarcated along the border of

the Plzeňský region, Ústecký region and the Středočeský region. We propose that these areas are drawing amenity migrants, given their natural and cultural potential.

This article is a revised and expanded version of the chapter: "Migration trends of inhabitants in rural space", which was published in the book "Amenitní migrace do venkovských oblastí České republiky" (Amenity Migration to Rural Areas in the Czech Republic – Bartoš et al., 2011).

2. Theoretical background

Migration is the most significant component in the spatial movement of populations. It dramatically influences population numbers and brings about changes in demographic, economic and social structures. There are predominantly negative impacts of those processes in the out-migration areas. The reduction of anthropogenic loading in an area left by emigrants, however, could have positive results. Conversely, in the in-migration areas, new people can become a fuel for future development, but also for anthropogenic loading on the territory.

Urbanization phases are defined in line with the theory of stages of urban development, according to the combined growth and decline of the urban centre and the urban fringe area (Ouředníček, 2000; Antrop, 2004). The theory of differential urbanization (Geyer and Kontuly, 1993) explains phases of urbanization as a diffusion wave. Antrop (2004) presents models of changing patterns of rural villages in Europe due to growth processes in the countryside. "Counterurbanization" is characterized as the third stage of urban development. The concept of "counterurbanization" is described by Mitchell (2004) as a migratory movement from "large" to "small" areas, as a negative relationship between settlement size and migration or as a negative relationship between settlement size and population growth.

Until the 1970s migration from rural areas to urban areas increased, but then this started to change. Boyle, Halfacree (1998) described the migration tendencies of the 1970s using the term "counterurbanization", a process in which people move from urban areas back to rural areas. Berry (1976) described this change in migration trends as well. Fielding (1992) carried out a deep analysis to verify these previously-mentioned changes and demonstrated the higher migration rates of people living in urban zones into rural settlements in the UK. This trend, however, has not been identified in all European countries, as indicated by Kontuly (1998). According to Walmsley (1998), counterurbanization in Australia (New South Wales) is long-standing as well. Migration processes from urban areas to the countryside in post-socialist countries have been discussed, especially with a focus on the phases of residential systems development according to the theory of differential urbanization (Kontuly and Geyer, 2003; Tammaru, 2003; Ouředníček, 2007; Šimon, 2011). Similar to the Czech Republic, migration from cities to rural areas was strengthened in Estonia in 1990s (Tammaru, 2003). However, it is not possible to unambiguously classify it in the model of differential urbanization (Kontuly, Geyer, 2003).

Suburbanization as a decentralizing migration process from urban areas generally prevails. It is not the only process, because residential deconcentration heads out of metropolitan areas too, especially to areas with predominantly rural traits (Šimon, Ouředníček, Novák, 2009). Berry (1976) calls both deconcentration processes, using the term "counterurbanization". It is not possible to consider "counterurbanization" as an opposite of the urbanization process, but rather as one of the follow-up processes (Šimon, 2011). An opposite term for urbanization could be considered "de-urbanization". Egan and Luloff (2000) use the term "exurbanization" for the process of urban people migrating to rural areas.

If we accept the concept of "counterurbanization" as a part of the urbanization process (Champion, 2001), then according to Čermák et al. (2009), both counterurbanization and suburbanization are taking place simultaneously in the Czech Republic, with a slight dominance of the first type of tendencies. At the same time, we can keep in mind other concepts of migration "from city to countryside", and thus consider "amenity migration" (Bartoš et al. 2011), "de-urbanization", "gentrification of countryside" (Phillips 2005 in Šimon, 2011, p. 233), exurban development (Taylor, 2009 in Šimon, 2011, p. 233) or peri-urban development (Fisher, 2003; Ford, 1999 in Šimon, 2011, p. 233). Such concepts consider a quality evaluation of particular migration processes.

Semantic differences between counterurbanization and suburbanization could be defined from a spatial point of view: the term "suburbanization" denotes a deconcentration of the population within the frame of a metropolitan region (city-hinterland), whereas counterurbanization describes interregional deconcentration (Šimon, 2006). However, the exact demarcation of the spatial frontier between suburbanization and counterurbanization is generally a purposefully-defined construction. Some authors demarcate this frontier through the evaluation of commuting (Escribano, 2007). Temelová et al. (2011)

note, however, that mobility (job and services commuting) is a crucial factor for rural people, even in peripheral areas, and thus can not be used for the demarcation of suburban space.

In the Czech Republic, strong urbanization is featured in this period. Champion (1998) provides explanations for migration from urban to rural regions but most of these can not be applied to the situation in the Czech Republic due to its political situation and central planning. Some of them, however, are applicable, such as the concentration of people from rural areas into local centres. Changes after 1990 can be accounted for by supported migration routes, suburbanization and counterurbanization. Counterurbanization could be influenced by the following reasons: more expensive living costs and social problems in cities; government donations for rural activities; more accessible and improved transport routes and communication technologies; improvement of education, health-care and other infrastructures in rural areas; increasing numbers of jobs in public/personal services; and economic recession influencing out-migration from rural areas to urban zones (Champion, 1998). Some factors (such as changing residential preferences of people and entrepreneurs) influence the suburbanization process to a greater extent, which is why it is necessary to analyze changes in public preferences.

Some migration streams from urban to rural areas could be classified as "amenity migration". There are two types of amenity migration: (i) a migration to ancient, culturally well-preserved downtowns of cities, and (ii) migration to rural conservation areas. Our research deals with the second type of migration – from urban areas to rural communities, where migrants find a pleasant and well-protected environment. Only a specific segment of the population has this preference. Some areas that suffered depopulation both in the past and present, are well protected environmentally, and thus have the potential to draw new residents. If these new migrants come, they may bring new lifestyles, attitudes and modern technologies.

A principal migration stream from urban to rural areas became significant in the USA and some countries of Western Europe in the 1970s. It decreased slightly in the 1980s but grew again in the 1990s (Stewart, 2002). This caused increasing population in formerly depopulated areas, especially in the mountain regions. It is one of the main change factors for rural areas in the USA (Stewart, 2002). This trend has not been explored in the Czech Republic as it did not take effect very much. Only migration to urban zones (urbanization) or migration from urban centres to the hinterlands of cities (suburbanization), have been explored. Moss (2006) has mentioned amenity migration in the region of Šumava in 1993, and other authors (see below) have been dealing with this issue from a sociological point of view.

The second type of amenity migration in Europe has been researched firstly in the Alps or Northern Europe: Perlik (2006) analysed the process of amenity migration in the Alps; Flogfeldt (2006) described the relationship between second homes and amenity migration in Norway; and Müller (2006) discussed the development of tourism related to amenity migration in the Swedish mountains (Tärna). The following researchers have addressed amenity migration in the Czech Republic: Librová (1994, 2003), Bartoš, Kušová (2005) and Bartoš et al. (2005). Librová (1994, 2003) discussed a specific group of amenity migrants, from a sociological point of view. She researched the reasons why people change their life habits and move from large cities to rural peripheral areas in order to live in a rural traditional way, in mostly uncultivated homesteads or farms. "Neo-ruralists", who are most inclined to a self-conscious defence of a rural way of life, are described by Gerlach, Lošťák and Mooney (2008) in the context of the "new social movements" paradigm in Eastern Europe, even evident in the communist era.

Bartoš et al. (2005) have analysed how tourism supports amenity migration. Rural migration can also be enhanced by the dynamic development of communication and information technologies (Reinöhlová, 2005). Rural space can become an option for locating businesses that are based on those technologies. In addition, the prices of the land in rural areas can be influential.

Some authors work with the optimistic hypothesis that amenity migration slows down the depopulation of rural space (e.g. Chipeniuk, 2004; Glorioso, 2000). Due to this fact the inequalities of various regions are reduced and environmental and cultural quality is enhanced. However, it must be questioned whether amenity migration to rural and periphery areas is just a phase of life (see Champion, 1998), and if there are variable tendencies found in different countries.

Second homes (using cottages for a certain part of the year), which is widespread in the Czech Republic, is considered fundamental to amenity migration. Moreover, this type of habitation is well mapped and there are various Czech scientists dealing with this topic, such as Bičík et al. (2001), Vágner, Fialová et al. (2004), or Bartoš et al. (2005).

The following analysis will deal only with permanent migration, because statistics about in-migration and out-migration are processed. Next, we need to assume that amenity migrants will be just a small part of the total number of migrants. Regardless, as a first step in the amenity migration analysis we will deal with migration and migration streams generally.

There is an interesting Czech survey related to the possible development of amenity migration, called "Our society" (Naše společnost). It was published by the Public Opinion Research Centre of the Sociological Institute in May, 2003. A sample of 1,048 people 15 years of age and older were interviewed. Though this survey was focused on how people are willing to move because of a new job, one of the most frequent reasons to move was not work, but rather dissatisfaction with living conditions in the place of residence (Lux et al., 2006). Based on this statement we consider the amenity migration research very important in order to discover internal migration trends in the Czech Republic, with special attention to migration trends to the rural areas of the Czech Republic.

