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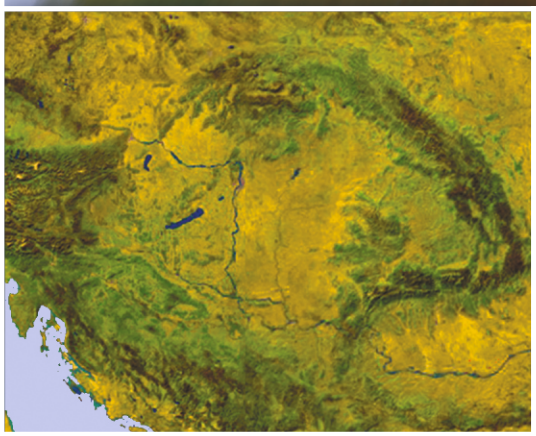

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Investigation of spectral properties of different Quaternary paleosols and parent materials

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Abstract

Diffuse Reflectance Spectroscopy (DRS) is a rapid, relatively new method in Quaternary research to analyse sediments and paleosols. This method takes into account clay mineral content, amount of Fe-bearing minerals and grain size composition of samples, simultaneously. Different Quaternary sediment samples were chosen for characterization and comparison their reflectance curves to detect the essential spectral properties of different paleosols and parent materials. Samples of different sediment types and paleosol variants were investigated from a loess-paleosol sequence from Malá nad Hronom (Slovakia) and from a fluvial-aeolian sediment complex from Pilismarót (Hungary). Five investigated curve sections were separated as the best indicators of reflectance properties of DRS curves. Spectral properties of samples were compared by using the length of investigated curve sections. This investigation showed quantifiable differences between the units of Pleistocene sediment successions, based on the reflectance properties. The influence of pedogenic processes was properly detectable. Significant discrepancies were observed between reflectance curves of well-developed paleosols and parent material samples in the visible and near-infrared range. Differences between the weak developed paleosol layers and their parent materials were only observed in the visible range. Fine sand, sandy silt and loess materials could be separated from each other based on the intensity of entire reflectance curves.

Keywords: diffuse reflectance spectroscopy, Pleistocene, loess, aeolian, alluvial, paleosol

Introduction and research background

The investigation of Quaternary sediments, such as loess-paleosol sequences, helps to reveal Pleistocene climate and environmental changes (Marković, S.B. *et al.* 2011, 2015; Újvári, G. *et al.* 2014; Horváth, E. and Bradák, B. 2014; Varga, G. 2015; Varga, G. *et al.* 2019). Besides the most commonly used proxies (e.g. grain size, magnetic susceptibility, carbonate content), applications of diffuse reflectance spectroscopy (DRS) method have become more widespread in this field (Buggle, B. *et al.* 2014; Krauss, L. *et al.* 2016; Vlaminck, S. *et al.* 2016; Zeeden, C. *et al.* 2018; Wu, Y. *et al.* 2018). The method allows measurements in a rapid, non-destructive way and does not require complicated sample preparation. The visible and near-infrared (VIS-NIR) spectra allow simultaneous investigations of various parameters.

Reflectance spectra of fine-grained minerals showed specific properties, which were observed for the first time by White, W.B. and Keester, K.L. (1966), and Adams, J.B. and Filice, A.L. (1967). Diffuse reflected light contains spectral information concerning the physical and chemical composition of the il-

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luminated sample (Baumgardner, M.F. *et al.* 1985). DRS detects the electronic transitions of atoms in the visible spectrum (VIS), while the vibration deriving from the stretching and bonding of molecules and from the alterations of the bond angle is obtained in the near-infrared (NIR) range (Shepherd, K.D. and Walsh, M.G. 2002). The instrumental colour determination eliminates the subjectivity of the Munsell colour scale (Post, D. *et al.* 1993); therefore, the different sequences will be comparable. Lithostratigraphic subdivision of sediment series can be achieved by using the so-called colourimetric indices. Different indices were calculated to interpret diffuse reflectance spectra (VIS range) of Quaternary sediments (especially concerning loess-paleosol sequences). These were different colourimetric indices or Hematite/Goethite (H/G) ratios.

Brightness values were calculated from the visible band primarily to identify the carbonate content of marine sediments (Balsam, W.L. *et al.* 1999). This proxy is equivalent to Lightness (Goddard, E.N. *et al.* 1948) and greyscale (Herbert, T.D. and Fischer, A.G. 1986). Ji, J.F. *et al.* (2001) used brightness as colourimetric index for investigation of loess-paleosol sequences for the first time. A strong relationship was observed between brightness and magnetic susceptibility (kappa low field, $_{K}$LF) values, similarly to lightness (Zhou, L.P. and Shackleton, N.J. 1998; Wang, Q. *et al.* 2016) and greyscale (Porter, S. 2000) proxies. Ji, J.F. *et al.* (2001) draws attention to the modifying effect of non-magnetic light and dark minerals, which may change the values of the colourimetric index and thus the strength of the correlation.

The redness index (RI) was calculated from the red band of DRS curve for the first time by Zhang, Y.G. *et al.* (2007) to identify the colourimetric parameters of marine sediments of South China Sea and were connected to hematite and goethite content – following the main assumption suggested by Barrón, V. and Torrent, J. (1986). RI used to replace the RR (Redness Rating: calculated from Munsell colour chart) values (Buntley, G. and Westin, F. 1965) and RI_{LAB} (Redness Index: calculated from CIE colour system; CIE 1978) values (e.g. Barrón, V. and Torrent, J. 1986; Viscarra Rossel, R.A. *et al.* 2006). RI is a widely used colourimetric index for investigation of loess-paleosol sequences (e.g. Guo, Z.T. *et al.* 2009; Sun, Y. *et al.* 2011; Buggle, B. *et al.* 2014). RI and $_{K}$LF values are in strong positive correlation (e.g. Buggle, B. *et al.* 2014), but it is always essential to take into account the possible colour-modifying effects of the organic matter and carbonate content (Sun, Y. *et al.* 2011).

Goethite and hematite can be transformed into each other due to changing climatic conditions (Schwertmann, U. 1971). Scheinost, A.C. *et al.* (1998) calculated the so-called H/G ratio based on the relevant sections of the DRS curve to detect the transformation. Hematite and goethite both have a vital role during the investigation of loess-paleosol sequences. Torrent, J. *et al.* (2007) improved the method for the study of loess-paleosol sequences of the Chinese Loess Plateau: hematite concentration showed a strong positive correlation with the values of frequency-dependent magnetic susceptibility. Based on previous investigations (e.g. Balsam, W.L. *et al.* 2004; Vidic, N.A. *et al.* 2004) it was stated, that H/G ratios are good paleoclimatic indicators – although specific questions are still open. H/G ratios do not show good correlation with $_{K}$LF values in each case (Wang, Q. *et al.* 2016), and hematite concentrations measured in a given range can be influenced by the presence of other materials (Liu, Q. *et al.* 2011).

Particular indices were calculated from DRS measurement data during the investigation of terrestrial sediments. These indices were added to multiproxy investigations and thus were used for more detailed description of profiles (Zhang, Y.G. *et al.* 2007; Krauss, L. *et al.* 2016; Vlaminck, S. *et al.* 2016; Zeeden, C. *et al.* 2018) in order to reveal the intensity of pedogenesis (Bábek, O. *et al.* 2011) and to reconstruct paleoclimate and paleoenvironment (Guo, Z.T. *et al.* 2009; Sun, Y. *et al.* 2011; Buggle, B. *et al.* 2014; Wang, Q. *et al.* 2016; Wu, Y. *et al.* 2018).

Compound loess-paleosol sequences can be divided into different groups and interpreted as stratigraphic units of loess-paleosol successions by applying cluster analysis of DRS data. This is a new approach introduced in loess research by Szeberényi, J. *et al*. (2020, in press). Three important frequency ranges were identified, which are the most critical sections in the entire measurement range: (1) The reflectance intensity of a sample in the 400–825 nm frequency range was modified by hematite and goethite, illite, montmorillonite, muscovite and calcite. (2) Mainly montmorillonite and kaolinite played important roles in modifying the reflectance curve of a sample in the 900–1,100 nm frequency range. Fe-bearing minerals had only a minimal influence in this range. (3) The reflectance curve was only modified by montmorillonite in the 1,445–1,460 nm range. This approach proved that the reflectance properties of DRS curves are suitable for the differentiation of paleosols and their parent materials (e.g. loess). Although the question is raised, whether it is easier to identify curve sections, that indicate apparent differences between reflectance properties of paleosol and parent material samples.

As a continuation of our previous studies, this paper reveals the relationship between the DRS curves of paleosols and their parent material. The basis of recent research was the most important curve sections (between 400–1,460 nm wavelength range) of the entire measurement range. The goal of the actual study was to quantify the significant differences between the original reflectance curves of paleosols and their parent materials in the case of different Quaternary sediment successions.

Site and sampling

Loess, alluvial sandy aleurite and fluvial sand are widespread Pleistocene sediment types in the Carpathian Basin. They generally serve as parent materials for soil development. Two successions were investigated in the present study: a loess-paleosol sequence and a fluvial-aeolian sediment complex. The loess-paleosol sequence is located in the vicinity of Malá nad Hronom, Slovakia (130–155 m a.s.l.; N47°49'46.0" and E19°02'33.6"). The abandoned brickyard is found in the western side of a dissected fluvial terrace of the Hron river, which is a tributary of the Danube river. The fluvial-aeolian sediment complex is located in the region of Pilismarót, Hungary (103–107 m a.s.l.; N47°48'6.44" and E18°52'31.45"). The abandoned gravel mine is on the lowest terrace of the Danube river *(Figure 1).*

One profile (MNH) was excavated in the loess-paleosol sequence at Malá nad Hronom *(Figure 2).* Seven different stratigraphical units were identified, which can be summarized from the top to the bottom as follows:

– *Unit L1* (0–160 cm): Greyish yellow, well-cemented, homogeneous, non-layered loess with low fine sand content. 16 samples were measured from this unit.
– *Unit T1* (160–220 cm): A light brownish intermediate layer was detected between L1 and P1. The silty material was loose, non-layered, without any sediment structure.
– *Unit P1* (220–320 cm): Light reddish-brown, weakly developed paleosol with granular ped structure. 8 samples were taken from this layer.
– *Unit T2* (320–390 cm): A yellowish/light brownish intermediate layer was observed between the two paleosols. The transition zone consisted of loose, non-layered silty material.
– *Unit P2* (390–490 cm): The paleosol of Unit P2 was characterized by two pedogenic horizons. The uppermost pedogenic horizon (390–420 cm) was clayey with dark brown colour and was described by well-developed blocky structure. A 50–60 cm thick, reddish-brown, weakly developed soil horizon was observed in the lower part of this unit (between 420–490 cm). 8 samples were measured from P2 paleosol unit.
– *Unit LCa* (490–520 cm): Well-compacted carbonate accumulation zone of the P2 paleosol.

Fig. 1. The geographical location of the investigated successions

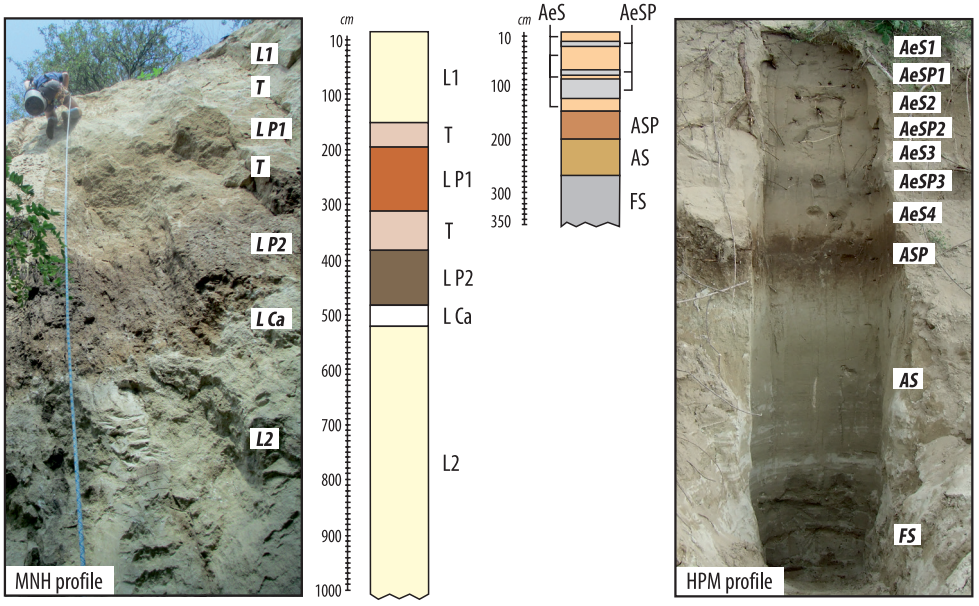

Fig. 2. The investigated successions. L1, L2 = loess units; T1, T2 = intermediate layers; LP1, LP2 = paleosol layers; LCa = carbonate accumulation horizon; AeS1, AeS2, AeS3, AeS4 = aeolian sand layers; AeSP1, AeSP2, AeSP3 = paleosol horizons in aeolian sand; ASP = paleosol layer on alluvial sand unit; AS = alluvial sand unit; FS = fluvial sand unit.

– *Unit L2* (520–1,010 cm): The base of the sequence was a grey/greyish-yellow loess layer with at least 5 m thickness. This unit was porous, loose, non-layered, and homogeneous. Secondary carbonates were observed in the field. 36 L2 samples were taken for reflectance measurements.

One profile (HPM) was investigated in the fluvial-aeolian sediment complex at Pilismarót (see *Figure 2*). Five different stratigraphical units were identified, which were described from the top to the bottom as follows:

– *Units AeS and AeSP* (0–150 cm): An aeolian sand-paleosol complex was identified in the upper part of the sequence, which consisted of several layers. 4 light grey/greyish-yellow, loose, homogeneous/finely laminated fine aeolian sand layers (AeS) were detected between 0–20, 30–70, 80–90 and 120–150 cm depth. 9 samples were taken from parent material unit. 3 grey/greyish yellow coloured, weakly developed paleosol horizons (AeSP) with granular ped structure were observed between 20–30, 70–80 and 90–120 cm depth. 6 paleosol samples were measured from these horizons.
– *Unit ASP* (150–210 cm): A well-developed, clayey reddish-brown paleosol was identified in the middle of the sequence. The angular blocky ped structure included clay coatings and slick and slide phenomenon. 6 ASP samples were taken for measurements.
– *Unit AS* (210–280 cm): Fine-grained alluvial silty sand was detected as parent material of the ASP paleosol. This stratum was divided into different sublayers. The lowermost part of the layer was a 30 cm thick, fine laminated, grey coloured material with limonite dots. This part was overlain by a 40 cm thick yellowish-grey, homogenous, non-laminated sandy silt layer. 5 samples were measured from this layer.
– *Unit FS* (280–360 cm): The base of the sequence was thick cross-bedded fluvial sand, which was grey, coarse-grained and contained fine pebbles and a thin gravel layer (320–330 cm).

Methods

The samples were air-dried and dry sieved trough a 250 μm sieve, as preparation for reflectance measurements. The samples were proceeded with a Shimadzu UV-3600 spectrophotometer (Geographical Institute, Research Centre for Astronomy and Earth Sciences, Hungary) in Hellma Precision cells made of quartz SUPRASIL 300 and were optimized in the UV-VIS-NIR range *(Figure 3).*

The test samples were very noisy in the most extended wavelength section of the NIR range (2,000–2,500 nm); therefore, the samples of the present study were measured only between 240 and 2,000 nm. Scan speed was 0.54 sec in 1 nm sampling interval. Optimal slit with was 20 nm. Change in the wavelength of the detector (Pbs/Pm) was at 830 nm, while light source (D2 deuterium/Wl halogen) change wavelength was at 310 nm and grating change wavelength was at 710 nm (green points on *Figure 3*), which were identified as uncertain measurement points. The diffuse reflectance was recorded by the LISR-3100 integrating sphere. Each sample spectra were corrected for background absorption by the division of the reflectance spectrum of standardized white $BaSO_4$ panel.

The reflectance intensity was expressed in percentage (R%) of the measurement range (240–2,000 nm). One DRS curve contains 1,760 data points (given in R%), which refer to the quantity of light reflected per nm. The entire reflectance spectra of samples could be displayed on a diagram (blue curve on *Figure 3*). All paleosol and parent material samples were analysed using the intensity of their entire reflectance curves, which helps to recognize the fundamental differences in their reflectance properties.

Several curve sections were identified to characterize and quantify the reflectance properties of samples. The most variable wavelength ranges (between 400–825, 90–1,000 and 1,445–1,460 nm) were separated from the full measurement range based on our earlier results (Szeberényi, J. *et al*. 2020, in press). Within these wavelength ranges five

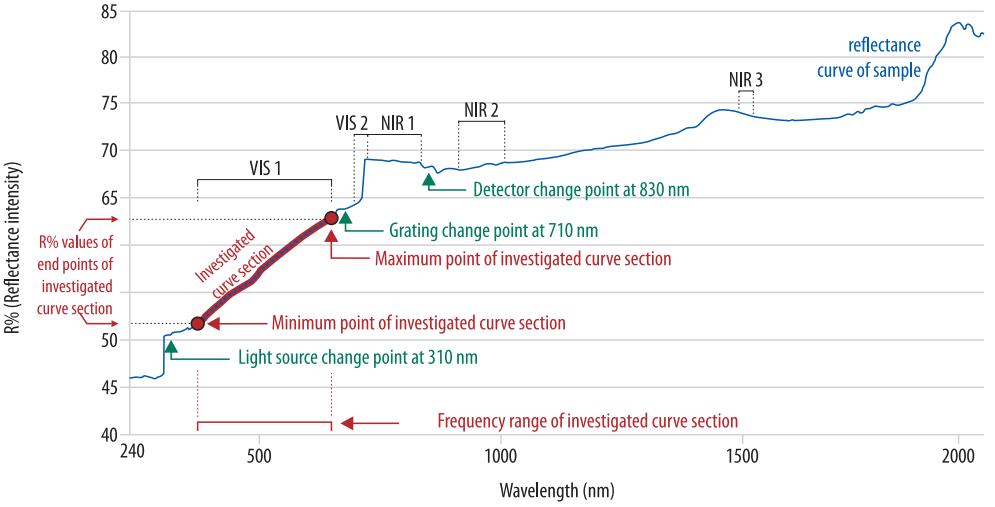

Fig. 3. The most important parameters of the method are shown on the entire reflectance spectra of one representative sample

investigated curve sections were identified for this study that generally rises or drops monotonically toward longer wavelengths (1), and not contains any uncertain measurement points such as detector, grating and light source change points (2). Two frequency ranges were identified in the visible band (VIS 1 and VIS 2) and three in the near-infrared range (NIR 1, NIR 2 and NIR 3). These investigated frequency ranges are the best indicators of reflectance properties of the DRS curves (see *Table 1* and *Figure 3*). The five investigated sections of reflectance curves of paleosol and parent material samples were compared to each other in this study.