3. Methodological approach

To study migration in the rural areas of the Czech Republic, it is necessary to define a rural area. The term "rural area" is mostly associated with villages, landscapes covered by agricultural land, forests, water bodies, and towns that are centres of local socio-economic development. It is also possible to use the term countryside.

Defining rural areas is not a simple issue and different countries use different criteria. It is obvious, however, that the terms "rural area" and "town" mingle, because features of urban life style penetrate into the furthest rural settlements (Müller, 2005). Generally, most of the socio-economic criteria cannot be used for more than one country at face value. The most common criterion is population density. OECD developed a definition in order to compare conditions in different areas. This definition distinguishes two hierarchical levels – local and regional. Rural areas on a local level are identified as areas with a density lower than 150 inhabitants per km^2. For our purposes, we analysed our case study using current administrative units, and the surface area of municipalities as of 1st January, 2010. A map of the distribution of rural areas in the Czech Republic is made according to this criterion. Rural areas defined on a local level cover 81.9 per cent of the territory of the Czech Republic and contain 29.5 per cent of the population.

OECD defines three types of region on a regional level – "predominantly" rural areas (more than 50 per cent of the population live in villages), "substantially" rural areas (15–50 per cent of the population live in villages), "predominantly" urban areas (less than 15 per cent live in villages). Those settlements where density is below 100 inhabitants per km^2 are defined as "villages".

From the regional point of view, "predominantly rural areas" occupy 22.6 per cent of the Czech Republic, with 8.5 per cent of the Czech population. "Substantially rural areas" occupy 62.8 per cent of the Czech Republic with 47.4 per cent of the population. "Predominantly urban areas" occupy 14.7 per cent of the Czech Republic with 44.1 per cent of the population. If there are less than 2,000 permanent inhabitants, the municipality is then called a "village" (OECD). Based on this criterion, villages occupy 72.8 per cent of the Czech Republic area, and contain 26.4 per cent of the Czech population.

We used these three OECD classifications ("local" rural areas, "regional" rural areas, and villages with a population less than 2,000 inhabitants) to evaluate migration. For this purpose we used statistical information about in-migration and out-migration during the period 1991–2010. Data about movements from 1991 to 2004 were taken from reports about change of address and migration (reporting units were Residence Registration Offices and Regional Foreign Police Offices). Since 2005 the Czech Statistical Office has taken over the data from the Ministry of the Interior and Headquarters of the Foreign Police Office. In order to characterize migrants demographically, the following variables are used: age, family status and citizenship. Migration itself is determined by the date of moving, and previous and current place of residence. The reasons for moving are very important, to find out whether the migration is or is not an amenity migration. However, this category has not been gathered since 2005.

To evaluate migration trends we used the databases of immigrants and emigrants of the Czech Statistical Office in the period 1991–2010. We calculated the balance for municipalities for two periods (1991– 2000 and 2001–2010). We then made categories of municipalities according to the balances that we had calculated. We created five categories, and of them two categories had a negative balance (significantly negative balance – more than 20% population decrease; negative balance – population decrease between 1% and 20%). The next category is characterized with a very small migration balance (between minus 1% to plus 1% of the population). Two categories are characterized with a positive balance (significantly positive with more than 20% population increase; positive – increase between 1% and 20% of population). The analysis of changes in migration trends was tested following Burt et al. (2009). Statistical analysis was carried out using chi-square tests of independence in contingency tables.

We chose three case study areas to provide detailed information and to analyse directions of migration to rural areas since 2000. These three case study areas are: Šumava (A), Třeboňsko (B) and "West Inner Periphery" (C). We chose to study these regions because we expected that their local environments would be very attractive for amenity migrants. We analyse the complete migration patterns with a special focus on villages with a population below 2,000 inhabitants, in order to distinguish urban centres. Using Geographical Information Systems, we processed maps that showed where people came from before moving, as well as where people from our regions of interest migrate to. Based on this spatial analysis we analyzed synthesis charts about immigrants and emigrants. Most of them belong to the category of economic migrants or their family members, who endeavour to improve their socio-economic position and standard of living. More often, the motive is more complex, and we considered the multifactorial determination of the migration process (Drbohlav, 2001). We still assume that the majority of migrants to rural areas are motivated by non-economic reasons (Lux et al., 2006). We propose that amenity migrants primarily move to areas with a high quality environment. For this reason, we decided to study in detail very environmentally precious areas – Šumava, Třeboňsko and the area between Křivoklátsko and Manětínsko subregions. We propose that amenity migrants come from cities most often. That is why we categorized municipalities as follows: municipalities in the studied region, cities with more than 50,000 inhabitants, and other municipalities in the Czech Republic or abroad. We expect that foreigners (e.g. Danish or Dutch people) also move into areas with high environmental quality located in our case study regions. Similarly, we evaluated data about people who left the regions. This analysis should describe directions and level of migration into rural areas. Then the research is oriented to amenity migration (in-depth interviews with important stakeholders in the particular region, as well as interviews with the amenity migrants themselves).

4. Characteristics of the case study regions

4.1 Case study of Region A: Šumava and its foothills

The Šumava mountains, including its foothills, was until the middle of the 1990s, an example of what can be called "the marginal area" (Těšitel, 1999) – low "economic performance", depopulation tendencies, state-limited investment into economic development, with a decrease of agricultural production intensity. Such areas are typical examples of the historical outlying periphery of the Czech Republic. However, due to its natural beauty and geographical location, tourism developed in the 1990s and has become the most important economic activity in this region. Another factor influencing the development of the area is the Šumava National Park (since 1991) and Protected Landscape Area (since 1963). They were both included in the UNESCO Biospheric reservations network under the umbrella of the international programme: Man and Biosphere. On one hand, both the National Park and the Protected Landscape Areas are considered high-quality environment guarantees and thus attractive for people. On the other hand, it creates some limits related to various economic activities, such as building construction for permanent residents out of existing municipalities (Kušová et al., 2008). This area is attractive for foreign amenity migrants due to the relative cultural and economic centres in the foothills of the Šumava Mountains and the possibility to exploit services in neighbouring Bavaria or Upper Austria (Glorioso, 1999). We carried out the majority of our interviews with amenity migrants just within the region of Šumava (Bartoš at al., 2008; Bartoš, Kušová, Těšitel, 2009). It turned out that out of the three case study regions, it is the Šumava Mountains which amenity migrants preferred the most as their final migration target.

The Šumava Mountains region is perhaps the most significant area in the Czech Republic according to the land use category measuring ecological quality (Perlín and Bičík, 2007). Ecologically important areas (forests, meadows, pastures and water bodies) exceed 10–20 times other areas, which are influenced by human activities (arable land, built-up and other areas). Mountain relief is typical for this territory, which is relatively more rugged when foothills turn to mountains in the central part of the Šumava Mountains. There are also other features of the landscape character: a valley phenomenon, plateaus, forests of unique size, and lower density.

We analyzed migration for the whole territory, which administratively belongs under the following municipalities: Sušice, Vimperk, Prachatice, Český Krumlov and Kaplice. There are 141 municipalities in this territory, but only 12 of them have more than 2.000 inhabitants. Besides municipalities with extended powers (with population 7,000–13,000 people), there are seven towns with populations between 2,000–4,200 inhabitants. The average size of a village with a population below 2,000 inhabitants is 496 people.

4.2 Case study of Region B: the Třeboňsko area and Česká Kanada

This case study region is situated in the south of the Czech Republic, in the Jindřichův Hradec district, crossing the historical border with Moravia. Thus the region can be divided into two separate parts – the

Třeboňská basin and the Česká Kanada highlands. The Iron Curtain influenced development here as it did not allow basic economic development. On the other hand it helped to preserve nature. This region has features of an "outward periphery" of the Czech Republic. The Třeboňsko region was added to the list of the UNESCO biospheric reservations in 1977 because of its huge natural resources potential. It was acclaimed a Protected Landscape Area in 1979. The water bodies in the Třeboňsko region are active places for nesting and bird migration. The original meanders of the rivers together with regularly flooded alluvial soil and woodland meadows were maintained. There are also extremely dry places of aeolian sands. Well-balanced natural segments of landscape and the unique and well-preserved architecture in towns and villages complement each other. From the "land use" point of view, the Třeboňsko region is a typical example of a pond landscape with a mosaic of water bodies, forests, meadows and grass lands.

The central part of the Česká Kanada area was proclaimed as a Natural Park in 2004. In comparison with the Třeboňsko area, this area is characterized by a more severe climate, vast forests and meadows, grasslands and ponds. Such a landscape character can bring to mind a comparison with lake areas in Canada.

Both areas have similar factors of attraction, which draw visitors and potential amenity migrants. These areas facilitate leisure-time activities such as hiking, cycling, water sports, picking mushrooms, fishing or hunting. Local inhabitants, however, do not consider tourism a major factor for economic development of the area. From an historical point of view, the local population has a stable character and they view newcomers suspiciously. Perhaps this is why it is possible amenity migrants are not as interested in moving to this area as much as they are to the Šumava Mountains area.