The investigated curve sections could be characterized by an increase or a decrease of R% value in the investigated frequency range. The minimum and maximum R% values could be measured at the endpoints of the investigated curve section (red on *Figure 3*). ΔR% gives the difference of maximum and minimum R% values in the investigated frequency range. If R% value increased in the investigated frequency range, the ΔR% value is positive. In contrast, a negative ΔR% value signifies a decreasing tendency between the endpoints of the investigated curve section. Steeper curve section could be characterized by higher ΔR% value.

Results

In general, the R% values showed an increasing tendency between 240 and 2,000 nm wavelength range. Minimum R% values were detected between 290–300 nm, whereas the maximum values were present between 1,950–1,955 nm. The sediment types could be characterized by different amplitudes of their reflectance curve. The most considerable difference (min: 47.6R%, max: 87.2 R%) was observed for loess, while the smallest difference (min: 47.5 R%, max: 76.4 R%) was characteristic for aeolian sand (*Figure 4*, a). The intensities of DRS curves regarding paleosols were lower than those of their parent material in each case (*Figure 4*, b, c, d).

Curve sections of Unit L1 and L2 samples could be characterized by the highest ΔR% value in the VIS 1 range (*Figure 5*, a), concerning the samples of the loess-paleo-

Table 1. Endpoints and uncertain points of investigated curve sections

Name of the frequency range	Light source change	VIS 1	Grating change	VIS 2	NIR 1	Detector change	NIR 2	NIR 3
End points of investigated frequency range, nm	–	400	–	715	725	–	900	1,445
	–	700	–	725	820	–	1,000	1,460
Uncertain measurement point, nm	310	–	710	–	–	830	–	–

sol sequence. Loess samples had the same values. The R% values of samples increased by 10.1–11.5 per cent from the minimum to the maximum value. ΔR values of curve sections of paleosols were smaller than those of their parent materials. The R% value of P1 paleosol increased by 9.2–9.7 per cent between the endpoints of the curve section, whereas the P2 paleosol showed only 5.8–7.8 per cent increase. An opposite trend was observed in the case of the alluvial units (ΔR of AS: 5.8–6.6% and ΔR of ASP: 6.2–9.7%), and there was no significant difference between aeolian samples (ΔR of AeS: 6.3–7.5% and ΔR of AeSP: 6.8–7.0%) (*Figure 5*, b, c).

The R% values of paleosols had slightly higher ΔR% values in the VIS 2 range than their parent material (*Figure 5*, d, e, f). The most significant difference was observed for the samples of the loess-paleosol sequence (ΔR of L1 and L2: 3.6–4.5%; ΔR of P1: 4.5–4.8% and ΔR of P2: 5.2–5.7%).

R% values of parent materials decreased in the NIR 1 range by -0.9–0.6 per cent (ΔR) for Loess, -1.3–1.1 per cent (ΔR) for AS and -0.8–0.6 per cent (ΔR) for AeS (*Figure 5*, g, h, i). A slighter decrease (ΔR: -0.8–0.5%) was characteristic for the weakly developed P1 paleosol, whereas the R% value of the AeSP paleosol remained constant (-0.6–0.1%) in relation to the parent materials of both units. The value of the well-developed paleosol of loess-paleosol sequence increased between the endpoints of NIR 1 curve section (ΔR of P2: 0.2–0.6%). ASP paleosol layer could be divided into two parts (ASPa and b) in this frequency range. The R% values of the middle part of alluvial paleosol increased (ΔR of ASPa: 0.1–0.5%), whereas the lower and upper part of alluvial paleosol could be characterized by a decreasing tendency (ΔR of ASPb: -0.2– -0.7%) (*Figure 5*, g, i).

The R% values of alluvial sandy aleurite decreased in the NIR 2, whereas loess and

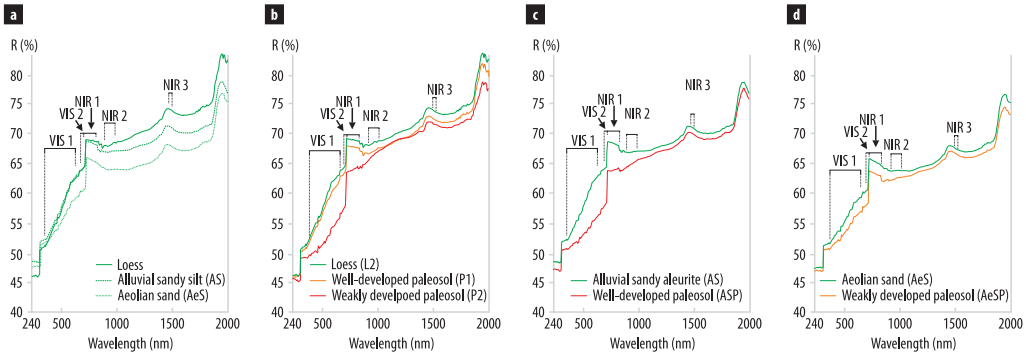

Fig. 4. Entire reflectance curves of samples

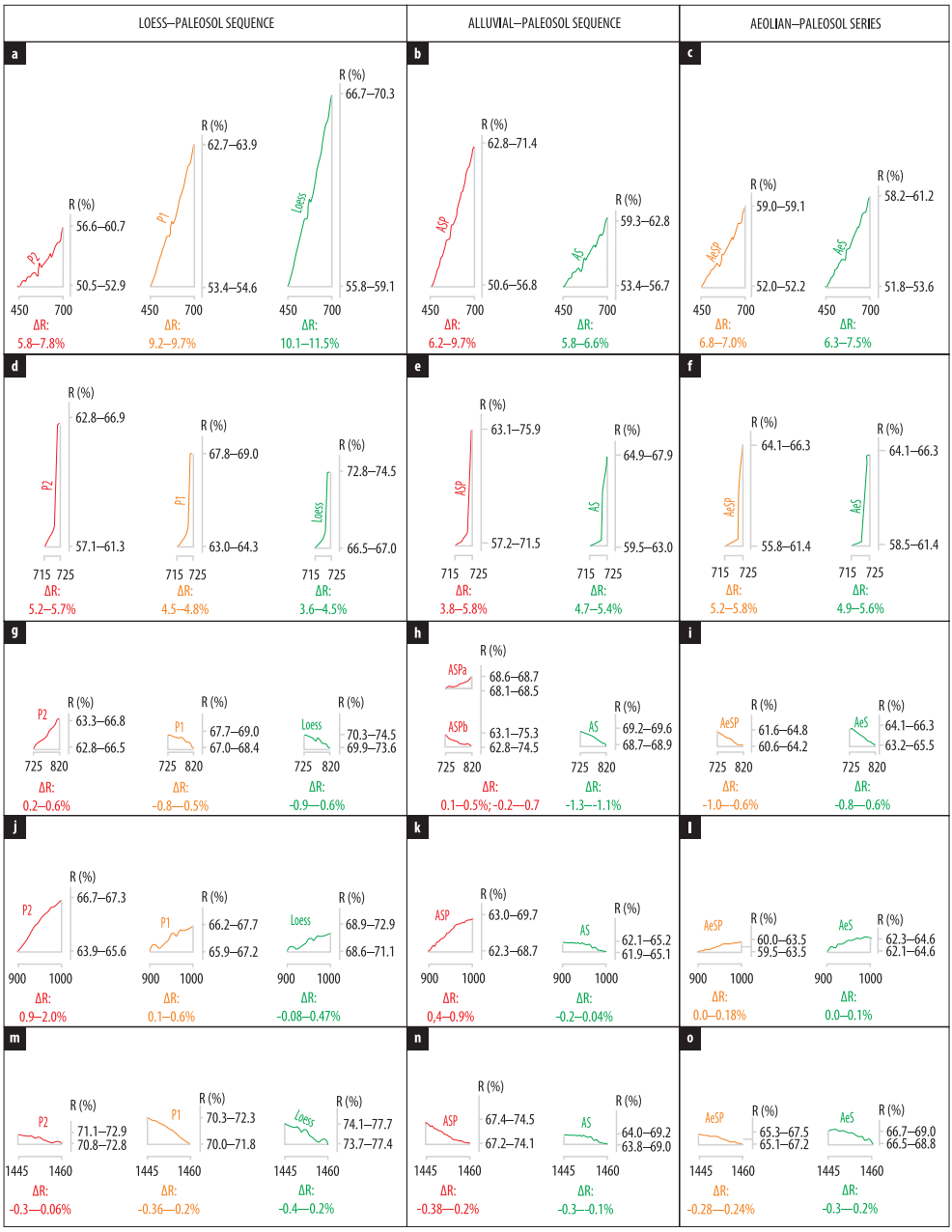

Fig. 5. Comparison of investigated curve sections in the investigated ranges

aeolian sand could be characterized by an increasing tendency. Only a slight difference was observed between the values of the weakly developed paleosols and their parent materials in the NIR 2 frequency range (ΔR of L1 and L2: -0.08–0.47%; ΔR of P1: 0.1–0.6%;

ΔR of AeS: 0.0–0.1% and AeSP: 0.00–0.18%) (*Figure 5*, j, l). Well-developed paleosols were characterized by steeper curve sections (ΔR of P2: 0.9–2.0%; ΔR of ASP: 0.4–0.9%) (*Figure 5*, j, k).

In general, R% values decreased concerning the NIR 3 frequency ranges. Minimal differences could be observed between loess-paleosol samples (ΔR of L1 and L2: -0.4– -0.2%, P1: -0.36– -0.20%, P2: -0.30– -0.06%), the alluvial-paleosol samples (ΔR of AS: -0.3– -0.1%, ASP: -0.38– -0.20%) and the aeolian sand-paleosol samples (ΔR of AeS: -0.3– -0.2%, AeSP: -0.28– -0.24%) (*Figure 5*, m, n, o).

Discussion

DRS measurements are useful for the differentiation between loess and sandy samples and for the recognition of possible differences between paleosols and their parent materials. Sediment types can be separated from each other, based on the mean intensity of the complete DRS curves. Aeolian sands can be differentiated from alluvial silty sands and loesses based on the visible and near-infrared bands (especially between 950–2,000 nm, see *Figure 4*, a). The entire DRS curves of paleosols were characterized by lower intensity than their parent materials. Besides the mineral components, the reflectance intensity was influenced by the grain size composition as well (Hunt, G.R. 1989; Clark, R.N. 1999). DRS curves of parent materials (fine sand, sandy silt, loess) and well-developed paleosol samples were definitely modified by these factors (especially concerning the presence of higher clay fraction).

By the help of the five curve sections, it was possible to reveal and quantify the most important reflectance properties of DRS curves. The most prominent changes were present in the VIS 1, NIR 1 and NIR 2 frequency ranges, although certain tendencies appeared to be identifiable in the VIS 2 and NIR 3 frequency ranges too *(Figure 6)*.

In general, significant differences could be shown between ΔR% values of well-developed paleosols (especially P2) and their parent materials. In contrast, only moderate or little differences were detected between weakly developed paleosols and their parent materials (see *Figure 6*). Changes of carbonate content, the formation of clay minerals and the transformation of Fe-bearing minerals were the reason for abovementioned phenomena, and those parameters are very important in relation to pedogenic processes. Generally, paleosols can be characterized by lower carbonate and goethite concentration, and higher hematite and clay mineral contents, which are all influenced by paleoclimatic and paleoenvironmental conditions. The involved minerals were very well detected components using diffuse reflectance spectroscopy. DRS measurements are sensitive to the changes of the amount of Fe-bearing minerals (Torrent, J. *et al*. 1983; Hunt, G.R. 1989; Deaton, B.C. and Balsam, W.L. 1991) and the carbonate content (Balsam, W.L. *et al.* 1999) of the sediments in the visible band; and to the changes of clay mineral content (Clark, R.N. 1999) in the near-infrared range.

The investigated weakly developed paleosols (especially P1) differentiated from their parent materials only in the visible range. On the contrary, significant differences were detected between well-developed paleosols and their parent materials both in the visible and near-infrared bands. The changes of carbonate content and the amount of Fe-bearing minerals is possibly connected to the earlier stage of pedogenic development, whereas the accumulation of clay minerals is related to longer time periods and/or to the presence of stronger pedogenic processes.

Furthermore, another interesting observation was that the reflectance properties of different sediment types (fine sand, sandy silt, loess) were comparable to each other, mainly in the visible range. AS and AeS samples could be characterized by the same values (ΔR in VIS 1: 5.8–7.5%; ΔR in VIS 2: 4.7–5.6%), whereas L1 and L2 samples had higher values (ΔR: 10.1–11.5%) in the VIS 1 and lower values (ΔR: 3.6–4.5%) in the VIS 2 band.

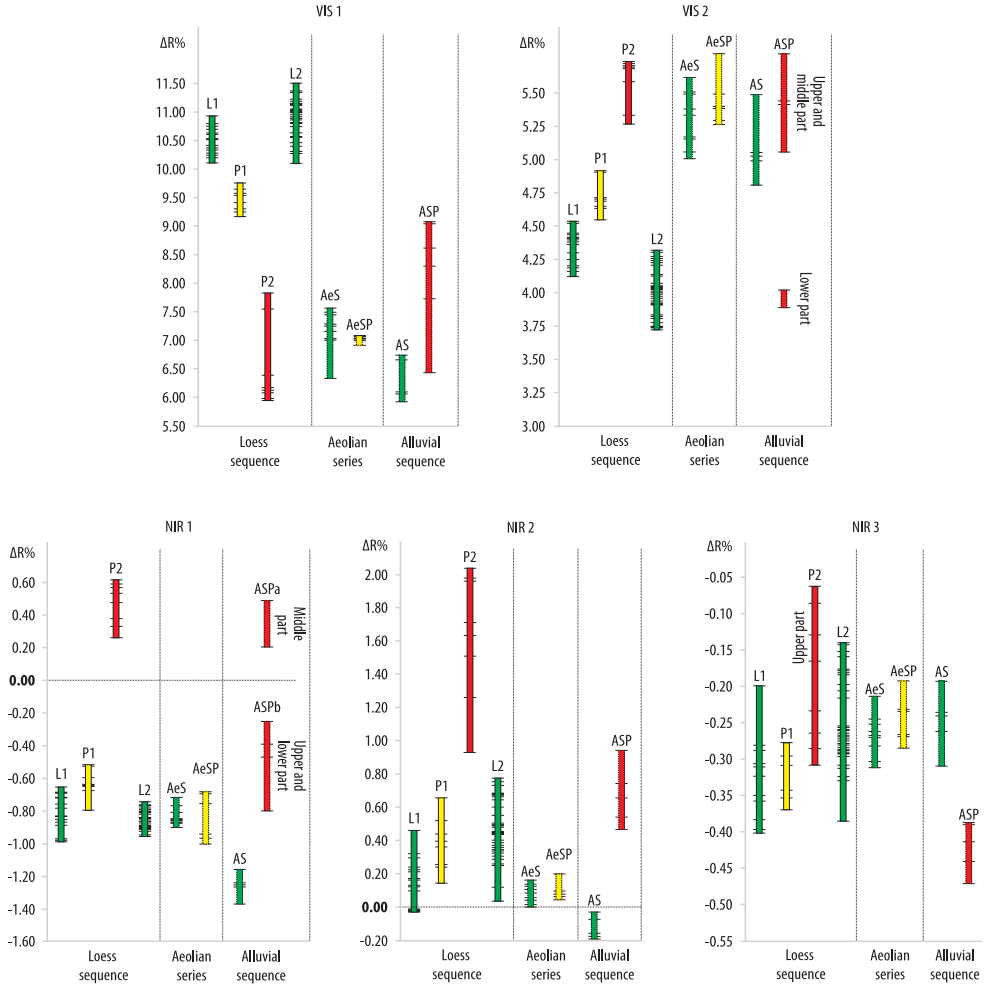

Fig. 6. Changes of ΔR% of curve sections in the five investigated frequency ranges

The 715–820 nm were substantial frequency ranges in our study, based on which the alluvial paleosol layer could be divided into three horizons. I can be seen on *Figure 6* that (1) the lower part of ASP layer was characterized by significantly lower ΔR% values in the VIS 2 than the other samples of this layer, and (2) the middle part of ASP had higher ΔR% values in the NIR 1 range, than their uppermost and lowermost horizons. The spectral features of illite and hematite can be traced in these frequency ranges, therefore, in this case, these minerals played the most important role during the pedogenesis, based on our earlier study (Szeberényi, J. *et al.* 2020, in press).

Generally, the alterations of curve sections are established mainly by different mineral groups and not by the individual minerals, except in the 1,445–1,460 nm frequency range based on our earlier results (Szeberényi, J. *et al.* 2020, in press). This narrow range is modified only by montmorillonite. This fact can be regarded as very important as signifi-

cant discrepancies were observed between the reflectance curves of two well-developed paleosols in the NIR 3 range. Curve section of P2 paleosol samples (especially the upper part of this layer) were steeper than those of their parent materials, which could be explained by montmorillonite enrichment. On the contrary, the curve section of ASP paleosol layer could be characterized by lower ΔR% values than the alluvial sandy aleurite samples (*Figure 6*). Probably the ASP paleosol can be characterized by low montmorillonite and high illite content (especially the middle part of this layer; *Figure 3*, NIR 1). Illite forms in potassium-rich soils by the transformation of high-temperature micas, usually muscovite (e.g. Jackson, M.L. 1964; Ellis, S. and Mellor, A. 1992; Righi, D. and Meunier, A. 1995). Reinbach, H. and Rich, C. (1975) indicated that the process of smectite/illite transformation is intimately associated with silica-poor and potassium-rich environment. Presumably, these processes are standing in the background of pedogenesis of ASP paleosol.

Conclusions

Reflectance measurements of samples in different Quaternary sediment successions were investigated and compared in order to reveal and quantify the most important reflectance properties. We found that (1) the assessment of DRS curves from Quaternary sediment successions indicated the presence and intensity of pedogenic processes; (2) the reflectance properties of DRS curves could be identified by both the mean intensity of the whole reflectance curve and the length of the investigated curve sections. Therefore, essential conclusions can be drawn from the investigation of curve sections regarding the intensity of pedogenic processes. The detectable differences of the length of investigated curve sections can be quantified by ΔR%.