We analysed migration processes in the whole area, which administratively belongs to the municipalities with extended powers of Jindřichův Hradec and Třeboň. There are 83 municipalities in total and eight of them have more than 2,000 inhabitants. Besides municipalities with extended powers (with 22,000 inhabitants, respectively 8,800 inhabitants), there are six municipalities with a population between 2,000 and 3,700. The average size of the rest of municipalities (with populations below 2,000) is 331 inhabitants.

4.3 Case study of Region C: "West Inner Periphery"

This area is a typical example of the inner periphery of the Czech Republic. It borders three Czech regions – the Plzeňský, the Středočeský and the Ústecký regions. Typical features of this area are: low economic performance, long-term depopulation, a former orientation to agriculture and poor infrastructure. In the past, this area was less exposed, remote from main urban centres and from main transport arteries. A very important decrease of population took place right after the Second World War, when German-speaking people were displaced, especially from the western part of this area. It is a typical agriculture - forest landscape. On the east it borders the Křivoklátsko Protected Landscape (since 1978) and the Biospheric Reservation of Křivoklátsko (1977), whose core area is currently being considered for national park status. The Rakovnicko area – peripheral to the Středočeský region – has good potential due to the natural, cultural and historical heritage, and it can be used for tourism development or amenity migration inducement. There are various attractive areas around the rivers Střela (Fig. 1 – see cover p. 4), Javornice, Berounka, and the entire Křivoklátsko. On the east of the Křivoklátsko, suburbanization influenced by the capital Praha (Prague) can be observed.

The territory of case region C is divided into a few landscape units. Forested hill country in the western part of the territory represents a region, whose structure was harmed right after World War Two. Manětínsko has a varied agricultural landscape with more rugged terrain and dominant morphological features, such as neo-volcanic forested table mountains. The settlement structure is characterized by small and architectonically precious localities. The middle part of Kralovicko is characterized by a higher proportion of arable land. The landscape quality is lower, but transport accessibility to Plzeň is very good. The territory then continues to Křivoklátsko, where forests prevail (in particular places even the original forest occurs) and it makes this area ecologically stable (Kopp, Novotná, 2008). The landscape characteristics are influenced very much by the deep canyons of the Berounka and Střela rivers and their tributaries. Forested valleys that are almost untouched create a foundation for the ecological landscape network. There are dominating rock outcrops on the steep elevations of valleys, sometimes highlighted by historical remains of medieval castles (Křivoklát, Rabštejn) or castle ruins (Krašov). Some sections of the valleys became targets for second houses: in particular for people from Praha, Plzeň (Pilsen) and the Most area.

We analysed almost the entire territory under the authority of Kralovice and Rakovník (municipalities with extended power), but excluded the territory under the influence of Plzeň and Praha because of the good transport system. For the same reason we excluded areas administrated by Nové Strašecí and Plasy municipalities. The area comprises 96 municipalities. Only two municipalities have more than 2,000 inhabitants and they have extended power (16,000 and 3,500 inhabitants). The average population of municipalities with population under 2,000 people is 379 inhabitants.

5. Results

5.1 Migration in rural areas

The population changes of municipalities in the Czech Republic between 1991 and 2010 demonstrate an increase of the number of inhabitants, especially in suburbanized areas around cities (Fig. 2).

Based on an analysis of the population size of municipalities, it is clear that the population increased after 2000 in 71 per cent of municipalities defined as rural at the local level, and in 57 per cent of rural municipalities at the regional level (see Table 1). Compared to the 1990s, the number of rural municipalities with increasing population was 37 per cent (local level) higher or 26 per cent higher (regional level). We can see that the "counterurbanization" process, which took place in both the USA and Western Europe, has started in the Czech Republic too. The change of the population size in rural municipalities measured on a regional level shows that villages in semi-rural regions are the

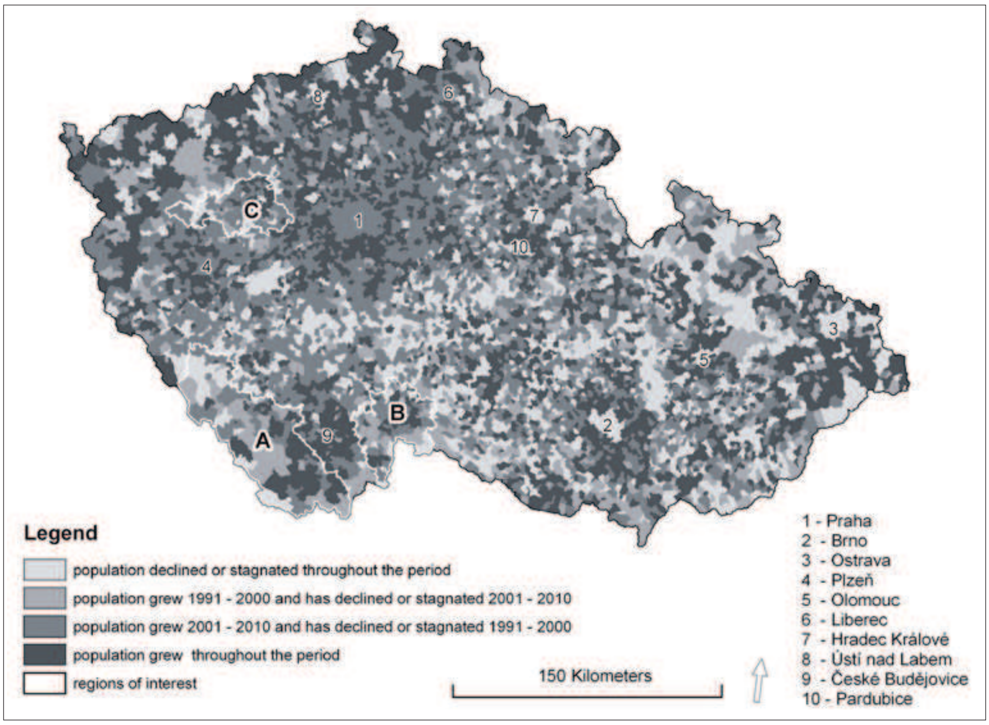

Fig. 2: Population changes in the municipalities of the Czech Republic in 1991–2010 (A – Šumava and its foothills region; B – Třeboňsko area and Česká Kanada; C – West Inner Periphery region)
Source: Czech Statistical Office (ČSÚ, 2011), Authors' elaboration

Type of region		1	2	3	4
		%			
Local level	urban	18.3	13.7	20.5	47.6
	rural	**16.4**	**12.4**	**38.9**	**32.3**
Regional level	urban	6.8	8.0	27.1	58.1
	semirural	16.8	11.9	39.0	32.4
	rural	**23.6**	**19.1**	**33.8**	**23.4**
Municipalities with more than 2000 inhabitants		26.0	19.9	19.0	35.1
Municipalities less than 2000 inhabitants		**15.5**	**11.7**	**38.6**	**34.2**
All municipalities		16.6	12.6	36.5	34.3

Tab. 1: Classification of municipalities by type of region: development of population size, 1991–2010
1 – number of inhabitants was decreasing in whole period 1991–2010; 2 – number of inhabitants increased in period 1991–2000, in period 2001– 010 decreased or stagnated; 3 – number of inhabitants decreased or stagnated in the period 1991–2000 and increased in period 2001–2010; 4 – number of inhabitants increased in whole period 1991–2010
Source: Czech Statistical Office, 2011, Authors' elaboration

fastest growing. The growth of urban regions is still obvious and we can still observe strong suburbanization processes. The results of size differentiation among the municipalities could be explained likewise. As for the age structure of rural municipalities, an older population predominates (ČSÚ, 2010). Population development thus influences the natural rate that has been decreasing. In spite of the fact that the population in rural areas naturally decreases, migration into those regions can be considered significant.

Figure 3 shows the regional differentiation in the balance of migration in the period 1991–2000, and Fig. 4 depicts regional differentiation in the following period (2001–2010).

In the period 2001–2010, the ratio of municipalities belonging to the category "rural area" on a local level, and also with a positive migration balance, was 25.0 per cent higher than in 1991–2000. In contrast, the ratio of municipalities with significantly negative balance decreased. On a regional level we can see a similar trend: there was a 20.1 per cent increase in the category of municipalities in rural areas with a positive migration balance, comparing the period 2001–2010 with 1991–2000. Again, a significant decrease of municipalities with a significant negative migration balance was recorded (see Table 2). Chi-square tests of independence in the seven contingency tables revealed very significant changes of migration trends between the periods 1991–2000 and 2001–2010 for all categories of municipalities, but somewhat less for those municipalities with more than 2,000 inhabitants or urban areas on a local level.

After 2000, the migration turnover grows. More people move and rural areas are significantly involved in this process. The data in Table 3 show that an in-migration ratio into rural areas in 2001–2010 was minor in comparison with the period 1991–2000, but this figure is influenced by the fact that foreign in-migration to urban areas significantly increased after 2000.

In the previous analysis no migration directions are measured and observed. It is not just currently measurable in adequate ways to distinguish if people move in the frame of particular region types, or among individual types. These directions could be partly described by analysis of "inter-district migration" (Fig. 5). However, this regional division is not appropriate for research in rural areas. Hence, we researched migration in detail in the case study areas, which had been divided into certain categories.

5.2 Migration in the case study regions

The absolute number of immigrants and emigrants has been growing in all case study regions since 2000. The Chi-square tests (df = 6) revealed that there are no significant differences between the relative structure of migration to or from the three case regions in the period 2000–2007 (see Tabs. 4 and 5). In all three case regions, the population increased in those

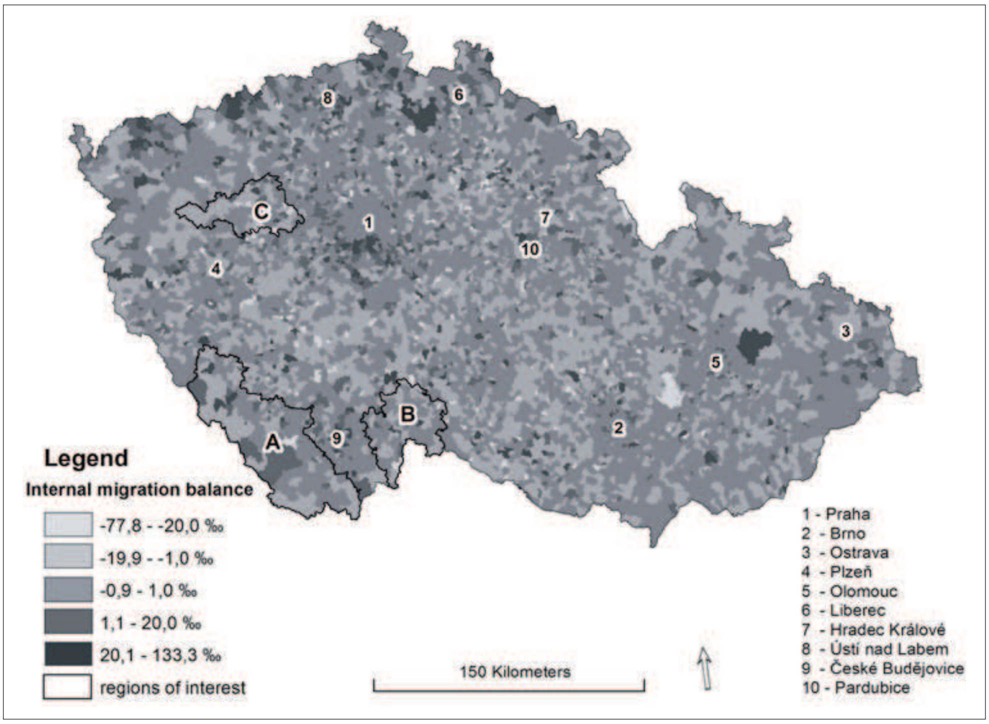

Fig. 3: Internal migration balance in the municipalities of the Czech Republic, 1991–2000
Source: Czech Statistical Office (ČSÚ, 2011), Authors' elaboration

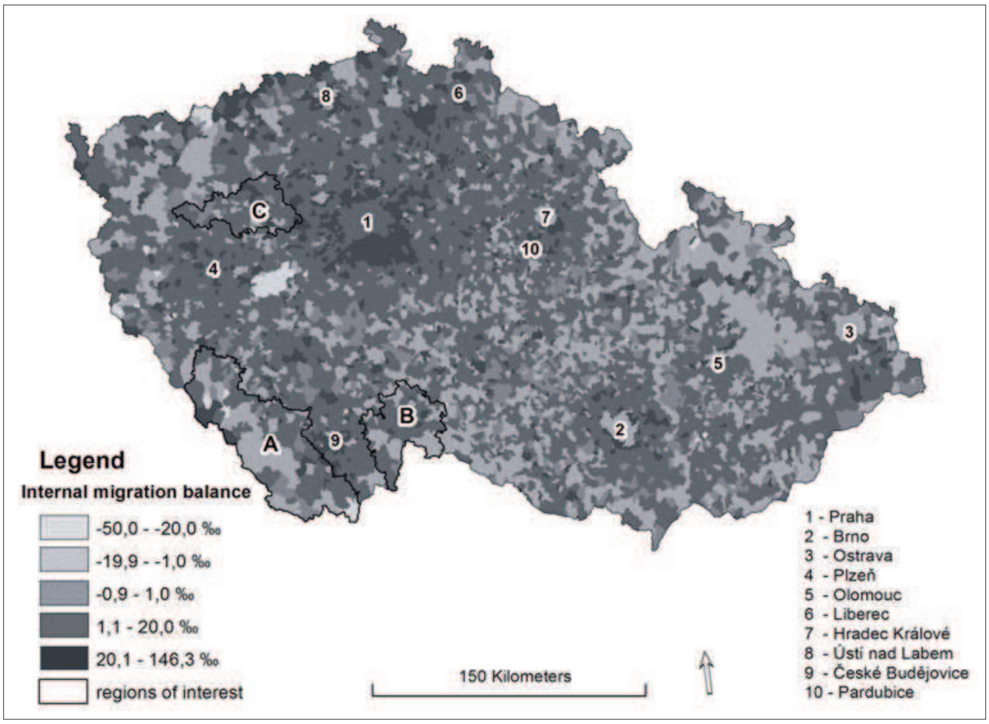

Fig. 4: Internal migration balance in the municipalities of the Czech Republic, 2001–2010
Source: Czech Statistical Office (ČSÚ, 2011), Authors' elaboration

Type of region		**Significantly negative**	**Negative**	**Neutral**	**Positive**	**Significantly positive**	**Total**	**chi-square test**
Local level	urban area 1991-2000	1	194	123	484	39	841	
	urban area 2001-2010	1	191	86	407	156	841	83.43
	rural area 1991-2000	177	2,087	623	2,321	197	5,405	
	rural area 2001-2010	34	1,057	442	3,218	654	5,405	855.79
Regional level	urban area 1991-2000	9	172	78	537	56	852	
	urban area 2001-2010	2	78	39	500	233	852	162.52
	semirural area 1991-2000	129	1,629	534	1,880	146	4,318	
	semirural area 2001-2010	18	862	373	2,564	501	4,318	648.62
	rural area 1991-2000	40	480	134	388	34	1,076	
	rural area 2001-2010	15	308	116	561	76	1,076	97.78
Municipalities with more than 2000 inhabitans 1991–2000			170	135	346	18	669	
Municipalities with more than 2000 inhabitans 2001–2010			221	86	316	46	669	31.13
Municipalities with less than 2000 inhabitans 1991–2000		178	2,111	611	2,459	218	5,577	
Municipalities with less than 2000 inhabitans 2001–2010		35	1,027	442	3,309	764	5,577	926.43

Tab. 2: Typological characteristics of municipalities in the Czech Republic by migration balance
Source: Czech Statistical Office, 2011, Authors' elaboration

Type of region classification		Area ratio	Population ratio (2010)	In-migrants (average figure per 1 year)				Out-migrants (average figure per 1 year)			
				1991 – 2000		2001 – 2010		1991 – 2000		2001 – 2010	
				total	%	total	%	total	%	total	%
Local level	urban	18.1	70.6	123,144	62.8	181,459	66.3	120,110	64.1	168,771	69.8
	rural	81.9	29.4	73,083	37.2	92,351	33.7	67,385	35.9	73,158	30.2
	total	100.0	100.0	196,227	100.0	273,810	100.0	187,505	100.0	241,929	100.0
Regional level	urban	14.7	44.1	72,745	37.1	120,333	43.9	69,186	36.9	101,920	42.1
	semirural	62.8	47.4	101,885	51.9	129,260	47.2	97,016	51.7	117,257	48.5
	rural	22.5	8.5	21,597	11.0	24,217	8.8	21,303	11.4	22,752	9.4
	total	100.0	100.0	196,227	100.0	273,810	100.0	187,505	100.0	241,929	100.0
Municipalities with more than 2000 inhabitans		27.2	73.6	130,008	66.3	184,462	67.4	127,451	68.0	175,948	72.7
Municipalities with less than 2000 inhabitans		72.8	26.4	66,219	33.7	89,348	32.6	60,054	32.0	65,981	27.3
Total		100.0	100.0	196,227	100.0	273,810	100.0	187,505	100.0	241,929	100.0

Tab. 3: In-migrants and out-migrants by rural or urban regions classified on local and regional levels, and municipalities classified according to size in the Czech Republic
Source: Czech Statistical Office, 2011, Authors´ elaboration