The method of this study took into account the changes of the mineral composition and the alterations of grain size at the same time. Reflectance properties of DRS curves were suitable for the recognition of the tracers of pedogenic processes in the case of Quaternary terrestrial successions, although some unresolved questions remained. Further investigations are needed to determine the degree of change, which influences the mineral and grain size compositions. It is an exciting topic to find the mineral (or minerals) that affect the alterations of the investigated curve sections using XRD measurements.

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REFERENCES

Adams, J.B. and Filice, A.L. 1967. Spectral reflectance of 0.4 to 2.0 microns of silicate rocks powders. *Journal of Geophysical Research* 72. 5705–5715.

Bábek, O., Chlachula, J. and Grygar, T.M. 2011. Non-magnetic indicators of pedogenesis related to loess magnetic enhancement and depletion: Examples from the Czech Republic and southern Siberia. *Quaternary Science Reviews* 30. 967–979.

Balsam, W.L., Deaton, B.C. and Damuth, J.E. 1999. Evaluating optical lightness as a proxy for carbonate content in marine sediment cores. *Marine Geology* 161. 141–153.

Balsam, W.L., Ji, J. and Jun Chen, J. 2004. Climatic interpretation of the Luochuan and Lingtai loess sections, China, based on changing iron oxide mineralogy and magnetic susceptibility. *Earth and Planetary Science Letters* 223. 335–348.

Barrón, V. and Torrent, J. 1986. Use of the Kubelka-Munk theory to study the influence of iron oxides on soil colour. *Journal of Soil Science* 37. 499–510.

Baumgardner, M.F., Silva, L.F., Biehl, L.L. and Stoner, R. 1985. Reflectance properties of soils. *Advances in Agronomy* 38. 1–44.

Buggle, B., Hambach, U., Müller, K., Zöller, L., Marković, S. and Glaser, B. 2014. Iron miner-

alogical proxies and Quaternary climate change in SE-European loess-paleosol sequences. *Catena* 117. 4–22.

Buntley, G. and Westin, F. 1965. A comparative study of developmental color in a Chestnut-Chernozem-Brunizem soil climosequence. *Soil Science of America Proceedings* 29. 579–582.

Clark, R.N. 1999. Spectroscopy of rocks and minerals, and principles of spectroscopy. In *Remote Sensing for the Earth Sciences: Manual of Remote Sensing*. Ed.: Rencz, N., New York, John Wiley and Sons, 3–52.

Commission Internationale de l'Eclairage (CIE) 1978. *Recommendations on Uniform Color Spaces, Color Differences, and Psychometric Colour Terms*. Paris, Calorimetry CIE, Suppl. no. 2 to Publication no. 15.

Deaton, B.C. and Balsam, W.L. 1991. Visible spectroscopy – a rapid method for determining hematite and goethite concentration in geological materials. *Journal of Sedimentary Petrology* 61. 628–632.

Ellis, S. and Mellor, A. 1992. *Soils and Environment.* London, Routledge.

Goddard, E.N., Trask, P.D., De Ford, R.K., Rove, O.N., Singewald, J.T. and Overbeck, R.M. 1948. *Rock color chart.* Boulder, Colorado, Geological Society of America.

Guo, Z.T., Berger, A., Yin, Q.Z. and Qin, L. 2009. Strong asymmetry of hemispheric climates during MIS-13 inferred from correlating China loess and Antarctica ice records. *Climate of the Past* 5. 21–31.

Herbert, T.D. and Fischer, A.G. 1986. Milankovitch climatic origin of mid-Cretaceous black shale rhythms in central Italy. *Nature* 321. 739–743.

Horváth, E. and Bradák, B. 2014. Sárgaföld, losz, lösz: short historical overview of loess research and lithostratigraphy in Hungary. *Quaternary International* 319. (1): 1–10.

Hunt, G.R. 1989. Spectroscopic properties of rocks and minerals. In *Practical Handbook of Physical Properties of Rocks and Minerals.* Ed.: Carmichael, R.S., Boca Raton FL, CRC Press, 597–669.

Jackson, M.L. 1964. Chemical composition of the soil. In *Chemistry of the Soil.* Ed.: Bear, F.E., New York, Reinhold, 71–141.

Ji, J.F., Balsam, W.L. and Chen, J. 2001. Mineralogic and climatic interpretations of the Luochuan loess section (China) based on diffuse reflectance spectrophotometry. *Quaternary Research* 56. 23–30.

Krauss, L., Zens, J., Zeeden, C., Schulte, P., Eckmeier, E. and Lehmkuhl, F. 2016. A multi-proxy analysis of two loess-paleosol sequences in the Northern Harz Foreland, Germany. *Palaeogeography, Palaeoclimatology, Palaeoecology* 461. 401–417.

Liu, Q., Torrent, J., Barrón, V., Duan, Z.Q. and Bloemendal, J. 2011. Quantification of hematite from the visible diffuse reflectance spectrum: effects of aluminium substitution and grain morphology. *Clay Minerals* 46. 137–147.

Marković, S.B., Hambach, U., Stevens, T., Kukla, G.J., Heller, F., McCoy, W.D., Oches, E.A., Buggle, B. and Zöller, L. 2011. The last million years recorded at the Stari Slankamen (Northern Serbia) loess-paleosol sequence: revised chronostratigraphy and long-term environmental trends. *Quaternary Science Reviews* 30. 1142–1154.

Marković, S.B., Stevens, T., Kukla, G.J., Hambach, U., Fitzsimmons, K.E., Gibbard, P., Buggle, B., Zech, M., Guo, Z., Hao, Q., Wu, H., O'Hara Dhand, K., Smalley, I.J., Újvári, G., Sümegi, P., Timar-Gabor, A., Veres, D., Sirocko, F., Vasiljević, D.A., Jary, Z., Svensson, A., Jović, V., Lehmkuhl, F., Kovács, J. and Svirčev, Z. 2015. Danube loess stratigraphy – Towards a Pan-European loess stratigraphic model. *Earth Science Reviews* 148. 228–258.

Porter, S. 2000. High-resolution paleoclimatic information from the Chinese eolian sediments based on grayscale intensity profiles. *Quaternary Research* 53. 70–77.

Post, D., Bryant. R.B., Batchily, A.K. and Huete, A.R. 1993. Correlations between field and laboratory measurements of soil color. In *Soil Color.* Eds.: Bigham, J.R. and Ciolkosz, E.J., Spec. Publ. 31. Madison WI, SSSA, 35–50.

Reichenbach, H. and Rich, C.I. 1975. Fine-grained micas in soils. In *Soil Components. Vol 2: Inorganic Components.* Ed.: Gieseking, J.E., Berlin, Springer Verlag, 60–86.

Righi, D. and Meunier, A. 1995. Origin of clays by rock weathering and soil formation. In *Origin and Mineralogy of Clays: Clays and the Environment.* Ed.: Velde, B., Heidelberg, Springer Verlag, 43–161.

Scheinost, A.C., Chavernas, A., Barron, V. and Torrent, J. 1998. Use and limitations of second-derivative diffuse reflectance spectroscopy in the visible to near-infrared range to identify and quantify Fe oxide minerals in soils. *Clays and Clay Minerals* 46. 528–536.

Schwertmann, U. 1971. Transformation of hematite to goethite in soils. *Nature* 232. 624–625.

Shepherd, K.D. and Walsh, M.G. 2002. Development of reflectance spectral libraries for characterization of soil properties. *Soil Science Society of America Journal* 66. 988–998.

Sun, Y., He, L., Liang, L. and An, Z. 2011. Changing colour of Chinese loess: Geochemical constraint and paleoclimatic significance. *Journal of Asian Earth Sciences* 40. 1131–1138.

Szeberényi, J., Kovács, J., Bradák, B., Barta, G., Csonka, D., Medveďová, A., Roštínský, P., Kiss, K. and Varga, G. 2020. Experiencing new perspectives in the application of reflectance spectroscopy in loess research. *Quaternary International* (in press).

Torrent, J., Liu, Q., Bloemendal, J. and Barrón, V. 2007. Magnetic enhancement and iron oxides in the Upper Luochuan loess-paleosol sequence, Chinese Loess Plateau. *Soil Science Society of America Journal* 71. 1570–1578.

Torrent, J., Schwertmann, U., Fechter, H. and Alférez, F. 1983. Quantitative relationships between color and hematite content. *Soil Science* 136. (6): 354–358.

Újvári, G., Varga, A., Raucsik, B. and Kovács, J. 2014. The Paks loess-paleosol sequence: A record of chemical weathering and provenance for the last 800 ka in the mid-Carpathian Basin. *Quaternary International* 319. 22–37.

Varga, G. 2015. Changing nature of pleistocene interglacials – is it recorded by paleosoils in Hungary (Central Europe)? *Hungarian Geographical Bulletin* 64. (4): 317–326.

Varga, G., Újvári, G. and Kovács, J. 2019. Interpretation of sedimentary (sub)populations extracted from grain size distributions of Central European loess-paleosol series. *Quaternary International* 502. Part A, 60–70.

Vidic, N.A., Singer, M.J. and Verosub, K.L. 2004. Duration dependence of magnetic susceptibility enhancement in the Chinese loess-paleosols of the past 620 ky. *Palaeogeograpaphy, Palaeoclimatology, Palaeoecology* 211. 271–288.

Viscarra Rossel, R.A., Minasny, B., Roudier, P. and McBartney, A.B. 2006. Colour space models for soil science. *Geoderma* 133. 320–337.

Vlaminck, S., Kehl, M., Lauer, T., Shahriari, A., Sharifi, J., Eckmeier, E., Lehndorff, E., Khormali, F. and Frechen, M. 2016. Loess-soil sequence at Toshan (Northern Iran): Insights into late Pleistocene climate change. *Quaternary International* 399. 122–135.

Wang, Q., Song, Y., Zhao, Z. and Li, J. 2016. Colour characteristics of Chinese loess and its paleoclimatic significance during the last glacial–interglacial cycle. *Journal of Asian Earth Sciences* 116. 132–138.

White, W.B. and Keester, K.L. 1966. Optical absorption spectra of iron in the rock-forming silicates. *American Mineralogist* 51. 774–791.

Wu, Y., Qiu, S., Fu, S., Rao, Z. and Zhu, Z. 2018. Pleistocene climate change inferred from multiproxy analyses of a loess-paleosol sequence in China. *Journal of Asian Earth Sciences* 154. 428–434.

Zeeden, C., Hambach, U., Veres, D., Fitzsimmons, K., Obreht, I., Bösken, J. and Lehmkuhl, F. 2018. Millennial scale climate oscillations recorded in the Lower Danube loess over the last glacial period. *Palaeogeography, Palaeoclimatology, Palaeoecology* 509. 164–181.

Zhang, Y.G., Ji, J.F., Balsam, W.L., Liu, L.W. and Chen, J. 2007. High resolution hematite and goethite records from ODP 1143, South China Sea: Co-evolution of monsoonal precipitation and El Niño over the past 600,000 years. *Earth and Planetary Science Letters* 264. 136–150.

Zhou, L.P. and Shackleton, N.J. 1998. Loess spectrophotometry: A tool for detecting climate-related events. In *Past Global Changes and Their Significance for the Future.* PAGES Open Science Meeting, 20–23. April 1998. London, Poster abstracts.

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Parameterizing the modified water cloud model to improve soil moisture data retrieval using vegetation models

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Abstract

The objective was to parameterize a modified water cloud model using crop coefficients (A and B). These crop coefficients were derived from Landsat-8 and Sentinel-2 data. Whereas coefficients C and D are of soil parameters. The water cloud model was modified using crop coefficients by minimizing the RMSE between observed VVσ^0 and Sentinel-1 based simulated VVσ^0. The comparison with observed and simulated VV polarized σ^0 showed low RMSE (0.81 dB) and strong R^2 of 0.98 for NDVI-EVI combination. However, based on other possible combinations of vegetation indices VVσ^0 and simulated VVσ^0 do not show a good statistical agreement. It was observed that the errors in crop coefficients (A and B) are sensitive to errors in initial vegetation/canopy descriptor parameters.

Keywords: NDVI, EVI, SAR, Sentinel, WCM

Introduction

Soil moisture is an important and key factor that influences the meteorological parameters directly or indirectly; therefore it is important to understand its patterns and cause of variations at the region level (Hornberger, G.M. 1998). The dynamics of soil moisture plays a critical role in the analysis of agricultural drought, weather forecast, flood forecasting, crop yield prediction and climatology (Berthet, L. *et al*. 2009; Beck, H.E. *et al*. 2009; Hegedűs, P. *et al.* 2013, 2015; Dezső, J. *et al*. 2019). The sensitivity of microwave signals is directly reciprocal to soil dielectric constant, which reflect the soil moisture; microwave signal can penetrate vegetation canopy and provide soil moisture states (Bindlish, R. *et al*. 2006). Soil moisture at a regional scale can be observed by the synthetic aperture radar (SAR) with fine spatial and temporal resolutions (Shi, J.C. *et al*. 1997; Pathe, C. *et al*. 2009; Paloscia, S. *et al*. 2013; Pasolli, L. *et al*. 2015).

Nowadays, many models are available for the quantification of soil moisture at a regional scale, but model complexity and exhaustive data input requirement limit their applications. However, the water cloud model (WCM) requires a lower number of input data (Attema, E. and Ulaby, F.T. 1978). The WCM has four empirical coefficients, namely canopy descriptor parameters (A and B) and soil parameters (C and D). At local scale to regional analysis, the vegetation/crop coefficients of the WCM

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are usually calculated by statistical analysis using in-situ datasets (Prevot, L. *et al.* 1993; Magagi, R. and Kerr, Y. 1997; Frison, P. *et al.* 1998). Kumar, K. *et al.* (2012) used a genetic algorithm (GA) to calculate vegetation coefficients (A and B) at the local scale using an empirical relationship between surface scattering and vegetation/crop biophysical parameters (using ENVISAT ASAR VV-pol data). Since these in-situ datasets are generally collected from specific observation sites, hence it is important to understand the usefulness of these observations in other regions. Consequently, in most of the crop models, crop coefficients vary from one location to another. It is important to develop a new approach or use existing approaches for the identification of crop coefficients, which does not require the in-situ observation of the biological and physical parameters of crops. Currently, WCM requires V_1 and V_2 vegetation parameters, which are associated with A, B, C, and D coefficients. Therefore, V_1 and V_2 must be precise, and easily available otherwise spatial variability of A, B, C, and D will be high. In the past, these two (V_1 and V_2) vegetation parameters were estimated using extensive fieldwork within the study area; therefore, parameterization of WCM was easy at a local scale. Rawat, K.S. *et al.* (2017, 2018) successfully estimated soil moisture using modified WCM (MWCM) by replacing V_1 and V_2 with NDVI value.

The study objective was to parameterize the MWCM using different combinations of vegetation indices. The combinations are categorized into Cases (I-IV) of combinations of vegetation indices such as Case I (V_1-V_2 = NDVI-EVI), Case II (V_1-V_2 = NDVI-NDVI), Case III (V_1-V_2 = EVI-EVI) and Case IV (V_1-V_2 = EVI-NDVI); where NDVI is normalized vegetation index, and EVI is the enhanced vegetation index).

Materials

Study area and ground data

The Bathinda district study located in the state of Punjab India and is a region with wheat being the dominant crop (from 30°4′30″ N to 30°21′20″ N latitude and from 74°47′50″ E to 75°10′00″ E longitude) with average elevation of 210 m from sea level *(Figure 1).* The district of Bathinda lies in the extreme southwestern part of Punjab and far away from the Shivalik ranges in the North of the state. The normal annual rainfall of this region is about 408 mm, 80 per cent of which is received during the southwestern monsoon season (First week of July to mid-September) and remaining during the winter season. Dust storms are a regular feature in summer season when the temperature reaches to 47.0 °C in the peak summer in May-

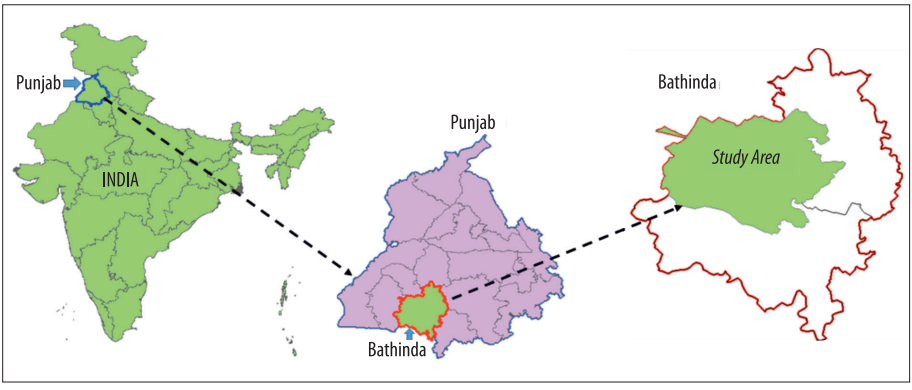

Fig. 1. Location map of the study area

June, however, in winter during December and January, the minimum temperature at night could reach 0.0 °C.

The soil in the area is mostly loamy sand and sandy loam and contained 68–70 per cent sand, 12–15 per cent silt and 18–21 per cent clay. Due to light texture, the water holding capacity of soil in the district varies from 25–30 per cent depends on the clay content and organic matter present in the soil. The arid brown soils are calcareous in nature; these soils are imperfectly to moderately drained and siezoram soils the accumulation of calcium carbonate (CGWB, 2017). Yadav, B.K. *et al*. (2018) determined that the soils were low in available nitrogen (N) low to medium in available phosphorous (P) and medium to high in available potassium (K) content. They also found that there was wide variation in soil fertility status has developed on various landforms in Bathinda District, but the soils were low in available N, low to medium in available P and medium to high in available K content. The measurements of soil moisture and vegetation parameters were carried out during the Sentinel-1 overpasses (dates are given in *Table 1*).

The Sentinel-1 mission provides active microwave data of C-band with 10 m resolution and has potential for soil moisture mapping. Further, European Space Agency (ESA) constellation of one more identical Sentinel-1A satellite on 25 April 2016 named Sentinel-1B which has two microwave Synthetic Aperture Radar (SAR) sensors for improvement in temporal resolution.

Total of thirty imageries were acquired during the winter wheat crop growing period (details are provided in *Table 1*). During each overpass of the satellite, in-situ soil moisture measurements were performed using a time-domain reflectometer instrument (TDR, Field Scout™ TDR 300, Spectrum Technologies, Aurora, IL, United States). From sampling sites, soil moisture was measured using a TDR at a soil depth of 0–5 cm. Calibration of the TDR instrument was performed as suggested by Rawat, K.S. *et al.* (2017, 2018). The ancillary data, namely surface roughness, leaf area index (LAI), crop height, crop coverage and crop physiological states data were also collected.