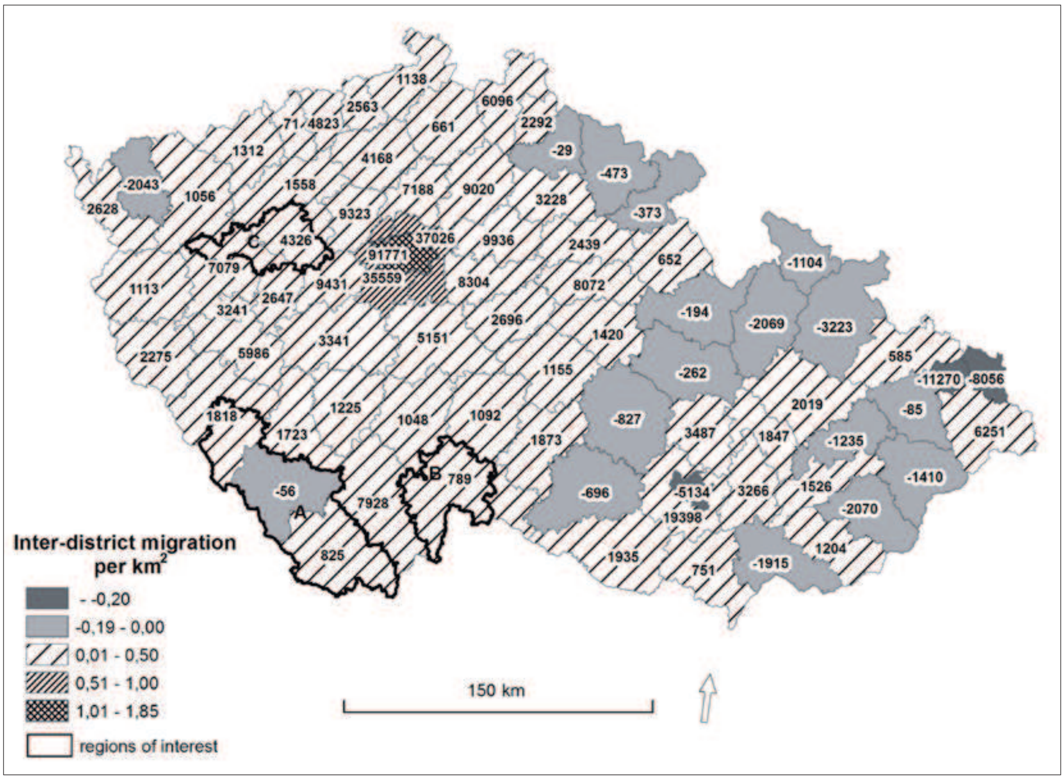

Fig. 5: Inter-district migration in the Czech Republic, 2002–2010
Source: Czech Statistical Office (ČSÚ, 2011), Authors' elaboration

Region	Migration within the region	Migration from cities	Migration from other parts of the Czech Republic	Foreign (Internationa) migration	In-migrants – total figure	chi-square test
	%					
Šumava – municipalities with less than 2000 inhabitans	48.8	11.9	24.9	14.4	17,107	
Třeboňsko – municipalities with less than 2000 inhabitans	57.8	9.8	26.4	5.9	6,027	
West Inner Periphery – municipalities with less than 2000 inhabitans	42.1	15.6	33.4	9.0	8,624	9.14
Šumava – municipalities with more than 2000 inhabitans	45.0	12.4	25.2	17.3	13,125	
Třeboňsko – municipalities with more than 2000 inhabitans	42.6	10.7	36.5	10.2	7,707	
West Inner Periphery – municipalities with more than 2000 inhabitans	37.2	10.7	33.5	18.6	3,635	5.76
Šumava region total	47.1	12.1	25.0	15.7	29,595	
Třeboňsko region total	49.3	10.3	32.1	8.3	13,734	
West Inner Periphery region total	40.6	14.1	33.4	11.8	12,259	

Tab. 4: In-migration to case study regions 2000–2007
Source: Czech Statistical Office (ČSÚ, 2008), Authors' elaboration

Region	Migration within the region	Migration to cities	Migration to other parts of the Czech Republic	Foreign (International) migration	Out-migrants – total figure	chi-square test
	%					
Šumava – municipalities with less than 2000 inhabitans	53.0	11.2	28.6	7.2	14,208	
Třeboňsko – municipalities with less than 2000 inhabitans	56.8	8.3	31.8	3.1	5,025	
West Inner Periphery – municipalities with less than 2000 inhabitans	47.3	13.3	36.4	2.9	6,791	5.66
Šumava – municipalities with more than 2000 inhabitans	46.0	15.8	29.7	8.4	13,932	
Třeboňsko – municipalities with more than 2000 inhabitans	47.6	13.6	33.6	5.1	8,220	
West Inner Periphery – municipalities with more than 2000 inhabitans	47.4	13.3	31.5	7.8	3,729	1.41
Šumava region total	49.5	13.5	29.1	7.8	28,140	
Třeboňsko region total	51.1	11.6	32.9	4.4	13,245	
West Inner Periphery region total	47.4	13.3	34.7	4.6	10,520	2.12

Tab. 5: Out-migration from case study regions 2000–2007
Source: Czech Statistical Office (ČSÚ, 2008), Authors' elaboration

municipalities with less than 2,000 inhabitants, but the municipalities with more than 2,000 inhabitants registered decreases (Fig. 6).

Between 40 and 50 per cent of migrants stay within the regions, and migration to small municipalities prevails. Migration from cities with more than 50,000 inhabitants into the regions accounts for some 10 per cent of in-migrants. This tendency is most obvious in the West Inner Periphery region. The ratio of migration from other parts of the Czech Republic to these regions is from one quarter to one third. The further away the region is located, the weaker the migration stream is (Fig. 7 and 9). In-migration from outside of the Czech Republic always exceeds the reverse. Immigration from abroad is higher than migration from cities in the Šumava region.

Most of the in-migrants coming from the cities can be considered "amenity migrants", moving to the countryside for a better environment or cheaper housing, even though parcels of land in the case study regions are expensive (Bartoš et al., 2008; Bartoš, Kušová, Těšitel, 2009). The rate of migration from cities to the countryside in particular regions is as follows: in the Šumava region 12 per cent; in the Třeboňsko region 10 per cent; and, in the West Inner Periphery 14 per cent (Fig. 7). Migrants from cities move to small municipalities in particular in the Šumava (Fig. 8 – see cover p. 4) and West Inner Periphery regions, which is definitely caused by the good quality of environment there. Migration to municipalities with more than 2,000 inhabitants slightly prevails in the Třeboňsko region. Local towns such as Třeboň, Jindřichův Hradec, similar to Sušice, Prachatice and

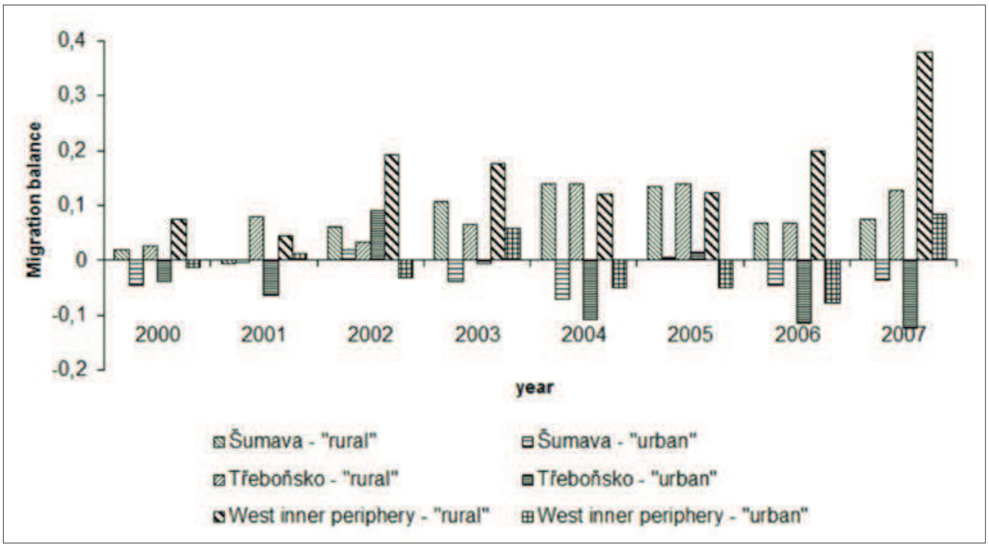

Fig. 6: Migration balance in case study regions, 2000–2007
Source: Czech Statistical Office (ČSÚ, 2008), Authors' elaboration

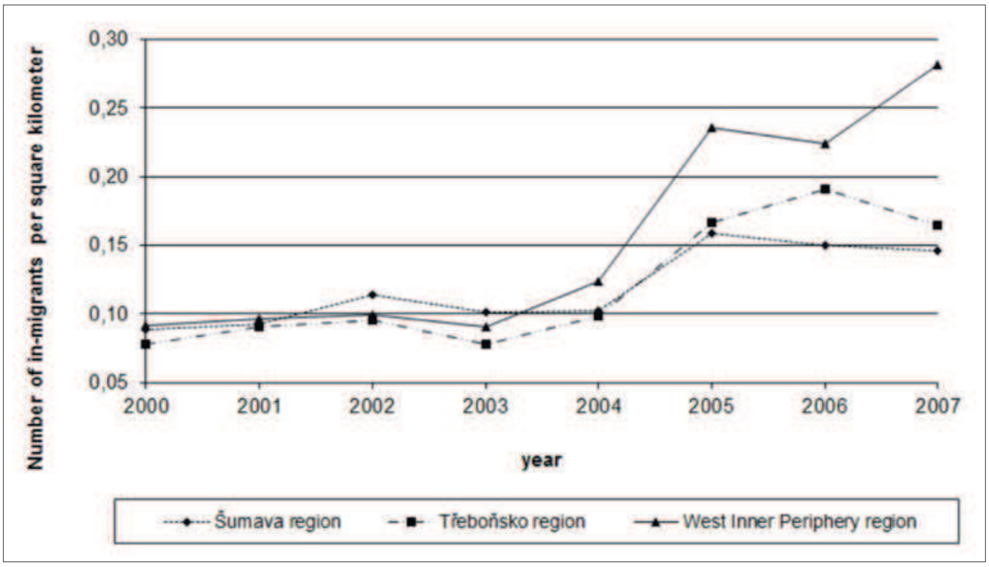

Fig. 7: Migration from cities to case study regions, 2000–2007
Source: Czech Statistical Office (ČSÚ, 2008), Authors' elaboration

especially Český Krumlov in the Šumava region, can draw both Czech and international migrants due to their historical features. Thus "cultural amenity" migration can be defined.