Landsat-8 and Sentinel-2 data

A total of sixteen Sentinel-2 and Landsat-8 datasets have been downloaded to estimate vegetation greenness in 2018 *(Table 1)*. The spatial resolutions of Landsat-8 and Sentinel-2 were 30 m and 10 m, respectively. After pre-processing, vegetation greenness was calculated using the Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI).

Since the date of data acquisition difference was very small, hence a limited or no change was observed in NDVI and EVI value. Therefore, we did not performed any interpolation of NDVI and EVI value along with SAR images.

Sentinel-1 data

The Sentinel-1 operates at 5.4 GHz frequency, and has four imaging modes, namely Stripmap model, Interferometric wide swath, extra-wide swath, and wave mode. In pre-

Table 1. Satellite data with a different date

Sensor	Dates in 2018	Spatial resolution
Sentinel-1A/B	January (20, 24), February (1, 5, 13, 17, 25), March (1, 9, 13, 21, 25), April (6, 14)	10 m
Sentinel-2A/B	January (1, 27), February (1, 6, 12, 18), March (1, 6), April (7, 15)	10 m
Landsat-8	January (8, 17), February (14, 22, 26), March (30)	30 m

sent research work, S1 TOPS-model SLC data of an interferometric wide swath mode has been used for soil moisture estimation.

The pre-processing (radiometric and orthorectification) was performed according to the Sentinel-1 user data handbook. The Sentinel-1 data sets were processed in the SNAP platform (http://step.esa.int/main/toolboxes/snap). The Sentinel-1 imageries were acquired in VV and VH polarization with an incidence angle near to 38°. We processed only VV polarization in our study because past studies (Rawat, K.S. *et al.* 2019a, b) showed that VH polarization does not provide relevant crop/soil information with WCM for our study area.

Time Domain Reflectometer (TDR) instrument

The instrument TDR with a 7.5 cm probe length was used to collect in-situ soil moisture. TDR has wide spectrum frequency; it also works in C-band frequency as the Sentinel-1. TDR is a lightweight, portable instrument, it was used for in-situ observation. Besides, TDR may be used to get a large number of measurements over a short period of time (within satellite overpass of the study area) (Rawat, K.S. *et al.* 2017, 2018, 2019a, b).

Methods

The Sentinel-1 data sets were processed for only VV polarization and generated backscattering coefficient (σ°) which is known as total σ^0 (or σ^0_{total}) because two σ^0 contribute in σ^0_{total}, backscattering from soil σ^0 (σ^0_{soil}) and backscattering from vegetation (σ^0_{veg}). The σ^0_{total} of in-situ observation sites were derived using SNAP software. Similarly, NDVI and EVI value of each in-situ measurement sites were derived from the Sentinel-2 and Landsat-8 data. There was no need for re-sampling of Landsat-8 into the Sentinel-2 or Sentinel-2 into Landsat-8 because our study area was homogenous and the size of the in-situ measurement plots was of dimensions more than 30 m × 30 m.

The MWCM was used to develop a semi-empirical model for soil moisture estimation using microwave data. In MWCM, vegetation descriptors (or V_1 and V_2) were replaced by a couple of vegetation indices as Cases (I-IV) (as V_1-V_2 = NDVI-EVI, V_1-V_2 = NDVI-NDVI, V_1-V_2 = EVI-EVI; V_1-V_2 = EVI-NDVI; where NDVI = normalized vegetation index [Bala, A. *et al.* 2015; Rawat, K.S. *et al.* 2017, 2019a, b] and EVI = enhances vegetation index).

Modified Water Cloud Model (MWCM)

The WCM has a great possibility to diminish the effect of vegetation by computing the σ^0_{veg}. It can be expressed by the following equation (1):

$$\sigma^0_{total}(dB) = \sigma^0_{veg} + \sigma^0_{veg+soil} + \tau^2 \sigma^0_{soil}, \quad \text{eq. 1}$$

For a given radar signal, σ^0 from the bare soil has a linear function of the soil moisture with depth (0.0–7.5 cm) (Attema, E. and Ulaby, F.T. 1978) and $\sigma^0_{veg+soil} \approx 0$; therefore, eq. 1 can be modified as:

$$\sigma^0_{total}(dB) = \sigma^0_{veg} + \tau^2 \sigma^0_{soil}, \quad \text{eq. 2}$$

where: $$\sigma^0_{veg}(dB) = AV_1 \cos(1\ \tau^2), \quad \text{eq. 3}$$

$$\tau^2 = \exp(2BV_2 / \cos\theta), \quad \text{eq. 4}$$

$$\sigma^0_{soil}(dB) = C + D \cdot SM, \quad \text{eq. 5}$$

where, θ is incident angle; A and B are vegetation coefficients that depend on the type of canopy, while coefficients C and D are soil dependent, SM is soil moisture. V_1 and V_2 are canopy parameters and WCM was modified by changing these parameters (V_1 and V_2) by NDVI or EVI. Magagi, R. and Kerr, Y. (1997) investigated that due to change in vegetation states, canopy properties (bio and physical) change temporally. Therefore, a vegetation index is capable of explaining vegetation growth states.

Model parametrization

Based on Magagi, R. and Kerr, Y. (1997), we have replaced V_1 and V_2 by a pair of vegetation

indices (by applying in eq. 3 and 4), namely NDVI and EVI, since no previous work was found on replacing particular vegetation parameter (e.g. V_1 or V_2) by specific vegetation index (e.g. NDVI or EVI) to obtain optimal value of MWCM coefficients. However, NDVI and EVI can describe the winter wheat crop canopy as canopy descriptors. We tested different possible pairs of NDVI and EVI for the parametrization of the MWCM. We assumed that different possible combinations of NDVI and EVI would be better to incorporate the spatial water content/status, its spatial distribution within a confined volume, and would stand out an accurate simulation of total σ^0. The inverse distance method was applied for interpolation to generate the spatial maps of soil moisture (Mishra, A. *et al.* 2009).

Vegetation index (NDVI/EVI)

Crop mapping and environmental research commonly use NDVI (Garroutte, E. *et al.* 2016). Huete, A.R. (1988) investigated that NDVI responses were high for canopy background variations and showed saturated signals for high biomass conditions. EVI, suggested by Qi, J. *et al.* (1994), improves sensitivity over dense vegetation conditions without the effect of the canopy background by minimizing canopy-soil variations (Huete, A.R. *et al.* 2002). We had selected two vegetation indices, and these vegetation indices were developed using equations (eq. 6, 7, 8 and 9). The particular band (blue, red, and near-infrared bands of Landsat-8 and Sentinel-2A/B) after atmospheric correction and conversion of digital number into reflectance of particular bands.

NDVI and EVI were used for the parametrization of vegetation and soil coefficients of MWCM (eq. 6 and eq. 7 for Landsat 8; eq. 8 and eq. 9 for Sentinel-2):

$$EVI = 2.5 \cdot \frac{(Band5 - Band4)}{(Band5 + 6 \cdot Band4 - 7.5 \cdot Band2 + 1)} \quad \text{eq. 6}$$

$$NDVI = \frac{(Band5 - Band4)}{(Band5 + Band4)} \quad \text{eq. 7}$$

$$NDVI = \frac{(Band8 - Band4)}{(Band8 + Band4)} \quad \text{eq. 8}$$

$$EVI = 2.5 \cdot \frac{(Band8 - Band4)}{(Band8 + 2.4 \cdot Band4 + 1)} \quad \text{eq. 9}$$

where, the value of 2.5 in eq. 6 and 9 is a gain factor while 7.5 and 2.4 in eq. 6 and 9 (https://webapps.itc.utwente.nl/librarywww/papers_2017/msc/nrm/adan.pdf) are coefficients, used to reduce aerosol effects and value 1 is the soil adjustment factor.

Model coefficients (A, B, C, and D) estimation

Images of the study period were downloaded of 20/01/2018 to14/04/2018. This study assumed that the roughness over the crop was constant during the study period because of the single wheat crop, a slight change in roughness. Hence the number of unknown variables reduces into four for MWCM: coefficients of A, B, C, and D estimation errors (for coefficients) due to different factors (e.g. SAR sensor measurement error, optical sensor measurement error and NDVI estimation error) were also reduced. This process diminishes the effects over coefficients. The following two steps were used to prepare data for the optimal value of coefficients:

– Measured σ^0 at soil moisture sampling (using TDR) point from each corresponding to the Sentinel-1 data.
– The NDVI was calculated at each sampling point in the series of data.

The iterative optimization method was applied in SigmaPlot-12.0 to estimate the model coefficients (A, B, C and D). These model coefficients are important in predicting in σ^0 using the MWCM.

Evaluation of observed and estimated σ^0

In this study, the estimated VV polarized σ^0 with the help of possible combinations of NDVI and EVI as canopy descriptor and generated MWCM coefficients were tested with observed VVσ^0 of Sentinel-1 using statistical

tests and method as explained in Rawat, K.S. *et al.* (2017, 2018). Statistical tests are the way to evaluate the accuracy of predicted data compared to observed data. However, there must be a sufficient number of datasets to draw a conclusion using statistical tests.

Results and discussion

For the simulation of VV σ^0, the vegetation and soil coefficients were estimated for four combinations of NDVI and EVI for V_1 and V_2 *(Table 2)*. The C and D soil coefficients have almost fixed values for each of the four combinations of vegetation indices (VIs) for VVσ^0; therefore, C and D are free from canopy properties in the MWCM. Also, this type of interpretation can only be driven when V_1 and V_2 replaced by different vegetation indices combinations. If V_1 and V_2 are replaced by same VI (may be NDVI or EVI) then it cannot be concluded that C and D are independent of canopy because same NDVI (V_1)-NDVI (V_2) or EVI (V_1)-EVI (V_2) combinations of VI gives us only one value of C and D. The value of A and B are different from different possible combinations of VIs (see *Table 2*). The values of A and B are completely governed by canopy properties (an orientation of leaf, the water content in leaf, and chlorophyll). It is further clarification of why more than one VI should be used for parameterization of MWCM. *Table 2*, non-zero values of A and B indicate that we cannot ignore the contribution of a canopy in microwave analysis.

MWCM parameterization using VIs was conducted by minimizing the RMSE with the best R^2 value between observed and predicted VV σ^0 to optimize the effective unknown coefficients (A, B, C, and D). The comparative results of RMSE and R^2 between observed and predicted VV σ^0 from different vegetation parameters in combination are presented in *Table 2* and shown in *Figure 2*.

MWCM Parameterization I: Estimation of A, B, and C, D coefficients using NDVI (V_1)-NDVI (V_2)

NDVI is a commonly used index to monitor crop canopy, health and spatial distribution of vegetation during the growing season in agriculture. Therefore, NDVI-NDVI combination (case I) was used instead of V_1-V_2 vegetation parameters in MWCM. The graphical simulation of generated VV σ^0 to VV σ^0 from microwave data over the wheat crop *(Figure 2*, a*)*. A total of 82 and observed data (NDVI and soil moisture) points (as input for σ^0 simulation) were used for NDVI-NDVI performance for predicting VV σ^0 from MWCM. The model simulated VV σ^0 with a good R^2 value of 0.61, while the RMSE was highest in this combination (see *Table 2*). The NDVI represents the crop canopy solely in terms of its biophysical properties, and canopy background incorporates the dielectric properties.

MWCM Parameterization II: Estimation of A, B, and C, D coefficients using NDVI (V_1)-EVI (V_2)

NDVI and EVI combination (case II) was used as the canopy descriptors in MWCM. The R^2

Table 2. Vegetation and soil coefficients with different possible combinations of vegetation parameters

Canopy parameters of MWCM		MWCM coefficients				RMSE	R^2
		Canopy coefficients		Soil coefficients			
V_1	V_2	A	B	C	D		
NDVI	NDVI	3.99	8.38	11.33	0.03	0.89	0.61
NDVI	EVI	-2.89	0.418	11.21	0.02	0.73	0.68
EVI	NDVI	-1.25	0.018	11.32	0.02	0.87	0.59
EVI	EVI	-5.65	0.171	11.30	0.15	0.79	0.63

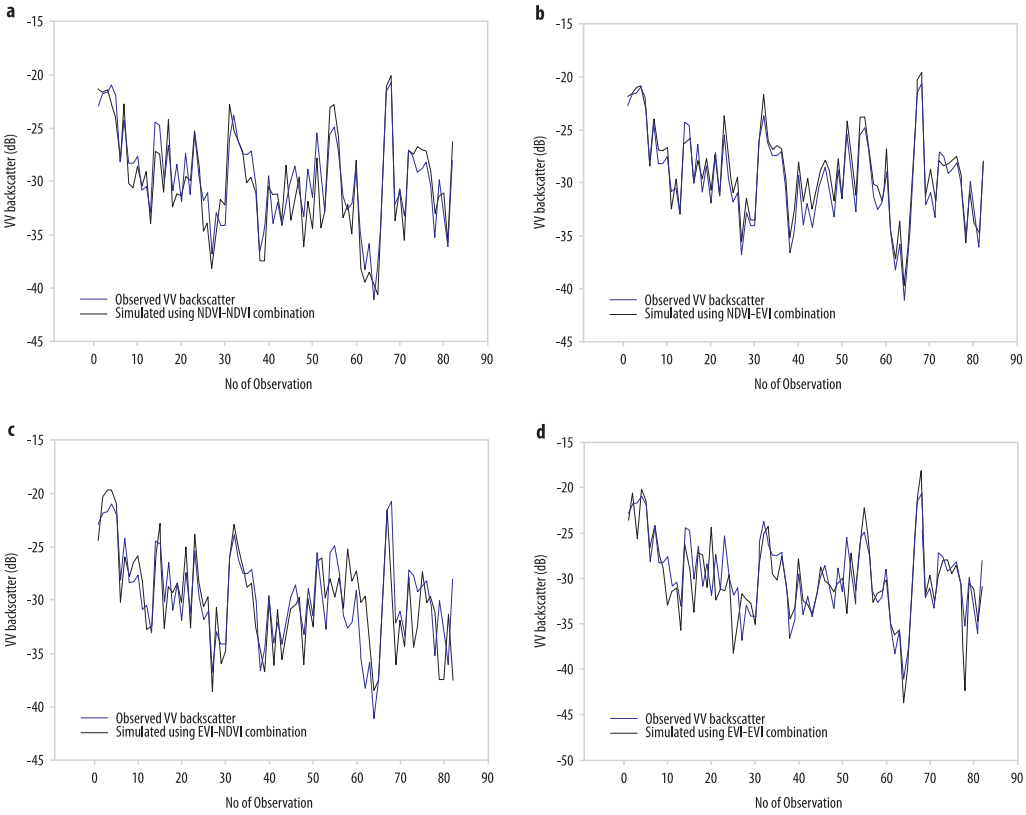

Fig. 2. Observed v/s simulated VV backscatter from the case I-IV. MWCM Parameterization I-IV: Estimation of A, B, and C, D coefficients using **a** = NDVI (V_1)-NDVI (V_2); **b** = NDVI (V_1)-EVI (V_2); **c** = EVI (V_1)-NDVI (V_2); **d** = EVI (V_1)-EVI (V_2).

and RMSE (0.68 and 0.73, respectively, see *Table 2*) show good correlation *(Figure 2*, b*)*. The MWCM retrieved VV σ^0 with a good accuracy based on statistical tests. It may be due to both conditions of crop/vegetation canopy information with a background (NDVI) and canopy information without the background (EVI). This possible combination also indicates that V_1 slightly dependent on canopy background while V_2 is independent of canopy background information (because EVI is free from canopy background information (Qi, J. *et al.* 1994; Huete, A.R. *et al.* 2002). Therefore, both VIs combinations make a good prediction of VV σ^0 from MWCM and moderately improves the performance.

MWCM Parameterization III: Estimation of A, B, and C, D coefficients using EVI (V_1)-NDVI (V_2)

The case III of VIs was EVI (V_1)-NDVI (V_2). A significant decrement was witnessed when the combination of EVI and NDVI was observed. The MWCM shows below the average R^2 (0.62) value in four possible combinations of two VIs (see *Table 2*). Based on statistical tests, MWCM works with low efficiency because this combination has a low R^2 value of 0.59 (see *Table 2*; *Figure 2*, c). The third combination of VIs was just opposite of case II, and from this condition, we have also concluded that V_1 slightly supports the canopy background in MWCM.

MWCM Parameterization IV: Estimation of A, B, and C, D coefficients using EVI (V_1)-EVI (V_2)

The case IV was EVI (V_1)-EVI (V_2). This combination gives a marginal improvement in the performance of MCM with the R^2 of 0.63 for VV σ^0 (see *Table 2*). There was a second highest preferable value of RMSE and R^2 for VV σ^0 in comparison to MWCM with different combinations of VIs *(Figure 2*, d*)*. Therefore, we can infer that EVI depicts the wheat crop canopy in a better way for the V_2 parameter in the MWCM.

Evaluation of observed and estimated σ^0

In this study, statistical tests showed that NDVI-EVI combination had the potential to provide good results with the agreement of nine statistical tests. The combination of NDVI-EVI as a combination of vegetation parameters or canopy descriptor (V_1-V_2) showed the least RMSE of 0.81 dB between observed and predicted VV σ^0 while highest R^2 value of 0.98 among other VIs combination for observed and predicted VV σ^0 *(Table 3).*

The accuracy of retrieval of VVσ^0 could be different when different combinations of VIs were chosen. Wang, L. *et al.* (2019) also found the accuracy of retrieval depends on the selection of VIs. The accuracy of retrieval of VVσ^0 was high when the V_1 replaced by NDVI and V_2 by EVI (see *Table 3*). Also, when the V_1 replaced by EVI and the V_2 by NDVI, retrieval accuracy decreases, which means that canopy background influences the V_1 parameter in MWCM while V_2 may be canopy background free. Because EVI is canopy background free while NDVI showed canopy as well as litter bit canopy background (soil) information, this analysis also revealed that any combination of VIs does not have much effect on soil coefficients C and D, because C and D depend entirely on soil properties (e.g., bulk density, soil texture, etc.) rather than vegetation properties. The C and D parameters were fixed by using linear equation eq. 5. Therefore, for any combination of VIs, the value of C and D does not change much. It was found that the errors in vegetation or canopy descriptors were sensitive to errors in the retrieval of VV σ^0 (Liu, C. and Shi, J. 2016).