Migration from foreign countries grew rapidly from 2000 to 2003, then it stagnated, but since 2006 it has grown again (Fig. 9). Most international immigrants are not amenity migrants but are labour migrants from the Ukraine, Slovakia and Vietnam, who head to these regions primarily. Amenity migrants come from Germany, the Netherlands, USA, France, Denmark or Belgium (see Table 6).

6. Discussion

The current state and perspectives on migration into the rural areas of the Czech Republic have to be put into the context of societal change during the era of socialism.

During the twentieth century, migration especially to towns took place in the Czech Republic. From the 1960s to the 1980s migration distances gradually diminished and regions and districts were closed to migration. During that time period people migrated primarily to medium-sized municipalities (between 10,000 to 50,000 inhabitants), because they

Immigrants to the Šumava region	Number	Immigrants to the Třeboňsko region	Number	Immigrants to the West Inner Periphery region	Number
Germany	176	Austria	43	Germany	23
Austria	123	Holland	33	France	19
Holland	83	Germany	28	USA	13
USA	36	the USA	18	United Kingdom	12
Italy	15	Italy	10	Holland	4
United Kingdom	14	Canada	8	Denmark	3
France	12	Switzerland	6	Switzerland	3
Switzerland	12	United Kingdom	3	Australia	2
Canada	9	Belgium	2	Italy	2
Australia	5			Japan	2
Israel	5			Austria	2
Denmark	3				
Belgium	2				
Total	**495**	**Total**	**151**	**Total**	**85**

Tab. 6: International migrants from developed countries to case study regions 2000–2007
Source: Czech Statistical Office (ČSÚ, 2008), Authors' elaboration

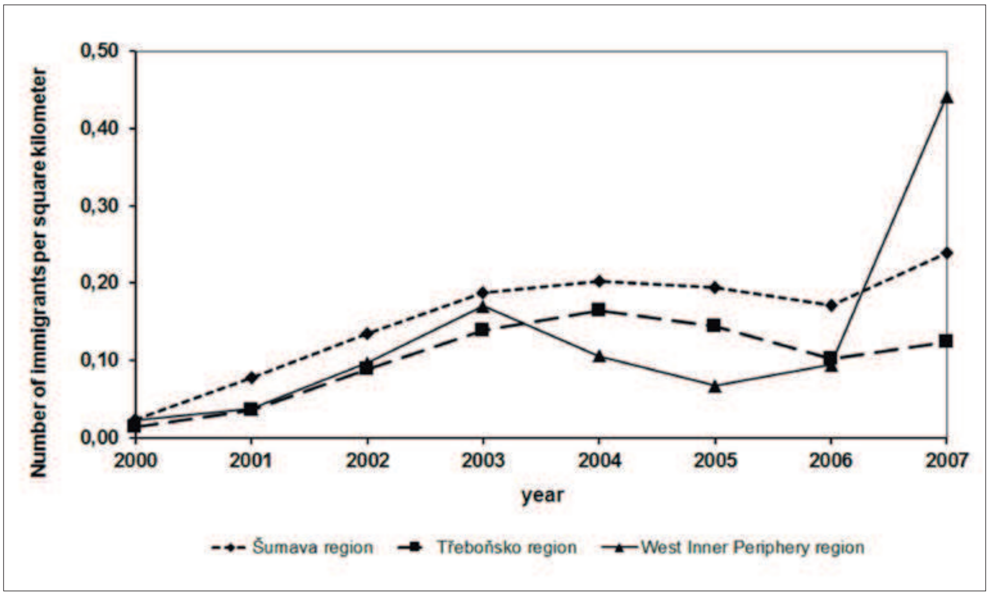

Fig. 9: Foreign immigrants to case study regions, 2000–2007
Source: Czech Statistical Office (ČSÚ, 2008), Authors' elaboration

were the most attractive due to lots of investment and construction (Pavlík, Kučera, 2002). Essentially the municipalities became homogenized, especially the centres. Migration was weakened and particular centres became similarly important. Small municipalities and the capital Praha suffered most due to this "socialist migration policy". Praha remained naturally attractive for continuous migration, but the state used several tools to prevent this natural attractiveness, as well as sub-urbanization processes (Pavlík, Kučera, 2002).

The situation in the Czech Republic was due to the fact that people moving to urban areas still used properties in rural areas as recreational places. The second house had become (and still is) a very important phenomenon in the Czech Republic. It has developed since the 1950s and correlates with human efforts to draw nearer to nature. Secondly, the development of second houses during socialism was also connected to limited possibilities for travelling and leisure time activities (Vágner, Fialová, 2004). Hence, at the beginning of the 1990s a decrease in the importance of second houses is recorded. However, after 2000 second houses seem to acquire a new importance once again. Some owners of rural properties could be considered amenity migrants, because they stay more than a half-year in their cottages and summer houses. They are mostly pensioners who do not have many commitments or obligations.

After 1989 a decrease in internal migration is recorded. There were two reasons: first, a bad situation in the market with properties with regulated rents, problems with restitutions, and some aspects of tenure reform, as discussed by Lux, Sunega (2010); and secondly, due to the specific Czech mentality related to proprietorship. While the statistics show that 220,000 people moved during 1989, the number decreased to 160,000 in 1996. The process of spatial mobility of the population thus decreased, and the process of concentration of the population had stopped (Pavlík, Kučera, 2002).

The balance of migration in the smallest villages in 1992 was significantly negative, and the population was decreasing due to migration also in towns with more than 20,000 people. During the 1990s, towns with 5,000 inhabitants and less became the most attractive for migrants (Pavlík and Kučera, 2002). In contrast, towns with 10,000 and more inhabitants lost their residents. Decentralization thus occurred – the most attractive destinations are those towns that are situated outside of the administrative borders of larger municipalities. Praha is the most obvious example of such a trend – its population has been decreasing since 1990 (in 1999, the population balance was – 4,000 inhabitants). Clearly, this is the suburbanization process[1] (Pavlík and Kučera, 2002; Müller, 2009).

The suburbanization process was analysed by Ouředníček (2007) in the various localities of the Praha urban region in the period 1995–2003. In addition, there is a growing importance of suburbanization around the major Hungarian, Polish and Slovak cities after 1990 (Kok, 1999; Drgoňa, Turnock, 2000).

Based on a spatial analysis of statistical data, we have determined that migration to rural areas which are further from urban centres has been growing since 2000. Rural space has become a socio-economically differentiated territory. Similarly, many of the more remote villages with low unemployment in Hungary's rural periphery also experienced net in-migration during the post-socialist transformation (Brown, Schafft, 2002).

Rural space in the Czech Republic is quite differentiated too, as demonstrated by the new typology developed by Perlín, Kučerová and Kučera (2000), based on a components analysis of statistical indices. The Šumava region is classified in this typology as a "recreationally problematic countryside" or as an "intensive recreational area". The regions of Třeboňsko and the West Inner Periphery are considered to be both "recreationally problematic countryside" and "core countryside". We need to mention that the "core countryside" type is impacted partially by the suburbanization processes around large cities (Praha, České Budějovice). Meanwhile, the "recreationally problematic countryside" and "intensive recreational area" types represent those areas where differentiated increase of in-migration has been identified after 2000. Potentially, this increase correlates with amenity factors.

An interesting tendency of the decentralization of settlement is now appearing, specific to the Czech countryside and towns (Librová, 2007). Librová's research assumes that the most significant factor in this movement is the desire of many people to flee from the large cities and industrial agglomerations in order to live in a healthy environment. Besides that desire, there is also the zeal to change one's life style, "which may be a significant phenomenon that responds to the historically unprecedented power of impulses generated by modern cities and by the modern era in general" (Librová, 1997, p. 38 – translated from the Czech original).

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[1] Suburbanization processes (negative balances) have taken place in Brno (1,300 people), Plzeň (600 people), Olomouc (400 people), Liberec and Hradec Králove (both 300 people).

Research focused on amenity migration (in-depth interviews with important stakeholders in the particular regions, as well as interviews with the amenity migrants themselves) then the statistical analysis was carried out. The research shows that two thirds of the respondents – amenity migrants – understand "amenities" as nature, landscape, a healthy environment and quiet places (environmental reasons), 10% see "amenities" as the possibility to own a garden or their own housing, and for 6% "amenities" means the possibility to be left alone on their own with a degree of privacy (Bartoš, Kušová and Těšitel, 2009). In the context of the push-pull theory of migration (Halliday, Coombes, 1995; Brown, Schafft, 2002), it was discovered by Bartoš, Kušová and Těšitel (2009) that the main reason for moving into a new rural place of residence was a positive attitude toward nature and landscape (main pull factor), and bad environment at the former place of residence (main push factor). The important impact of environmental factors influencing migration (quality of environment; calm; natural values of the territory) has been demonstrated in the research work of Šimon (2012), who studied such factors in model areas of the remote Czech countryside.

7. Conclusion

The post-socialist development of internal migration in the Czech Republic is characterized by prevailing suburbanization in the hinterlands of large cities. It turns out that the migration rate to rural areas that are farther away from urban centres has been growing since 2000. While in the past migration from rural areas to urban areas prevailed, currently the direction is the opposite: the population in rural areas with good natural and socio-cultural environments has increased because of migration. All small municipalities in the case regions have a positive migration balance, except small municipalities in the Třeboňsko region, which have a slightly negative balance with municipalities out of their region. Municipalities in the case regions with more than 2000 inhabitants have a negative balance in comparison to small municipalities within their region and with cities in the Czech Republic.

In contrast, they have a significantly positive balance with immigrants from outside of the Czech Republic. We can propose that these trends are influenced primarily by the importance of savings as well as social problems in cities, the increase in motorization and communication technologies development, the increasing migration of pensioners, who settle in properties of second housing, and changes in the residential preferences of people and entrepreneurs. These trends can be due to the developing amenity migration into the areas with a well-preserved environment. Theoretically this phenomenon could be identified as a start of counterurbanization in the Czech Republic. With respect to the environmental motives for amenity migration discovered in some case study areas (Bartoš et al., 2008; Bartoš, Kušová and Těšitel, 2009), the phenomenon of counterurbanization according to Mitchell (2004) could be classified rather as ex-urbanization or anti-urbanization. The increase in migration can be positively fuelled by human potential, but on the other hand can cause pressures on the landscape (Moss, 1994, 2006). This process is already observed in the hinterlands of large cities (Antrop, 2004; Ouředníček, 2007). That is the rationale for continuing to research new forms of rural settlements and the identification of negative impacts that are rooted in the conflicts between the needs of society and traditional rural landscape structures.

This article has dealt with counterurbanization using two different criteria or scales of enquiry: (i) at the level of the entire territory of the Czech Republic, and (ii) at the level of the case study regions. At the national level, migration processes highlight that the growth of population in small municipalities is significantly caused by suburbanization processes. That is why different exposures of counterurbanization have been found in different regions. The source of the migration rate is due not only to the stakeholders of amenity migration. The following reasons for migration to rural areas, as Boyle, Halfacree (1998) stated, could be specified for the studied regions: the accelerated migration of pensioners supported by the strong tradition of second homes, cheaper living costs in rural areas, improved transportation and communication technologies, as well as changing preferences of productive-age people and businessmen for living places. As Šimon (2011) points out, if counterurbanization is being studied, it is necessary not only to quantify changes in population distribution, but also to explore the qualitative shift of the population distribution itself and its purpose. Currently, there are more detailed investigations taking place in particular case study areas (Bartoš et al., 2011; Šimon, 2012).

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References:

ANTROP, M. (2004): Landscape change and the urbanization process in Europe. Landscape and Urban Planning, Vol. 67, p. 9–26.

BARTOŠ, M, KUŠOVÁ, D. (2005): „Amenitní" migrace jako specifická forma globální migrace obyvatel a její vliv na kvalitu života. Životné prostredie, Vol. 39, No. 6, p. 315–318.

BARTOŠ, M., KUŠOVÁ, D., TĚŠITEL, J. (2009): Motivation and life style of the Czech amenity migrants (case study). European Countryside, Vol. 1, No. 3, p. 164–179.

BARTOŠ, M., KUŠOVÁ, D., TĚŠITEL, J. (2005): Amenity migration and tourism. In: Hasman, M., Šittler, E. [eds.]: Sustainable development and Tourism. Tábor: Faculty of Agriculture, Department of Travel Trade, p. 7–21.

BARTOŠ, M., KUŠOVÁ, D., TĚŠITEL, J., KOPP, J., NOVOTNÁ, M. (2008): Amenity migration in the context of landscape-ecological research. Journal of Landscape Ecology (CZ-IALE), Vol. 1, No. 2, p. 5–21.

BARTOŠ, M. et al. (2011): Amenitní migrace do venkovských oblastí České republiky. Kostelec nad Černými lesy: Lesnická práce, 196 p.

BERRY, B. (1976): The counterurbanization process: urban America since 1970. In: Berry, B. [ed.]: Urbanisation and Counterurbanisation. Beverly Hills, California, Sage, p. 17–30.

BIČÍK, I., FIALOVÁ, D., VÁGNER, J. (2001): Druhé bydlení v Česku. Praha, Univerzita Karlova v Praze, 167 pp.

BOYLE, P., HALFACREE, K. [eds.] (1998): Migration into Rural Area. Chichester, John Wiley & Sons, 330 p.

BROWN, D. L., SCHAFFT, K. A. (2002): Population deconcentration in Hungary during the post-socialist transformation. Journal of Rural Studies, Vol. 18, p. 233–244.

BROWN, L. (1993): Rural community satisfaction and attachment in mass consumer society. Rural sociology, Vol. 58, p. 387–403.

BURT, J., BARBER, G. M., RIGBY, D. L. (2009): Elementary statistic for geographers. New York, London, The Guilford Press, 653 pp.

ČERMÁK, Z. HAMPL, M., MÜLLER, J. (2009): Současné tendence vývoje obyvatelstva metropolitních areálů v Česku: dochází k významnému obratu? Geografie, Vol. 114, No. 1., p. 37–51.

ČSÚ (2008): Databáze demografických údajů za obce ČR. Plzeň: Český statistický úřad. (zpracování na objednávku – Depon. Katedra geografie FPE ZČU v Plzni).

ČSÚ (2011): Databáze demografických údajů za obce ČR. [online]. Český statistický úřad, Praha. [cit. 20. 2.2011]. Available at: URL: < http://www.czso.cz/cz/obce_d/index.htm >.

Drbohlav, D. (2001): Evropa a proces mezinárodní migrace. Institut pro evropskou politiku Europeum, Praha [online] [cit.10.09.2010]. Available at: URL: <www.europeum.org>.

DRGOŇA, V., TURNOCK, D. (2000): Policies for rural Eastern Europe in transition: The case of Slovakia. GeoJournal, Vol. 50, p. 235–247.

FIELDING, A. (1992): Migration social mobility: South East England as an „escalator region". Regional Studies, Vol. 26, p. 1–15.

FIELDING, T. (1998): Counterurbanization and social class. In: Boyle, P., Halfacree, K. [eds.]: Migration into Rural Areas. Chichester, John Wiley & Sons, p. 41–60.

FLOGNFELDT, J. (2006): Second homes, work commuting and amenity migrants in Norway's mountain areas, In: Moss, L. A. G. [ed.]: The amenity migrants: Seeking and sustaining mountains and their cultures. Wallingford, UK and Cambridge, USA, CABI Publishing, p. 232–244.

GEYER, H. S., KONTULY, T. M. (1993): A Theoretical Foundation for the Concept of Differential Urbanization. International Regional Science Review, Vol. 17, p. 157–177.

GLORIOSO, S. (1999): Amenity migration in the Šumava bioregion, Czech Republic: Implications for ecological integrity. In: Gode, P. M., Price, M. F, Zimmermann. F. M. [eds.]: Tourism and development in mountain regions. Wellingford, CABI Publishing, p. 275–295.

GORLACH, K., LOŠŤÁK, M., MOONEY, P. H. (2008): Agriculture, communities, and new social movements: East European ruralities in the process of restructuring. Journal of Rural Studies, Vol. 24, p. 161–171.

HALLIDAY, J., COOMBES, M. (1995): In search of counterurbanization: some evidence from Devon on the relationship between patterns of migration and motivation. Journal of Rural Studies, Vol. 11, p. 433–446.

EGAN, A., LULOFF, A. E. (2000): The exurbanization of America's forests-research in rural social science. Journal of Forestry, Vol. 88, No. 3, p. 26–30.

ESCRIBANO, M. J. R. (2007): Migration to rural Navarre: questioning the experience of counterurbanization. Tijdschrift voor Economische en Sociale Geografie, Vol. 98, No. 1, p. 32– 41.

HANOUSEK, J., KOČENDA, E., SVEJNAR, J. (2007): Origin and concentration: Corporate ownership, control and performance in firms after privatization. Economics of transition, Vol. 15, No. 1, p. 1–31.

CHAMPION, T. (1998): Studying counterurbanization and the rural population turnaround. In: Boyle, P., Halfacree K. [eds.]: Migration into Rural Areas. Chichester, John Wiley & Sons, p. 21–40.

CHAMPION, T. (2001): Urbanization, Suburbanization, Counterurbanization and Reurbanization. In: Paddison, R. [ed.]: Handbook of Urban Studies. Sage Publications, London, s. 143–161.