Conclusion

In this study, WCM was modified using vegetation/canopy descriptor to simulate VVσ^0. The current research focused on the parameterization of MWCM. In the current research work, a combination of vegetation indices and backscattering (VV) simulated

Table 3. Statistical evaluation of estimated with respect observed VV backscatter (σ^0), based on NDVI as crop canopy descriptor and on investigated coefficients

Observed	-27.24	-31.39	-25.24	-29.59	-31.88	-30.98	-36.88
$E_{NDVI-NDVI}$	-29.28	-29.93	-24.11	-27.49	-35.16	-33.98	-39.45
$E_{NDVI-EVI}$	-26.86	-30.95	-25.21	-29.2	-31.91	-31.03	-38.89
$E_{EVI-NDVI}$	-28.28	-30.93	-25.11	-28.49	-34.73	-32.98	-37.45
$E_{EVI-EVI}$	-25.28	-25.99	-24.70	-27.96	-33.66	-31.09	-36.22
Statistical performance measures				NDVI-NDVI	NDVI-EVI	EVI-NDVI	EVI-EVI
R^2				0.83	0.98	0.90	0.75
RMSE				2.34	0.81	1.46	2.38
R-RMSE				0.08	0.02	0.05	0.08
MAE				0.89	0.12	0.68	1.19
NRMSE				-0.08	-0.03	-0.05	-0.08
MAE				0.89	0.12	0.68	-1.19
SEE				2.53	0.87	1.58	2.57
RMSE, %				-1.10	-0.38	-0.69	-1.12
IR				1.03	1.00	1.02	0.96

from Sentinel-1 was studied. The assumed hypothesis was that surface roughness during wheat crop period was constant. A total of four combinations were tested for the comparison of $VV\sigma^0$ to the observed $VV\sigma^0$. Our results revealed that MWCM could be parameterized with NDVI and EVI as canopy descriptors. The basis of optimization of A, B, C and D by reducing RMSE between MWCM predicted and Sentinel-1 observed $VV\sigma^0$. The retrieval of $VV\sigma^0$ converges to the correct (with good accuracy or free from errors) values of the vegetation or canopy descriptors.

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REFERENCES

Attema, E. and Ulaby, F.T. 1978. Vegetation modelled as a water cloud. *Radio Science* 13. (1): 357–364.

Bala, A., Pawar, S.P., Misra, A.K. and Rawat, K.S. 2015. Estimation and validation of actual evapotranspiration for wheat crop using SEBAL model over Hisar District (Haryana), India. *Current Science* 113. (1): 134–141.

Beck, H.E., Jeu, R.A.M., Schellekens, J., Dijk, A.I.J.M. and Bruijnzeel, L.A. 2009. Improving curve number based storm runoff estimates using soil moisture proxies. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* 2. (4): 250–259.

Berthet, L., Andréassian, V., Perrin, C. and Javelle, P. 2009. How crucial is it to account for the antecedent moisture conditions in flood forecasting? Comparison of event-based and continuous approaches on 178 catchments. *Hydrology Earth System Science* 13. (6): 819–831.

Bindlish, R., Jackson, J.T., Gasiewski, A.J., Klein, M. and Njoku, E.G. 2006. Soil moisture mapping and AMSR-E validation using the PSR in SMEX02. *Remote Sensing of Environment* 103. (2): 127–139.

CGWB 2017. *Ground Water Information Bathinda District, Punjab*. Chandigarh, North Western Region. Central Ground Water Board, Ministry of Water Resources Government of India. Available at http://cgwb.gov.in/District_Profile/Punjab/Bathinda.pdf

Dezső, J., Czigány, S., Nagy, G., Pirkhoffer, E., Słowik, M. and Lóczy, D. 2019. Monitoring soil moisture dynamics in multilayered Fluvisols. *Bulletin of Geography. Physical Geography Series* 16. (1): 131–146.

Frison, P., Mougin, E. and Hiernaux, P. 1998. Observations and interpretation of seasonal ERS-1 wind scatterometer data over northern Sahel (Mali). *Remote Sensing of Environment* 63. 233–242.

Garroutte, E., Hansen, A. and Lawrence, R. 2016. Using NDVI and EVI to map spatiotemporal variation in the biomass and quality of forage for migratory elk in the Greater Yellowstone Ecosystem. *Remote Sensing* 8(5):404. Available at https://doi.org/10.3390/rs8050404.

Hegedűs, P., Czigány, S., Balatonyi, L. and Pirkhoffer, E. 2013. Analysis of soil boundary conditions of flash floods in a small basin in SW Hungary. *Open Geosciences* 5. (1): 97–111.

Hegedűs, P., Czigány, S., Pirkhoffer, E., Balatonyi, L. and Hickey, R. 2015. Analysis of spatial variability of near-surface soil moisture to increase rainfall-runoff modelling accuracy in SW Hungary. *Open Geosciences* 7. (1): 126–139.

Hornberger, G.M. 1998. *Elements of Physical Hydrology*. Baltimore, MD, USA, Johns Hopkins University Press.

Huete, A.R, Didan, K., Miura, T., Rodriguez, E.P., Gao, X. and Ferreira, L.G. 2002. Overview of the radiometric and biophysical performance of the MODIS Vegetation indices. *Remote Sensing of Environment* 83. 195–213.

Huete, A.R. 1988. A soil-adjusted vegetation index (SAVI). *Remote Sensing of Environment* 25. (3): 295–309.

Kumar, K., Prasad, K.S.H. and Arora, M.K. 2012. Estimation of water cloud model vegetation parameters using a genetic algorithm. *Hydrological Sciences Journal* 57. 776–789.

Liu, C. and Shi, J. 2016. Estimation of vegetation parameters of Water Cloud Model for global soil moisture retrieval using Time-Series L-Band Aquarius Observations. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* 9. (12): 5621–5633.

Magagi, R. and Kerr, Y. 1997. Retrieval of soil moisture and vegetation characteristics by use of ERS-1 wind scatterometer over arid and semi-arid areas. *Journal of Hydrology* 188. 361–384.

Mishra, A., Gairola, R.M., Varma, A.K., Sarkar, A. and Agarwal, V.K. 2009. Rainfall retrieval over Indian land and oceanic regions from SSM/I microwave data. *Advances in Space Research* 44. 815–823.

Paloscia, S., Pettinato, S., Santi, E., Notarnicola, C., Pasolli, L. and Reppucci, A. 2013. Soil moisture mapping using Sentinel-1 images: Algorithm

and preliminary validation. *Remote Sensing of Environment* 134. 234–248.

Pasolli, L., Notarnicola, C., Bertoldi, G., Bruzzone, L., Remelgado, R., Greifeneder, F., Niedrist, G., Chiesa, S.D., Tappeiner, U. and Zebisch, M. 2015. Estimation of soil moisture in mountain areas using SVR technique applied to multiscale active radar images at C-band. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* 8. (1): 262–283.

Pathe, C., Wagner, W., Sabel, D., Doubkova, M. and Basara, J.B. 2009. Using ENVISAT ASAR global mode data for surface soil moisture retrieval over Oklahoma, USA. *IEEE Transactions on Geoscience and Remote Sensing* 47. (2): 468–480.

Prevot, L., Dechambre, M., Taconet, O., Vidal-Madjar, D., Normand, M. and Gallej, S. 1993. Estimating the characteristics of vegetation canopies with airborne radar measurements. *International Journal of Remote Sensing* 14. 2803–2818.

Qi, J., Chehbouni, A., Huete, A.R., Kerr, Y.H. and Sorooshian, S. 1994. A modified soil adjusted vegetation index. *Remote Sensing of Environment*. 48. (2): 119–126.

Rawat, K.S., Sehgal, V.K., Pradhan, S. and Ray, S.S. 2017. Retrieval and validation of soil moisture from FRS-1 data set of Radar Imaging Satellite (RISAT-1). *Arabian Journal of Geosciences* 10. (445): 1–10. Doi: 10.1007/s12517-017-3195-6.

Rawat, K.S., Sehgal, V.K. and Ray, S.S. 2018. Semi-empirical model for retrieval of soil moisture using RISAT-1 C-band data over a sub-tropical semi arid area of Rewari District State of Haryana (India). *Journal of Earth System Science* 127(2). Doi: 10.1007/s12040-018-0919-2.

Rawat, K.S., Singh, S.K. and Pal, R.K. 2019a. Synergetic methodology for estimation of soil moisture over agricultural area using Landsat-8 and Sentinel-1 satellite data. *Remote Sensing Applications: Society and Environment* 15(100250).

Rawat, K.S., Singh, S.K. and Ray, R.L. 2019b. An integrated approach to estimate surface soil moisture in agricultural lands. *Geocarto International* 2019(11). Available at https: //doi.org/10.1080/10106049.2019.1678674.

Shi, J.C., Wang, J., Hsu, A.Y., Neill, P.E.O. and Engman, E.T. 1997. Estimation of bare surface soil moisture and surface roughness parameter using L-band SAR image data. *IEEE Transactions on Geoscience and Remote Sensing* 35. (5): 1254–1266.

Wang, L., He, B., Bai, X. and Xing, M. 2019. Assessment of different vegetation parameters for parameterizing the coupled water cloud model and advanced integral equation model for soil moisture retrieval using time series Sentinel-1A data. *Photogrammetric Engineering & Remote Sensing* 85. (1): 43–54.

Yadav, B.K., Sidhu, A.S. and Kumar, D. 2018. Distribution and indexation of plant available nutrients in Bathinda district of south-west Punjab, India. *Journal of Soils and Crops* 28. (1): 8–18.

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Comparison of pipette method and state of the art analytical techniques to determine granulometric properties of sediments and soils

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Abstract

The determination of particle size distribution is a crucial issue in various fields of earth sciences (e.g., Quaternary research, sedimentology, stratigraphy, structural geology, volcanology), environmental sciences as well as diverse industrial applications (e.g., pharmaceuticals, cement industry). New measurement techniques developed as a result of industrial demands have also gained ground in environmental and Earth sciences research. The new techniques (especially laser diffraction) have enabled the particle characterisation in the broader size-range with a more detailed resolution. Still, they have to be compared with data obtained by classical methods. In light of the above, the primary aim of our research is to examine the methods of particle size determination critically. Excessive oversimplifications of particle size analyses routinely have used in paleo-environmental and paleo-climatological reconstructions, and other sedimentary studies, as well as insufficient knowledge of the background of the applied methods, distort the interpretation of the results. Over the past four decades, laser diffraction particle size analysers have proven to be practical tools of particle size characterisation. However, the shape of the natural sediment and soil particles are irregular and, therefore, affects the particle size distribution results obtained by different methods. The results of the traditional pipette method differed from laser diffraction results. The presence or absence of the pretreatments did control the differences between the two techniques. The results of Fraunhofer optical method were significantly different from Mie theory because it can detect much lower volume percentages of finer particles. Grain size results of coarse-grained samples measured by different laser diffraction devices were more comparable than the results of more clayey samples. The ratios of different sizes were changed due to the hydrochloric acid and hydrogen peroxide pretreatments. The comparison of different techniques is necessary to revaluate standards in grain size measurements which can enable the shift from conventional methods to more productive and reproducible methods. Still, light scattering techniques have not yet been able to displace classical methods in Earth sciences completely, in contrast to industrial applications.

Keywords: grain size analysis, laser diffraction, pipette method, particle shape

Introduction

Grain size is a fundamental property of the soils and sediments, which can provide information on their origin with particular regard to transport dynamics, deposition and post-depositional alterations of sedimentary mineral particles. These properties can be deciphered from the particle size distribution. Generally, the sedimentary deposits may contain a wide range of particle sizes from boulder fraction to the smallest size, clay and colloid (McCave, N. and Syvitski, J.P.M. 1991). In most landscape development system, the particle size distribution of the constituent sediments reflects the morphological characteristics associated with the physical processes of development processes (Switzer, A.D. 2013). The importance of the particle size distribution lies in resembling the physico-chemical properties of materials (e.g., particle size) which are determined by the power and capacity of the transporting agent. Furthermore, sediments and soils have

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specific features that depend on their particle size distribution, e.g., hydraulic properties (porosity, mass density, water content, water retention), thermal conductivity, and specific surface area (Campbell, G.S. and Shiozawa, S. 1992; Udvardi, B. *et al*. 2017).

Before the recent paradigm shift (Blott, S.J. and Pye, K. 2006; Újvári, G. *et al.* 2016; Varga, Gy. *et al.* 2019a) particle size distribution was measured by sieving and sedimentation method. This can be expressed as a percentage by size class, as a fraction of total dry grains by volume or weight. The relatively new and fast-spreading of laser diffraction methods raises the question of how similar are the data by laser particle sizing and classical techniques. Numerous studies were published to discuss the difference between the results of new particle size determination methods and conventional approaches (e.g. Syvitski, J.P.M. *et al.* 1991; Konert, M. and Vandenberghe, J. 1997; Beuselinck, L. *et al.* 1998; di Stefano, C. *et al.* 2010; Centeri, Cs. *et al.* 2015a, b). The object of these studies is generally to determine and compare the clay fraction with the results obtained by the different methods. Simultaneously, the question may arise, where to draw the boundary of the clay fraction. The limits of the ranges may change during sample preparation (aggregates disintegration, removal of grain coatings by chemical pretreatment). From these studies, it can be concluded that the clay content of a sample depends on its clay mineral composition and properties, including particle shape characteristics.

Materials and methods

Recent soil and sediment samples were investigated in the present study. Various methods analysed the particle size distribution of Gleysol horizon B, haplic Luvisol horizon B_t and podzolic Luvisol horizon C. Furthermore, loess and sandy loess were included in the particle size studies. Samples were collected from Hungarian locations with special attention to the representation of samples with generally different granulometric character (from clayey to more sandy texture). Loess and sandy loess were collected from Kőszárhegy, Podzolic Luvisol and haplic Luvisol samples were taken from Sopron, lastly, Gleysoil was collected from Cegléd-bercel *(Figure 1). Table 1.* shows the applied methods which performed on the samples.

Large aggregates and rock-fragments were separated using a 2 mm sieve. Before the first set of measurements, the samples were only pretreated with sodium pyrophosphate (5%) to disintegrate aggregates into individual particles. During the next series of measurements, the organic matter and $CaCO_3$ coatings were also removed from the test samples by using hydrogen peroxide (30%) and hydrogen chloride (10%). Pipette method and laser diffraction were used during the study.

The pipette method is based on the change in density over time calculated from suspension settling time (t) and depth (z), which gives all the grains in the original concentration ($Vs \leq z / t$). This assumes that the particles settle independently, there is no flocculation, and the temperature is constant. The solid material content of the test sample is determined by evaporation and mass measurement. A correction value is used to subtract the dissolved salts of the sample. The cumulative curve of the mass of sedimentation fractions can be determined by the Stokes law:

$$Vs = \Delta\rho \cdot g \cdot d^2 / 18\mu,$$

where $\Delta\rho$ is the density difference between the liquid and the particles, d is the diameter of the particles, μ is the molecular viscosity, and g is acceleration by gravity (McCave, N. and Syvitski, J.P.M. 1991). The pipette method expresses the number of particle size classes by weight.

During the procedure of pipette method, 25–25 g of material was weighed together with 1 litre of distilled water in the settling cylinders (5 sets). Larger particles were trapped using a 250 μm sieve. Three (Podzolic Luvisol horizon C, haplic Luvisol horizon B_t, and loess) of the five samples were used for the evaluation of the pipette method.

Fig. 1. Map of the sampling areas

Table 1. Applyed grain size analysis methods in the case of different samples

Samples	Measurements by	
	pipette method	laser diffraction
Loess Luvisol Podzolic Luvisol	5 repetiton	5 repetition
Sandy loess	Ø	
Gleysol	Ø	

Deviations from the results calculated using the theoretical Stokes law (suspecting spherical particle shapes) can be expected if the particles are irregularly shaped, as most clay particles have a flat, lamellar shape. The non-spherical particles settle with their maximum cross-section projection perpendicular to the settling direction. Consequently, this situation increases the expected tensile strength of the particle and reduces the settling rate. The particle shape affects the results, as an overestimation of the so-called fine fraction (di Stefano, C. *et al.* 2010). The pipette method has more other drawbacks: it is time-consuming, highly dependent on laboratory technique and operator error (Syvitski, J.P.M. *et al.* 1991). It requires a large volume of samples (at least 20–25 g) for analysis. Hence, the speed of the method is not sufficient to accurately analyse large numbers of samples (Beuselinck, L. *et al.* 1998).

The laser diffraction particle size analysis is based on the interaction of laser light and the particles, as reflection, refraction, absorption and diffraction of light (caused by the particle) result in a specific light scatter pattern depending on particle size. The angle and intensity of scattered light are transformed into particle size distribution by different optical theories. The traditional laser diffraction analysers are based solely on the principle that particles of a given size diffract the light at a given angle. The angle of diffraction increases with decreasing particle size (McCave, N. and Syvitski, J.P.M. 1991).

Generally, two optical models can be used to calculate particle size from the light intensity: Fraunhofer and Mie theories (Gee, G.W. and Or, D. 2002). Fraunhofer diffraction calculates only by the angle of light diffraction (de Boer, G.B.J. *et al.* 1987), while Mie theory also takes into account the events of light absorption and refraction during particle size determination (Eshel, G. *et al.* 2004). Both theories assume that the particles are spherical. Thus, the particle diameter obtained from the laser diffraction is equivalent to the sphere that gives the same diffraction as the particle (di Stefano, C. *et al.* 2010). The sphere is the only shape which cross-sectional diameter is constant, regardless of the angle at which it is viewed.

The problem is that natural particles have different cross-sections in all directions. Thus, the cross-sectional area of a non-spherical particle is larger than that of a sphere having the same volume as the particle. It places this tested particle in a larger size range than can be inferred from its apparent radius. Thus, there is a shift in size distribution towards coarser fractions (Eshel, G. *et al.* 2004). The laser diffraction gives the particle size distribution as a percentage by volume. The laser diffraction devices which originate from different manufacturers usually differ from each other. These differences based on the laser systems, the number of detectors and the measuring range (*Table 2*).

During the refraction and absorption adjustments, the Mie theory was applied to the

Table 2. Measuring properties of laser diffraction devices

Manufacturer	Device	Measuring range, μm	Number of sensors	Optical method	Type of laser
Horiba Ltd.	LA-950 Laser Particle Size Analyser	0.01–3,000	n.d.	Mie	650 nm (red), 405 nm (blue)
Fritsch GmbH.	Analysette 22	0.01–2,100	57	Fraunhofer, Mie	532 nm (green), 850 nm (infrared)

n.d. = No data.

Horiba Partica LA 950 V2 with a refractive index of 1.45 and a light absorption value of 0.1 (according to the recommendations of Varga, Gy. *et al.* 2019b). The other device which was used during the study was the Fritsch Analysette 22 Microtec Plus. Quartz refractive index of 1.54 and light absorption value of 0.1 was selected in the measurements settings (additionally, the Fraunhofer settings were also applied during the Fritsch measurements). Measurements were made in wet dispersion in the case of both devices (RI of water [1.33] was applied).

The shape of the particles can be characterised by various properties, e.g., shape, roundness, and sphericity of the irregularity (Blott, S.J. and Pye, K. 2008). The shape of a particle can be described by its three-dimensional characteristics, which are defined by the ratio of length, thickness, and width (Sneed, E.D. and Folk, R.L. 1958). Convexity describes how closely the shape of a given particle approximates the form of a real sphere (in two dimensions, this property is called circularity). If the surface of a particle has significant depressions (concavity) and protrusions (convexity), its shape can be sensed irregular (Blott, S.J. and Pye, K. 2008). The method was applied to each of the five samples in order to obtain information on the shape of the particles examined.

The shape information of the tested sediments and soils was provided by the Malvern Morphologi G3-ID automated static image analyser. Recently, morphological characterization of grains is a dynamically developing method for investigating various sediments (Moss, A.J. 1966; Rogers, C.D.F. and Smalley, I.J. 1993; Varga, Gy. *et al.* 2018; Varga, Gy. and Roettig, C.-B. 2018; Király, Cs. *et al.* 2019). The number of analysed grains was not sufficient for robust statistical analysis. This problem has been successfully overcome with automatized systems (Cox, M.R. and Budhu, M. 2008). Image analysis provides direct observational data of particle size, and due to the automatic measurement technique, a large number of particles are characterised allowing us a more robust and objective granulometric description of particles compared to manual microscopic approaches (Varga, Gy. *et al.* 2018). Image analysis-based measurements were organised into a number-based database, which can be transformed into a volumetric database as well. All of the particles have their identity number (ID). The applied greyscale intensity threshold was 0–45 with 20× objective. The shape parameters were determined automatically. Circularity and aspect ratio were analysed in this study as attributes of the individual particles. Aspect ratio is the ratio of width and length, and circularity parameter of a particle describes the proportional relationship between the circumference of a circle equal to the object's projected area and perimeter.

Particle size ranges of pipette method were also used in the case of laser diffraction to compare the results of the two approaches adequately. However, during comparison of the results of the two laser diffraction devices, the three distribution curves (Fritsch Analysette 22 Mie and Fraunhofer models, Horiba Partica LA 950 V2 Mie theory) with the original grain size bin allocations were plotted together. For samples that only have undergone laser diffraction measurements,

a different representation was used. This definition applies to sandy loess and B horizon of Gleysol. The same chart shows the results of untreated and pretreated samples per device. Bar chart and connected dot chart types were used to display data. Beyond the visual evaluation of the graphs, the results were compared by performing the linear regression analyses (n = 13).

Results

Comparison of laser diffraction and pipette results

For the untreated sample of loess (*Figure 2*, a), the <2 μm fraction can be characterised by the highest volumetric proportion compared to other ranges. This trend is valid for all four distributions. The results of the pipette method were not significantly different from the laser diffraction. For the pretreated samples (*Figure 2*, b), the proportion of the <2 μm range decreased and the volumetric contribution of silt fractions (10–20 μm and 20–50 μm), increased in the case of all four methods.

Based on *Figure 3* (a), and *Figure 3* (b), it can be stated that the hydrochloric acid and hydrogen peroxide pretreatment resulted in a more even distribution in all three cases. Typical loess distribution was obtained with a minor deviation for the smallest fractions. In the case of untreated (*Figure 3*, a) elemental particles, there are some differences in the distribution curves, especially in the sub-micron fraction. It is also important to note that the difference between Fraunhofer diffraction and Mie theory was also apparent, although the same instrument measured it. The Fraunhofer optical model does not show a secondary maximum in the untreated sample, in contrast to the Mie theory. Besides, the result obtained by the Horiba instrument shows the highest secondary peak for the same sample. So, the difference was reflected in the results obtained by the same optical model, which was measured with different manufacturers' equipment. In the case of the pretreated sample (*Figure 3*, b) the difference is reduced, partly because of the larger particle size ranges converge. The regression coefficient between the two devices was above 0.94 ($R^2_{untreated} = 0.93$).

In the case of Luvisol, similarly to loess, pretreated (*Figure 2*, d and *Figure 3*, d) samples show a more uniform distribution than the untreated ones (*Figure 2*, c and *Figure 3*, c). The ratio of the <2 μm particles was materially reduced by hydrogen peroxide pretreatment, especially in the case of Horiba particle size analyser, where the volume percentage of the <0.5 μm fraction decreased from 12 to 0 per cent. Simultaneously, the proportion of larger particle increased, especially for 31–63 μm and 63–125 μm. The regression coefficient showed a higher value for pretreated samples of laser diffraction devices ($R^2_{untreated} = 0.72$; $R^2_{pretreated} = 0.89$).

The third sample, the horizon C of Podzolic Luvisol, was subjected to pretreatment combined with the pipette method. The comparison was made by using two series of pipette measurements. As a result, the size of the particles was influenced by the duration of pretreatment (*Figure 2*, g). The mass proportions of the finest and the coarsest size fractions showed a significant decreasing trend as a function of pretreatment time. A general increase of silt-sized particles could be detected after longer pretreatment. The parallel measurements size distribution with longer pretreatment time was much more similar to the results obtained by laser diffraction. That is why it was used to compare the different method's grain size distributions.

In the case of Podzolic Luvisol sample, there were substantial differences between the untreated and pretreated samples. *Figure 2* (e) shows that the distributions of untreated samples are following two types of curves. The Mie and Fraunhofer results of Fritsch device are almost identical. However, they differ from the Horiba values and the results of the pipette method. The former has detected a larger ratio in size range of <20 μm. The latter shows a steady increase in diameter towards the larger particles. As an effect of the pretreatment (*Figure 2*, f), the size data which were obtained by Fritsch device got closer to the

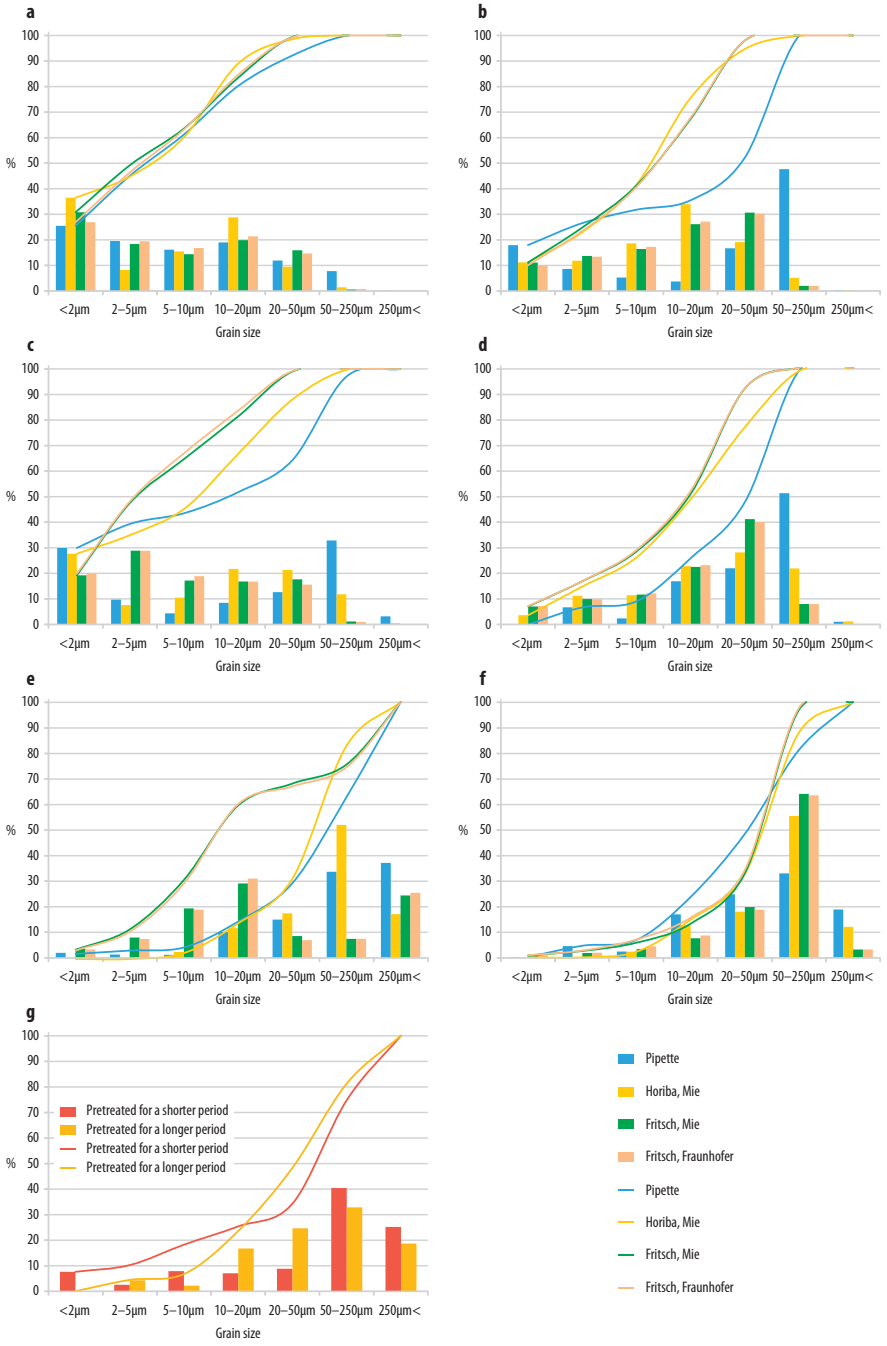

Fig. 2. Particle size distributions of the samples as regards the results obtained by the laser diffraction method and pipette. – Pipette = percentage by weight; Laser diffraction = percentage by volume; a = Loess, untreated; b = Loess, pretreated; c = Luvisol, untreated; d = Luvisol, pretreated; e = Podzoic Luvisol, untreated; f = Podzolic Luvisol, pretreated; g = Podzolic Luvisol, pretreated by two methods

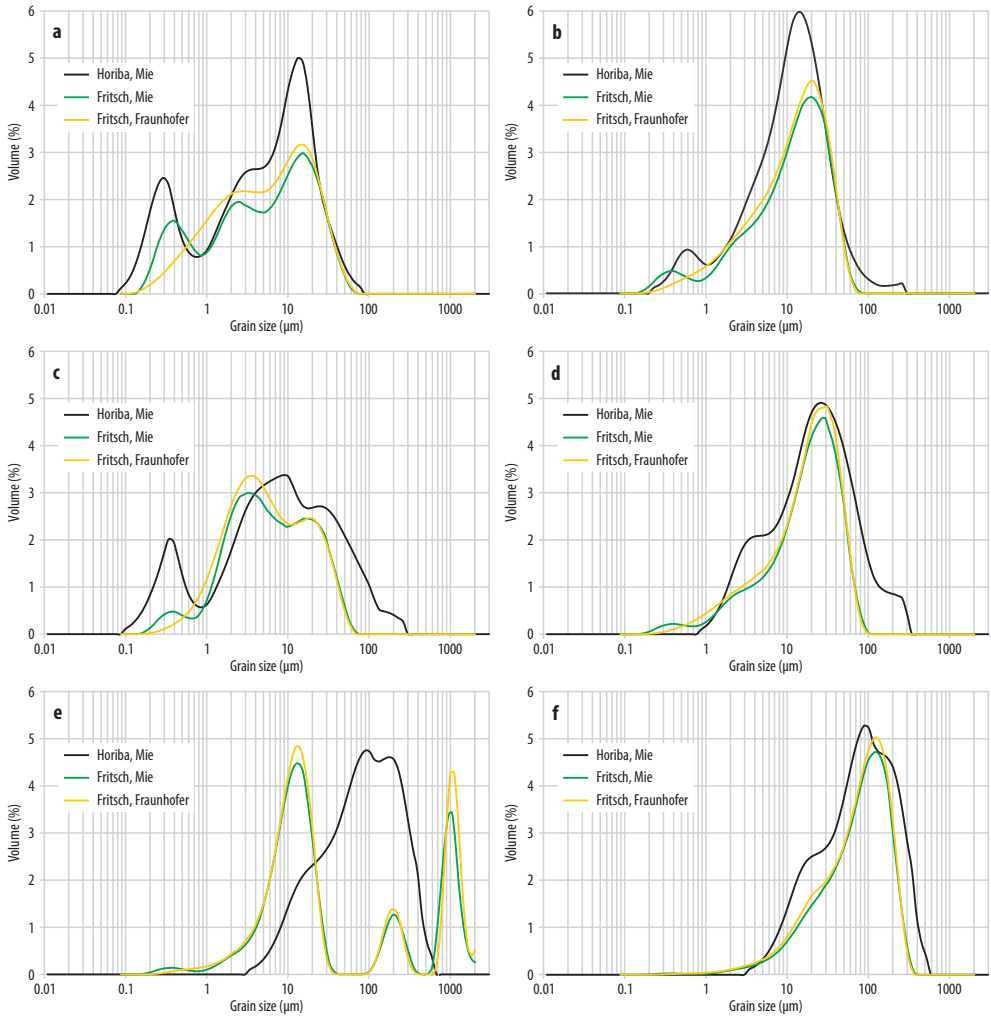

Fig. 3. Particle size distributions of samples based on laser diffraction results. Comparison of different instruments. – a = Loess, untreated; b = Loess, pretreated; c = Luvisol, untreated; d = Luvisol, pretreated; e = Podzolic Luvisol, untreated; f = Podzolic Luvisol, pretreated

Horiba's and pipette method's results. The value of the R^2 increased to 0.93 between the two laser diffraction devices obtained by the Mie theory ($R^2_{untreated}$ = 0.0). In the case of the Fritsch instrument (*Figure 3*, e), there are two secondary maxima in the Fraunhofer as well as in the Mie distributions. The maximum is at 14 µm, and the other two additional peaks are at 200 µm and 1,000 µm. In the case of the Horiba instrument, the distribution is much smoother, since the smallest value of the distribution is ~3.4 µm, while the maximum is at ~100 µm. All in all, the results of the two devices are entirely different. The pretreatment, however, resulted in much more uniform distributions of Podzolic Luvisol samples (*Figure 3*, f). Similar significant differences were reported by Varga, Gy. *et al.* (2019b).

Comparison of different optical models of laser diffractometry and effects of sample pretreatments

Results of laser diffraction measurements of sandy loess samples are presented in *Figure 4* (a) and (b). Volumetric proportions of <10 μm fractions of treated and untreated Horiba results were significantly different from each other; the pretreatment resulted in a substantial decrease in this range, but, the two secondary maxima remained the same. The Mie results of Fritsch device shows a similar tendency: as a result of the pretreatment (*Figure 4*, b), the percentage of <10 μm fraction has decreased. The value of the regression coefficient increased as a result of pretreatment as measured by the Horiba and Fritsch instrument using Mie theory: $R^2_{treated} = 0.87$; while $R^2_{untreated} = 0.43$. It is worth noting that results calculated by using the Fraunhofer theory were profound than the grain sizes of Mie settings. However, the three laser diffraction curves are moving together in the ranges above 100 μm. The result of the horizon B of Gleysol obtained by the Horiba laser diffraction particle size analyser shows typical characteristics of the tendency in the literature (*Figure 4*, c), that the proportion of smaller particle size diameters increases after pretreatment procedures (Di Stefano, C. *et al.* 2010). The same tendency can be observed in the case of Fritsch device (*Figure 4*, d), with only a slight shift towards smaller particle size ranges. In the case of the Fraunhofer optical model, it should be emphasised that the pretreatment did not perform the expected result, as no secondary maximum was achieved after the pretreatment. How-

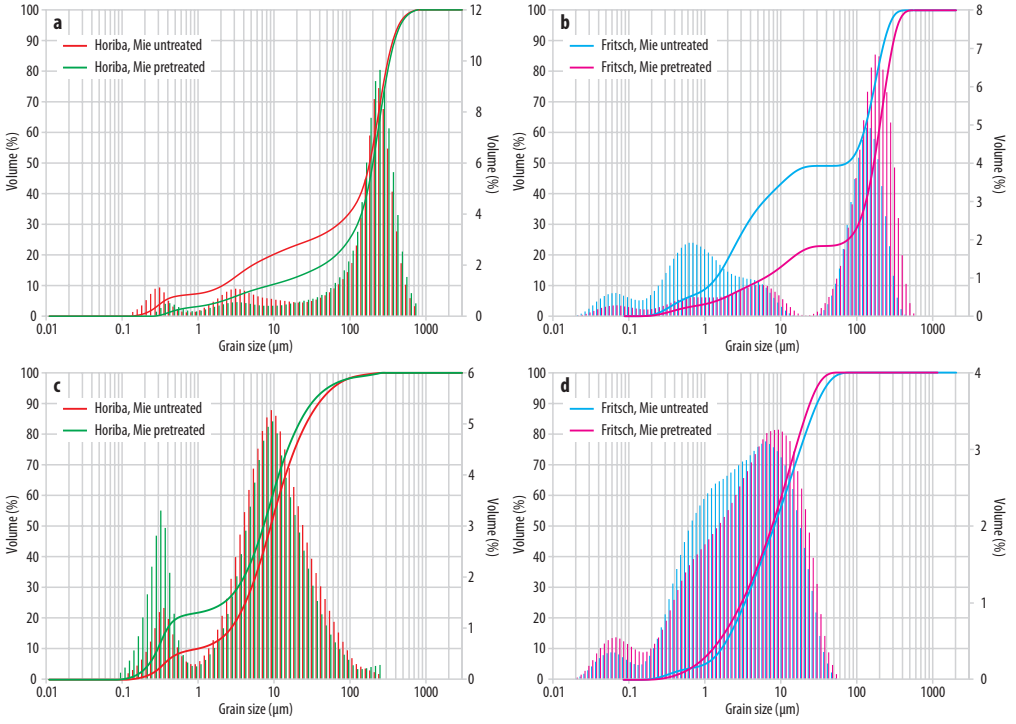

Fig. 4. Particle size distributions of samples based on laser diffraction results. Comparison of different instruments. – a = Sandy loess, Horiba Partica LA 950 V2; b = Sandy loess, Fritsch Analysette 22; c = Gleysol, Horiba Partica LA 950 V2; d = Gleysol, Fritsch Analysette 22

ever, the value of the regression coefficient decreased in this case as a result of pretreatment between Horiba and Fritsch instrument results: $R^2_{treated} = 0.63$ and $R^2_{untreated} = 0.8$.