CHIPENIUK, R. (2004): Planning for amenity migration in Canada: current capacities of interior British Columbian mountain communities. Mountain Research and Development, Vol. 24, p. 327–335.

KOK, H. (1999): Migration from the city to the countryside in Hungary and Poland. GeoJournal, Vol. 49, p. 53–62.

KONTULY, T. (1998): Contrasting the counterurbanization experience in European nations. In: Boyle P., Halfacree K. [eds.]: Migration into Rural Areas. Chichester, John Wiley & Sons, p. 61–78.

KONTULY, T., GEYER, H. S. (2003): Lessons Learned from Testing the Differential Urbanisation Model. Tijdschrift voor Economische en Sociale Geografie, Vol. 94, No. 1, p. 124–128.

KOPP, J., NOVOTNÁ, M. (2008): Krajinně-ekologické a environmentální změny na Plzeňsku v transformačním období. In: Dubcová, A., Krogmann, A. [eds.]: Geografické informácie 12. Nitra, Univerzita Konštantína Filozofa v Nitre, p. 16–23.

KUŠOVÁ, D., TĚŠITEL, J., MATĚJKA, K., BARTOŠ, M. (2008): Biosphere reserves – An attempt to form sustainable landscapes. Landscape and Urban Planning, Vol. 84, No. 1, p. 38–51.

LIBROVÁ, H. (1994): Pestří a zelení – kapitoly o dobrovolné skromnosti. Brno: Veronica, 218 pp.

LIBROVÁ, H. (1996): Decentralizace osídlení – vize a realita. Část první: vize, postoje k venkovu a potenciální migrace v ČR. Sociologický časopis, Vol. 33, No. 1, p. 27–40.

LIBROVÁ, H. (1997): Decentralizace osídlení – vize a realita. Část druhá: decentralizace v realitě České republiky. Sociologický časopis, Vol. 32, No. 3, p. 285–296.

LIBROVÁ, H. (2003): Vlažní a váhaví. Brno, Doplněk Publishing, 320 pp.

LUX, M., SUNEGA, P. (2010): The future of housing systems after the transition – The case of the Czech Republic. Communist and Post-Communist Studies, Vol. 43, p. 221–231.

LUX, M., SUNEGA, P., MIKESZOVÁ, M., MATYÁŠ, F. (2006): Analýza opatření bytové politiky směřující k podpoře flexibility práce v ČR. 2. díl – výsledky empirických šetření. Praha: Sociologický ústav AV ČR. 132 pp.

MAJEROVÁ, V. et al. (2006): Sociologie venkova a zemědělství. Praha, Česká zemědělská univerzita v Praze. 254 pp.

MITCHELL, C. J. A. (2004): Making sense of counterurbanization. Journal of Rural Studies, Vol. 20, p. 15–34.

MOSS, L. A. G. (1994): Beyond Tourism: The Amenity Migrants, in Coherence and Chaos: Visions, Means, Action. In: Mannermaa, M., Inayatullah, S., Slaughter, R. [eds.]: School of Economics Turku, Finland, p. 125–137.

MOSS, L. A. G. [ed.] (2006): The amenity migrants: seeking and sustaining mountains and their cultures. Wallingford, UK and Cambridge, USA, CABI Publishing, 336 pp.

MÜLLER, J. (2005): Venkov očima geografa. In: Venkov, jeho proměny a územní plánování. Telč: Asociace urbanismu a územního plánování ČR, p. 4–11.

MÜLLER, J. (2009): Změny a trendy ve vývoji osídlení po roce 1990. Urbanismus a územní vývoj, Vol. 12, No. 4 Supplement, p. 11–16.

MÜLLER, D. K. (2006): Amenity migration and tourism development in the Tärna Mountains, Sweden, In: Moss, L. A. G. [ed.]: The amenity migrants: Seeking and sustaining mountains and their cultures, Wallingford, UK and Cambridge, USA, CABI Publishing. p. 45–58.

OUŘEDNÍČEK, M. (2007): Differential Suburban Development in the Prague Urban Region. Geografiska Annaler – series B. Human Geography, Vol. 89, No. 2, p. 111–125.

OUŘEDNÍČEK, M. (2000): Teorie stádií vývoje měst a diferenciální urbanizace. Geografie, Vol. 105, No. 4, p. 361–369.

PAVLÍK, Z., KUČERA. Z. [eds.] (2002): Populační vývoj České republiky 1990–2002. Praha, Univerzita Karlova v Praze, 98 pp.

PERLÍN, R., BIČÍK. I. [eds.] (2010): Lokální rozvoj na Šumavě: závěrečná publikace shrnující výsledky projektu Analýza vývoje Národního parku Šumava za období uplynulých 15 let. Sborník z výzkumu na Šumavě, Vol. 4,Vimperk, Správa NP a CHKO Šumava, 187 pp.

PERLÍN, R., KUČEROVÁ, S., KUČERA, Z. (2010): Typologie venkovského prostoru Česka. Geografie, Vol. 115, No. 2, p. 161–187.

REINÖHLOVÁ, E. (2005): Informační a komunikační technologie pro rozvoj periferních oblastí. In: Novotná, M. [ed.]: Problémy periferních oblastí. Praha, Univerzita Karlova v Praze, p. 36-43.

SLEPIČKA, A. (1981): Venkov a/nebo město, lidé, sídla krajina. Praha: Svoboda, 367 pp.

STEWART, S. I. (2002): Amenity migration. In: Luft, K., MacDonald, S. [eds.]: 5th Outdoor Recreation and Tourism Trends Symposium. Michigan State University Department of Park, Recreation and Tourism Resources, Lansing MI, p. 369–378.

ŠIMON, M. (2006): Teoretické přístupy ke studiu urbanizace. Karlova univerzita v Praze, Přírodovědecká fakulta, katedra sociální geografie a regionálního rozvoje. 43 pp. [www.urbanizace.cz – 20.06.2008].

ŠIMON, M., OUŘEDNÍČEK, M., NOVÁK, J. (2009): Search of Counterurbanization: Some Evidence from the Czech Republic. 3rd International Workshop on Post-communist Urban Geographies: Actors Shaping Urban Change, 17. 9. 2009, Tartu, Estonsko, MS.

ŠIMON, M. (2011): Kontraurbanizace: Chaotický koncept? Geografie, Vol. 116, No. 3., p. 231–255.

ŠIMON M. (2012): Exploring Counterurbanization in a Post-Socialist Context: Case of the Czech Republic. Sociologia ruralis. Article first published online: 11 OCT 2012, DOI: 10.1111/j.1467-9523.2012.00576.x.

TAMMARU, T. (2003): Urban and rural population chase in Estonia: patterns of differentiated and undifferentiated urbanisation. Tijdschrift voor Economische en Sociale Geografie, Vol. 94, No. 1, p. 112–123.

TEMELOVÁ, J., NOVÁK, J., POSPÍŠILOVÁ, L., DVOŘÁKOVÁ, N. (2011): Každodenní život, denní mobilita a adaptační strategie v periferních lokalitách. Sociologický časopis, Vol. 43, No. 4, p. 831–858.

TĚŠITEL, J., KUŠOVÁ, D., BARTOŠ, M. (1999): Non marginal parameters of marginal areas. Ekológia (Bratislava), Vol. 18, No. 2, p. 39–46.

VÁGNER, J., FIALOVÁ, D. et al. (2004): Regionální diferenciace druhého bydlení v Česku. Praha, Univerzita Karlova, 286 pp.

WALMSLEY, D. J., EPPS, W. R., DUNCAN, C. J. (1998): Migration to the New South Wales North Coast 1986–1991: Lifestyle Motivated Counterurbanization. Geoforum, Vol. 29, No. 1, p. 105–118.

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MORAVIAN GEOGRAPHICAL REPORTS

Aims and Scope of the Journal

Moravian Geographical Reports [MGR] is an international peer-reviewed journal, which has been published in English continuously since 1993 by the Institute of Geonics, Academy of Sciences of the Czech Republic, through its Department of Environmental Geography. It receives and evaluates articles contributed by geographers and by other researchers who specialize in related disciplines, including the geosciences and geo-ecology, with a distinct regional orientation, broadly for countries in Europe. The title of the journal celebrates its origins in the historic land of Moravia in the eastern half of the Czech Republic. The emphasis at MGR is on the role of 'regions' and 'localities' in a globalized society, given the geographic scale at which they are evaluated. Several inter-related questions are stressed: problems of regional economies and society; society in an urban or rural context; regional perspectives on the influence of human activities on landscapes and environments; the relationships between localities and macro-economic structures in rapidly changing socio-political and environmental conditions; environmental impacts of technical processes on bio-physical landscapes; and physical-geographic processes in landscape evolution, including the evaluation of hazards. Theoretical questions in geography are also addressed, especially the relations between physical and human geography in their regional dimensions,

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Fig. 1: Rabštejn nad Střelou – Rural houses used for recreation have great potential for conversion to permanent housing (Photo: J. Kopp)

Fig. 8: Migrants in Šumava often build in traditional mountain style (Photo: M. Bartoš)

Illustrations related to the paper by M. Novotná, J. Preis, J. Kopp and M. Bartoš