Table 3 summarises the average values of two Malvern Morphologi G3-ID particle shape parameters (circularity and aspect ratio). The size-dependence of these properties were also tested; the circularity values decrease from the smaller fractions towards the larger sizes (*Figure 5*, a–e), but larger grains typically have high aspect ratio, although their circularity parameter is relatively low.

Table 3. Comparison of the volume-weighted mean shape properties of the untreated tested samples, Malvern Morphologi G3-ID

Samples	Circularity	Aspect ratio
Loess	0.921	0.841
Luvisol horizon B_t	0.960	0.879
Podzolic Luvisol horizon C	0.884	0.821
Sandy loess	0.933	0.844
Gleysol horizon B	0.944	0.885

Discussion

By the spread of new techniques, several research groups have tried to compare and match the results obtained with different techniques. These studies reported the clear uncertainties of determination of the clay and fine silt fractions, and unknown particle morphology was proposed to be a possible cause of the mismatches (Konert, M. and Vandenberghe, J. 1997; Beauselinck, L. *et al.* 1998; Pieri, L. *et al*. 2006; di Stefano, C. *et al.* 2010).

The results of this paper only partially reflect the trends found in the literature. According to di Stefano, C. *et al.* (2010), the laser diffraction underestimates the proportion of clay fraction compared to the pipette method, however, this tendency is only partially true for our results since the ratios of different size fractions (including the clay-sized particles) were changed (primarily) due to the hydrochloric acid and hydrogen peroxide pretreatments. In the case of loess, the laser diffraction detected a higher proportion of the <2 μm fraction in the untreated sample than the pipette method. However, this phenomenon reversed as a result of carbonate removal. The smallest particles of Luvisol has practically disappeared according to pipette method after the pretreatment (<2 μm fraction of the untreated sample was ~29.8%). The case of Podzolic Luvisol was different; the emphasis was on the >10 μm ranges and their changes. These phenomena are because the investigated materials had different mineral composition and organic content. The disintegration of aggregates and removal of grain coatings which were responsible for the larger grain size these established smaller particles, even nanometres in size which can no longer be detected by these methods. So the emphasis shifted towards the relatively larger size ranges.

The particle size distribution measured by laser diffraction particle size analyser does not match the values determined by classical methods, which has several causes. Laser diffraction gives a percentage by volume, whereas conventional methods (sedimentation, sieving) give a percentage by weight. The result of laser diffraction is generally independent of the density of the particles, whereas the pipette method is based on the change of density over time (Syvitski, J.P.M. *et al.* 1991). These few differences are enough to give different results for the same sample.

The literature on the results of laser diffraction instruments is controversial, according to di Stefano, C. *et al.* (2010) there is no significant difference between the cumulative distribution curves determined by the two optical theories. While Baywel, L.P. and Jones, A.L. (1981) and de Boer, G.B.J. *et al.* (1987) report significant differences in the smaller grain size ranges. Based on our study, results of Fraunhofer diffraction are significantly different from Mie theory, because it can detect much lower volume percentages of finer particles. This theory assumes that the laser beam is parallel, and the sensors are at a great distance relative to

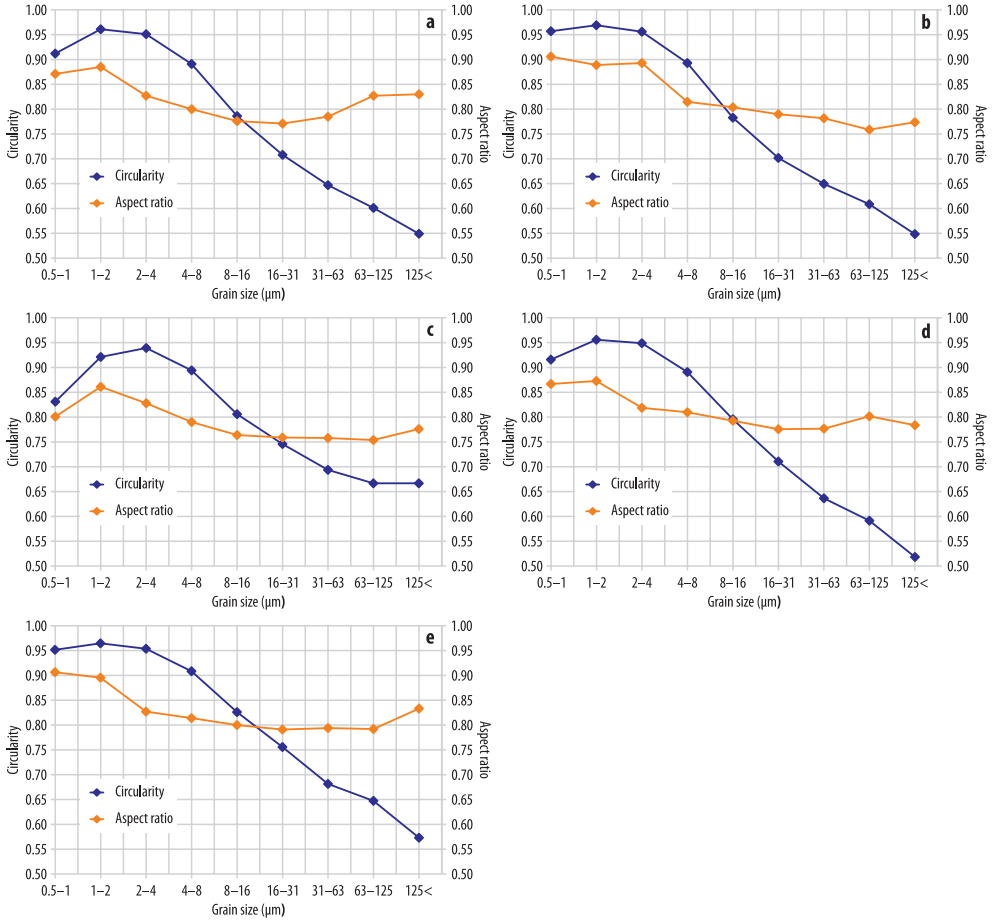

Fig. 5. Comparison of the volume weighted mean shape properties of the size ranges of the untreated tested samples, Malvern Morphologi G3-ID. – a = Loess; b = Luvisol; c = Podzolic Luvisol; d = Gleysol; e = Sandy loess

the size of the diffracted particle (Loizeau, J.L. *et al.* 1994). If the particles are larger than the wavelength of the light, the interaction can be interpreted as diffraction (de Boer, G.B.J. *et al.* 1987). The Fraunhofer theory becomes inapplicable when the particle diameter approaches the wavelength of light. As the refraction of the grain falls within this size range, this principle is no longer applicable (Loizeau, J.L. *et al.* 1994). Therefore, any comparison of fine-grained (clay- and fine silt-sized) fractions measured by different laser and traditional methods will provide different results for each sedimentary sample (Varga, Gy. *et al.* 2019b).

According to Varga, Gy. *et al.* (2019b), if only one laser diffraction device is used with the same optical settings for all samples from the investigated profile, the significant relative changes of measured data and calculated values will reveal the general trends. Nevertheless, absolute values can only be compared if the same optical settings and the same devices were used. Unfortunately,

a large proportion of research papers still do not discuss the applied laser diffraction measurement settings properly, and the specification of the applied optical approach and complex refractive index are the most commonly missing pieces of information (Varga, Gy. *et al.* 2019b).

All in all, Horiba and Fritsch grain size results of samples with a higher volumetric proportion of larger particles (sandy loess, Podzolic Luvisol, loess) were more comparable than the results of more clayey samples. This may be because the coarse-grained samples are characterized by a higher proportion of more spherical particles than the clayey Gleysol with more irregular mineral grains. The shape of sand-sized grains is more similar to a sphere than the particles of smaller size ranges (Polakowski, C. *et al.* 2014). Therefore, the methods were more compatible with sandy samples. The results of particle shape analysis by optical microscope were also contradictory since particle circularity of smaller size ranges (<4 μm) were closer to 1 than the larger grains. This was contrary to the trend found in the literature. The reason for this was probably due to the presence of adhesives ($CaCO_3$, organic matter), which formed aggregates in the sample, thus were distorting the shape distribution. The number of pixels decreases with grain size. The smaller particles have smaller area covered by pixels, which can lead to simplified shape properties compared to larger grains. In the case of Luvisol the circularity property was the highest among the other samples. This sample had a relatively large amount of small particles (0.5–2.0 μm) which did not led to proper shape properties over the whole sample. Consequently, analysis by separating aggregates is warranted. However, the device does not show a three-dimensional image of the shape of the particles. The third dimension of particles cannot be accurately determined by automated static image analysis as the orientation of individual particles is not random, they are facing into the CCD-camera with their largest surface area (Varga, Gy. *et al.* 2018).

Conclusions

Nowadays, the laser diffraction technique is one of the most advanced methods for determining particle size distribution. In contrast to the classical techniques, these measurements are faster, more reproducible, and need a relatively small amount of material.

Depending on the purpose of the measurements, the question of the need for chemical pretreatment of samples has to be taken into account too. It can be stated that it greatly influences the obtained results. It may be questionable to what extent it is advisable to use hydrochloric acid pretreatment for loess since a significant part of the sediment is composed of carbonate. Is it worth removing carbonates completely if they build up real grains?

If the purpose of the measurements with different devices is data harmonization, it is advisable to use the same unit of measurement. It is not advisable to represent the measurement methods together in various dimensions, treating them in the same plane since they measure different properties of the particles. When combining data from different laser diffraction devices, special care should be taken to ensure that measurements are made with the same optical adjustment, with particular reference to the value of the refractive index. In the case of measurements of the smallest grain fractions, the obtained results must be treated with caution. The laser diffraction devices which were used in this study have different structure, the results obtained by them may not be the same; dual laser systems developed by different manufacturers do not operate in the same wavelength range, however, according to Varga, Gy. *et al.* (2019b), the wavelength of built-in laser(s) do(es) not have an effect on the results. It may be advisable to include a device capable of measuring in the submicron range (photon correlation spectroscopy). An inter-laboratory comparison could help for optimizing techniques for different sediment types as well as set new standards in particle size determination methods. Also,

it is worth getting some information about the mineral composition and shape of the particles (optical microscopy, electron microscopy), which can help to explain certain phenomena and differences between the distribution curves. When using an optical microscope, it is worth considering the irregularity of the particles as a function of the aspect ratio of the particles rather than the circularity parameter.

Even before the expansion of the laser diffraction technique, the standardisation of particle size distribution was difficult. For more than two decades, Syvitski, J.P.M. *et al.* (1991) have stated that although there are many methods for determining particle size, none in sedimentology and geomorphology can be accepted as an uncompromising procedure.

In the present study, the particle size distributions were compared, however, beyond these methods there are more complex analyses which can be used depending on what property is desirable (simple statistical methods, ratio-based indicators, mathematical-statistical methods). In geomorphology and sedimentology, the determination of particle size distribution is rarely the ultimate goal. The objectives are to determine the evolution of surface forms, and the conditions of transport as well as the deposition of the grains. One of its key components is the determination of particle size distribution (Switzer, A.D. 2013). Interpretation of granulometric (particle size and particle shape) data enables understanding and reconstruction of sedimentation environments and processes controlling surface evolution.

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REFERENCES

Bayvel, L.P. and Jones, A.R. 1981. *Electromagnetic scattering and its applications*. Applied Science, London, Englewood N.J.

Beuselinck, L., Govers, G., Poesen, J., Degraer, G. and Froyen, L. 1998. Grain-size analysis by laser diffractometry: comparison with the sieve-pipette method. *Catena* 32. (3–4): 193–208.

Blott, S.J. and Pye, K. 2008. Particle shape: a review and new methods of characterisation and classification. *Sedimentology* 55. (1): 31–63.

Campbell, G.S. and Shiozawa, S. 1992. Prediction of hydraulic properties of soils using particle-size distribution and bulk density data. In *Indirect methods for estimating the hydraulic properties of unsaturated soils*. Eds.: van Genuchten, M.T., Leij, F.J. and Lund, L.J., Riverside, University of California, 317–328.

Centeri, Cs., Jakab, G., Szabó, Sz., Farsang, A., Barta, K., Szalai, Z. and Bíró, Zs. 2015a. Comparison of particle-size analysing laboratory methods. *Environmental Engineering and Management Journal* 14. (5): 1125-1135.

Centeri, Cs., Szalai, Z., Jakab, G., Barta, K., Farsang, A., Szabó, Sz. and Bíró, Zs. 2015b. Soil erodibility calculations based on different particle size distribution measurements. *Hungarian Geographical Bulletin* 64. (1): 17–23.

Cox, M.R. and Budhu, M. 2008. A practical approach to grain shape quantification. *Engineering Geology* 96. 1–16.

de Boer, G.B.J., de Weerd, C., Thoenes, D. and Goossens, H.W.J. 1987. Laser diffraction spectrometry: Fraunhofer versus Mie scattering. *Particle Characterisation* 4. (1–4): 14–19.

di Stefano, C., Ferro, V. and Mirabile, S. 2010. Comparison between grain-size analyses using laser diffraction and sedimentation methods. *Biosystem Engineering* 106. (2): 205–215.

Eshel, G., Levy, G.J., Mingelgrin, U. and Singer, M.J. 2004. Critical evaluation of use of laser diffraction for particle-size distribution analyses. *Soil Science Society of America* 68. 736–743.

Gee, G.W. and Or, D. 2002. Particle size analysis. In *Soil science society of America book series, Vol. 5. Methods of soil analysis, Part 4. Physical methods*. Eds.: Dane, J.H. and Topp, G.C., Madison, WI, 255–293.

Király, Cs., Falus, Gy., Gresina, F., Jakab, G., Szalai, Z., and Varga, Gy. 2019. Granulometric properties of particles in Upper Miocene sandstones from thin sections, Szolnok Formation, Hungary. *Hungarian Geographical Bulletin* 68. (4): 341–353.

Konert, M. and Vandenberghe, J. 1997. Comparison of laser grain size analysis with pipette and sieve analysis: a solution for the underestimation of the clay fraction. *Sedimentology* 44. 523–535.

Loizeau, J.L., Arbouille, D., Santiago, S. and Vernet, J.P. 1994. Evaluation of a wide range laser diffraction grain size analyser for use with sediments. *Sedimentology* 41. 353–361.

McCave, N. and Syvitski, J.P.M. 1991. Principles and methods of geological particle size analysis.

In *Principles, methods and application of particle size analyses*. Ed.: Syvitski, J.P.M., Cambridge, Cambridge University Press, 3–22.

Moss, A.J. 1966. Origin, shaping and significance of quartz sand grains. *Journal of the Geological Society of Australia* 13. 97–136.

Pieri, L., Bittelli, M. and Pisa Rossi, P. 2006. Laser diffraction, transmission electron microscopy and image analysis to evaluate a bimodal Gaussian model for particle size distribution in soils. *Geoderma* 135. 118–132.

Polakowski, C., Sochan, A., Bieganowsky, A., Ryzak, M., Földényi, R. and Tóth, J. 2014. Influence of the sand particle shape on particle size distribution measured by laser diffraction method. *International Agrophysics* 28. (2): 195–200.

Rogers, C.D.F. and Smalley, I.J. 1993. The shape of loess particles. *Naturwissenschaften* 80. 461–462.

Sneed, E.D. and Folk, R.L. 1958. Pebbles in Lower Colorado River, Texas: a study in particle morphogenesis. *Journal of Geology* 66. (2): 114–150.

Switzer, A.D. 2013. Measuring and analysing particle size in a geomorphic context. In *Treatise on Geomorphology 14. Methods in geomorphology*. Eds.: Shroder, J., Switzer, A.D. and Kennedy, D.M., San Diego, CA, Academic Press, 224–242.

Syvitski, J.P.M., Leblanc, K.W. and Asprey, K.W. 1991. Interlaboratory, instrument calibration experiment. In *Principles, methods and application of particle size analyses.* Ed.: Syvitski, J.P.M., Cambridge, Cambridge University Press, 174–193.

Újvári, G., Kok, J.F., Varga, Gy. and Kovács, J. 2016. The physics of wind-blown loess: Implications for grain size proxy interpretations in Quaternary paleoclimate studies. *Earth-Science Reviews* 154. 247–278.

Udvardi, B., Kovacs, I.J., Fancsik, T., Konya, P., Batori, M., Stercel, F., Falus, G. and Szalai, Z. 2017. Effects of particle size on the attenuated total reflection spectrum of minerals. *Applied Spectroscopy* 71. (6): 1157–1168.

Varga, Gy. and Roettig, C.-B. 2018. Identification of Saharan dust particles in Pleistocene dune sand-paleosol sequences of Fuerteventura (Canary Islands). *Hungarian Geographical Bulletin* 67. (2): 121–141.

Varga, Gy., Kovács, J., Szalai, Z., Cserháti, C. and Újvári, G. 2018. Granulometric characterisation of paleosols in loess series by automated static image analysis. *Sedimentary Geology* 370. 1–14.

Varga, Gy., Újvári, G. and Kovács, J. 2019a. Interpretation of sedimentary (sub)populations extracted from grain size distributions of Central European loess-paleosol series. *Quaternary International* 502. 60–70.

Varga, Gy., Gresina, F., Újvári, G., Kovács, J. and Szalai, Z. 2019b. On the reliability and comparability of laser diffraction grain size measurements of paleosols in loess records. *Sedimentary Geology* 389. 42–53.

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Two decades of changes in spatial distribution of retail and commercial services: Czech experience

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Abstract

The aim of this paper is to introduce basic developmental consequences, changes, trends and the current situation in amenities through retail and commercial services in the rural areas of the Czech Republic. The example illustrated herein is the South Moravian Region. Methodically, the text is built on previous survey (2002), and on our own survey conducted in municipalities up to 3,000 inhabitants of the South Moravian Region in 2018 (n = 355). There are semi-structured interviews (n = 18) that link back to these surveys. The data obtained was processed by the methods of statistical and graphical analysis, comparison, interpretation and synthesis. The paper concludes that since 2002, commercial amenities have experienced remarkably negative development. The smaller municipalities in the periphery have encountered the greatest decline, but stagnation is also seen in the suburban areas of Brno. From among types of commercial amenities, the ones most weakened were specialized shops, which could no longer compete with large retail chains. Almost a fourth of municipalities support commercial trade and services, mainly through subsidies or lowered rent. The regions also provide subsidies. Even simplifying red tape or providing tax relief on the part of the public sector would support civic amenities. Another key may be retaining young and educated people in municipalities where they will live and work. Contributing to this could be not only developing infrastructure in municipalities, but also for example the next wave of digitalization and introduction of stable, high-speed Internet service in rural areas.

Keywords: retail, commercial services, South Moravian Region, amenities, Czech Republic, spatial distribution, municipality size

Introduction

The Bohemian and Moravian countryside, after undergoing 30 years of transformational activities, face different conditions and development. In the Czech Republic, there are both areas with social and economic decline and also positive development. Also suburbanization or counter urbanization process and inflow of foreign direct investment take part (Hruška, V. and Piša, J. 2019). In the Czech Republic, there are different types of rural areas ranging from regions in social and economic decline, via non-developing regions to developing areas (Perlín, R. *et al.* 2010). Topics discussed in professional circles and the general public alike not only include questions of demographic aging and depopulation, the departure of young, educated people to the cities, and the lack of jobs and attractive opportunities for doing business, but also the development of service and retail activities of cultural and social traditions (Mladek, J. *et al.* 2018; Patay, T. 2018; Tonev, P. *et al.* 2018). One may express general concern over the loss of the social and economic importance of the rural environment in consequence of the decline in retail and services felt over most European countries (McEachern, M.G. and Warnaby, G. 2006; Karlsson, E.B. 2012; Križan, F. *et al.* 2017).

The basic service functions (retail and services, or civic amenities) are in reality becoming gradually weakened in rural communities, which translates to substantial problems for and threats to these communities. Grocery

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stores or restaurants, etc., satisfy not only the needs of purchasing and possibilities of using services, but they also serve as one of the main places for people to interact and for social life to play out locally. These places in small communities are disappearing, however, and it is not possible to realistically replace them with anything else (Križan, F. 2009).

The basic service functions are linked to selected public policies at the state, regional and municipal level, declaring an important public interest (especially transport accessibility and serviceability, social policy, employment, population and migration policy, supporting business, etc.). The mentioned retail and service functions are crucial for the stability and social status of rural areas, and are to a certain extent irreplaceable (Clarke, I. and Banga, S. 2010; Amcoff, J. *et al.* 2011; Szczyrba, Z. *et al.* 2013; Spilková, J. 2018). The consequence of the weakening of retail in these rural areas may even be the origin of so-called food deserts (Bilková, K. *et al.* 2017).

The aim of this paper is to introduce basic developmental consequences, changes, trends and the current situation in amenities through retail and commercial services in the rural areas of the Czech Republic, where one example is the South Moravian Region. The analysis, comparison, interpretation and assessment are built, inter alia, on a foundation of ascertained data and previous survey (2002) and on our own survey performed in municipalities of the South Moravian Region in 2018. Besides the assessment of municipal amenities, the authors attempt to point out the risks of this unfortunate development outside the cities, but also the possibilities of public support and an outlook to the future.

Amenities and service functions: barriers and opportunities

The distribution of amenities is significantly influenced by several linked factors that develop thanks to new technological and communications solutions leading to a change in the hierarchical arrangement of providing services. One of the key aspects is the greater opportunity for mobility of consumers regarding the highly dynamic development of personal automobile transportation and public transport in the form e.g. of so-called integrated transport systems, functioning in modern countries since the 1980s (Illeris, S. 1991). This phenomenon is constantly deepening with the advancing globalization and with changes in consumer purchasing behaviour (Birkin, M. *et al.* 2010; Spilková, J. 2012; Kunc, J. *et al.* 2013; Križan, F. and Lauko, V. 2014). Citizens have ever-growing options in alternative shopping for food, by which the transformation of their purchasing preferences continues to deepen (Spilková, J. 2018).

Rural areas are afflicted by a series of social, demographic and economic problems. Typically, the rural municipality faces different development (Perlín, R. *et al.* 2010, or Hruška, V. and Piša, J. 2019). The part of the countryside that is in decline is mainly located on periphery and faces to an aging population, worsened quality of housing or lack of new places for living, and (younger) population departure to cities or suburban areas (Benedek, J. and Ivan, K. 2018; Mládek, J. *et al.* 2018; Patay, T. 2018; Kubeš, J. and Nováček, A. 2019). Amenities of municipalities and commuting to retail and services, especially in peripheral areas are significantly influenced by commuting to work regarding the long-term loss of jobs in rural communities, especially in agriculture and industry (Kunc, J. *et al.* 2018; Tonev, P. *et al.* 2018).

In the Czech Republic, there is a persistent lack of tax revenue drawn from small municipalities due to developmental needs and the condition of municipal assets (Peková, J. *et al.* 2012). Municipalities, especially small ones with a population of up to 500, have, thus, faced the long-term problem of insufficient civic amenities, whereas the situation is getting slightly worse. Civic and technical amenities are meanwhile essential for ensuring the quality of life in rural areas and the right conditions for developing agriculture, business and employment (Binek, J. *et al.* 2007; Szczyrba, Z. *et al.* 2013; Šilhan, Z. 2018).

Discussions in professional literature mention that the most threatened areas from all Czech and Slovak territories are internal peripheries and border areas, which are the most influenced by weakening of amenities and service functions (e.g. Szczyrba, Z. *et al.* 2013; Maryáš, J. *et al.* 2014; Križan, F. *et al.* 2014; Šilhan, Z. 2018). On one hand, border areas can be relatively well equipped thanks to shopping tourism (Mirwaldt, K. 2010). Weakening of rural areas, however, is far from the domain of just the nations of Central and Eastern Europe (see also Páll, Z. and Hanf, J.H. 2013; Stanciu, S. 2015), similar problems have been indicated in more modern countries too, specifically in England (Moseley, M.J. *et al.* 2004, or Paddison, A. and Calderwood, E. 2007), in Scotland (Cunningham, J. 1999), in Germany (Trebbin, A. *et al.* 2013), in northern Finland (Jussila, H. *et al.* 1992) and in Denmark (Nørgaard, H. 2011), but also outside the typical European spaces such as Iceland and the Faroe Islands (Karlsson, E.B. 2012). It is obvious, that the stated disparities and developmental barriers, or rather existential problems of rural areas, have been resonating for two decades across Europe.

On the other hand, new kind of services are emerging in rural areas of Europe. For example, in remote sparsely populated areas in Norway, there is a combination of multiple types of shops in one place (e.g. selling food, local produce, pharmacy, library, tourist information kiosk, cafe, etc.) (Båtevik, F.O. and Halvorsen, L.J. 2016). Another example could be the development of groceries (shops selling fruits and vegetables) associated with the role of the local community and promoting of the health benefits (Palermo, C. *et al.* 2017). In the Czech Republic, attention has been focused on research in the area of new shopping centers (e.g. Maryáš, J. *et al.* 2014) rather than to new types of services in rural areas.

Another factor mentioned in the literature in relation to rural service functions is the oft-discussed influence of the Internet and high-speed stable data, which are important not only for economic support of rural areas (working from home), but they also specifically increase selection and comfort when shopping, and facilitate communications with sellers. For periphery economies, where sellers are limited by the transport infrastructure and inconsistent offer of raw materials, the Internet is one of the paths towards resolving these difficulties (Freathy, P. and Calderwood, E. 2013). Further point out that the large national sellers bring goods via Internet purchasing to cities, but do not offer online service to areas with lower population density. In the question of online purchasing, success depends mainly on the capability of customers in using the Internet to shop and on Internet user behaviour (Singleton, A.D. *et al.* 2016).

Shop closure in a rural municipality might not be the only consequence of low demand, there might also take part other reasons (problematics of generation exchange of independent entrepreneur (Haberman, H. and Danes, S.M. 2007), competition of newly opened shops, primarily supermarkets (Kupper, P. and Eberhardt, W. 2013; Maryáš, J. *et al.* 2014) or roadbuilding infrastructure (Ronse, W. *et al.* 2015), for example, construction of bypass roads.

Support of commerce and commercial services in rural areas has become a frequently discussed matter in the Czech Republic in recent years, not only in academia, but mainly at the regional and national level in the framework of the relevant organizations and institutions. It is an important problem, because basic amenities satisfy needs mainly of socially threatened citizens (seniors, citizens lacking the possibility of individual automobile travel). Discussions revolve primarily around sustainability of retail outlets in smaller municipalities with a population of up to 500 (Kunc, J. *et al.* 2013; Maryáš, J. *et al.* 2014; Šilhan, Z. 2018). While the number of municipalities with a population of over 500 and their populations has been rising over roughly the past 10–15 years, the number of municipalities with a population of up to 500 has been decreasing. Municipalities with a population of up to 200 register a more significant relative drop in the number of their inhabitants (Ministry of

Agriculture of the Czech Republic and Czech Chamber of Commerce, 2018; Association of Czech Traditional Trade, 2019).

The Czech government sector and associations of Czech independent retailers mutually cooperate and agree that independent retail represents an important employer and ensures commercial service of rural areas, which has a positive effect on the social task in general. Based on these experiences, efforts exist to systematically deal with improving the serviceability of rural areas through gradual steps (Ministry of Agriculture of the Czech Republic and Czech Chamber of Commerce, 2018; Association of Czech Traditional Trade, 2019).

The issue of commercial service in municipalities also appears e. g. in strategies of public authorities, association affiliating managers of grocery shops and local NGOs. The development program of the South Moravian Region (Jihomoravský kraj, 2017) includes goal "Supporting the equipment of rural municipalities" and "Support for specific solutions of commercial services in small municipalities". Czech Traditional Retail Association associates independent traders. It communicates with the Ministry of Industry and Trade in order to negotiation its priorities (AČTO, 2019), especially lobbying by reducing bureaucracy and taxes. Typical local NGOs include local action groups for example "LAG Partnertsví venkova". One of the goals of its strategic document (MAS partnertsví venkova, 2020) is "improving the quality and availability of services". In the European countryside this problem is solved mainly thanks to the tool of spatial planning, which can affect commercial development (Cheshire, P.C. *et al.* 2014).

Methods and data

Over the course of 2018, a survey was conducted in municipalities in the South Moravian Region concerning two main areas:

1) commuting to a grocery store and selected services;

2) amenities of municipalities in terms of retail and selected service facilities.

A supplemental question then ascertained whether municipalities support retail and commercial services.

For the purposes of this paper, we will analyse and assess only the survey on amenities and the municipalities up to 3,000 inhabitants.

The selection of a specific form of the survey came due to comparability over time from the current status of examination in the area of commuting to a grocery store and selected services, and amenities of municipalities in the South Moravian Region. The South Moravian Region already performed a survey on amenities of municipalities back in 2002 through the Department of Regional Development of the South Moravian Region. Municipalities were surveyed electronically and then by telephone. Support on the part of the highest regional representatives provided a response rate in 2002 nearly 100 per cent. Considering these facts, basic types of retail and services were represented, as well as higher types of service. Both from categories grocery stores, hospitality facilities, stores, commercial services. The paper then analyses the ones most typical for rural areas, i.e. food and mixed goods retail, and service of basic civic amenities. Municipalities were only surveyed on the presence of at least one operation of the given type of civic amenities. The number of operations was not ascertained in the survey.

For the purpose of this paper, only surveys from 2002 and 2018 are analysed for types of civic amenities, which were ascertained in both these years:

– grocery stores,
– restaurants and hospitality facilities,
– hairdressers,
– automobile repair shops.

The survey was linked to qualitative research by means of semi-structured interviews with municipal representatives (Mayor) and municipal associations (manager of microregion or local action group), and retails stores (operator of grocery store or hospitality facility) within the South Moravian Region.

Changes in amenity since 2002 has been considered during the selection of municipalities for the interview (Only the municipalities where the change was registered were selected) Representatives of the micro-region and local action groups were selected due to good knowledge of the area. The communication partners came from areas "SO POU" – the smallest administrative unit in the Czech Republic, which is larger than the municipality. It is similar to "small" LAU 1. The areas with the greatest (retail and commercial services change index 2018/2002[2] smaller or equal to –10) decline in amenities are included. The mentioned index of change is also used for demonstration of geographical differentiation of rural municipalities. For diversity, a condition was then selected for various territories to be represented based on their location in relation to the central city of Brno, and would not be just a neighbouring territory *(Table 1).*

Among the main discussion topics were the condition, development, causes and consequences of changes in amenities of municipalities in terms of retail and commercial services, and space inclusion. Also discussed were possible measures for resolving the commercial serviceability of municipalities. Semi-structured interviews (thematic analysis, coding) were evaluated by common methods. Insights from the interviews in the article are supplemented by the results of the survey, and options are determined for supporting commercial serviceability of municipalities. Also

Table 1. Overview of communication partners for semi-structured interviews

Area (SO POU)	Territory	Interview partner, municipality size category
Hodonín	Borderland (border with Slovakia)	Municipality 501–750 inhabitants Representative of entrepreneur associating grocery stores mainly in municipalities with less than 1,000 inhabitants Local action group Jižní Slovácko
Vranov nad Dyjí	Borderland (border with Austria)	Municipality 201–350 inhabitants Hospitality facility in municipality 0–200 inhabitants Microregion Vranovsko
Ivanovice na Hané	Internal periphery (border with the Zlín and Olomouc regions)	Municipality 351–500 inhabitants Hospitality facility in municipality 351–500 inhabitants Local action group Vyškovsko
Velké Opatovice	Internal periphery (border with the Pardubice and Olomouc regions)	Municipality 351–500 inhabitants Grocery store in municipality 201–350 inhabitants Local action group Partnerství venkova
Rosice	Wider suburban area of the regional capital city Brno	Municipality 2,001–3,000 inhabitants Grocery store in municipality 501–750 inhabitants Microregion Kahan
Kuřim	Suburban area of the regional capital city Brno	Municipality 751–1,000 inhabitants Grocery store in municipality 1,001–2,000 inhabitants Microregion Kuřimsko

Source: Own survey and elaboration.

[2] For each area, the retail and commercial services change index 2018/2002 was calculated: (number of municipalities where individual types of amenity have been new appeared since 2002) minus (number of municipalities where individual types of facilities have disappeared since 2002) per (number of municipalities where at least one individual types of amenity occurred in 2002) x 100. 14 types of services are included in the calculation. They are presented in *Figure 2* and *3*.

individual regions of the Czech Republic were contacted regarding the question of support.

All municipalities of the South Moravian Region (673) were addressed via email and phone. All municipalities and even urban ones were addressed because they are centres of countryside service using. However, the article focuses especially on the amenity in rural areas (municipalities with less than 3,000 inhabitants, which is the boundary for cities according to the Czech Municipalities Act number 128/2000). Questionnaire forms were addressed directly to the given mayor or to the municipal registry office. The aim was to obtain data representative of the entire territory of the South Moravian Region and avoid any intentional selection of municipalities for the survey. For the response rate, the size categories of municipalities and their geographic location were observed. The resulting number of municipalities with a population below 3,000 inhabitants engaged in the survey was 355 (57.2% of all municipalities in the region smaller than 3,000 inhabitants), which, in light of the spatial and population representation, can be considered sufficiently representative. The representativeness of the survey is proved by its return according to the size categories of municipalities in *Table 2.* Size categories were chosen according to the Czech Statistical Office.

The Czech settlement structure is fragmented more than in other European countries (comparable only to Slovakia or France). Distribution into size categories with small spacing allows a more detailed look at the researched issue. In comparison between 2002 and 2018 there are present only municipalities that responded both in 2002 and 2018. The sample is the same.

Table 2. Research sample from questionnaire survey

Size category	Number of		Return rate, %
	municipalties	responses	
0–200	107	57	53.3
201–350	110	67	60.9
351–500	83	51	61.4
501–750	101	61	60.4
751–1,000	81	52	64.2
1,001–2,000	104	52	50.0
2,001–3,000	35	15	42.9
Total	*621*	*355*	*57.2*

Source: Own survey and elaboration.

Retail and service functions of municipalities of the South Moravian Region in 2018

Most frequently represented in the sample of 355 municipalities were municipalities with the presence of at least one self-service store with mixed goods (COOP, Jednota, etc.). One can be found in a total of 258 municipalities (72.7% of all monitored 355 municipalities). The presence of this type of store or service greatly depends on the size of the municipality. A self-service store with mixed goods starts being entirely common in the higher categories with a population over 500, reaching an over 90 per cent share.

If a proper self-service store with mixed goods does not exist in the municipality, it is usually represented by a store with mixed goods with a smaller sales space and only over-the-counter sale of goods. For larger municipalities, it may serve as a supplement to a supermarket or self-service store. Over-the-counter sale appears overall in 78 municipalities (22.0% of 355 municipalities). A supermarket, or possibly a discount store, is found later in the population category of 2,000 and more and has a larger catchment area that includes smaller municipalities. It is not a typical service for municipalities up to 3,000 inhabitants *(Table 3).*

No brick-and-mortar store, even with basic groceries, was found in a total of 53 municipalities (14%). In seven municipalities of the size category of 0–200 and 201–350 inhabitants, a mobile shop with mixed goods forms a partial replacement. In two smaller municipalities, only order-based sale of groceries functions. In 44 municipalities of the smallest size categories (population 0–750), there was no option of purchasing groceries whatsoever. According to our opinion and available data this mainly concerns municipalities with a very low population in remote areas with decreasing competitiveness of the population or in the wider territory of Brno (heavy competition of the big city) *(Figure 1).*

Table 3. Typical representation of diverse retail shops based on a population size of a given municipality

Kind of service	Total, %	Share of presence of services in municipalities by size category, %						
		0–200	201–350	351–500	501–750	751–1,000	1,001–2,000	2,001–3,000
Self-service	72.7	21.1	5.7	86.3	90.2	92.3	96.2	100.0
Mobile shop with select goods	37.7	17.5	29.9	43.1	41.0	51.9	44.2	46.7
Mixed goods over-the-counter	22.0	21.1	25.4	19.6	13.1	25.0	23.1	40.0
Smoked and fresh meat	12.7	0.0	4.5	5.9	3.3	21.2	30.8	66.7
Mobile shop with mixed goods	7.3	8.8	4.5	5.9	4.9	15.4	5.8	6.7
Fruits and vegetables	7.3	0,0	3.0	3.9	1.6	13.5	19.2	26.7
Bakery	6.2	1.8	1.5	2.0	1.6	3.8	13.5	60.0
Order-based sale of food	3.1	0.0	3.0	3.9	3.3	7.7	0.0	6.7
Supermarket	1.1	0.0	0.0	0.0	0.0	1.9	3.8	6.7

Source: Own survey and elaboration.

Mobile shops with select goods (fresh and smoked meat, fruits and vegetables) are more common than mobile shops with mixed goods. They are present in a total of 134 municipalities (37,7% of 355 municipalities). These "food trucks" most frequently head out to municipalities in size categories of 350–1,000 inhabitants, which form a supplement for local brick-and-mortar stores with basic groceries (see *Table 3*). Less populated municipalities have weaker buying power and smaller demand.

The line in the middle of the box indicates the typical size of the municipality where a service is present (median). Mixed goods

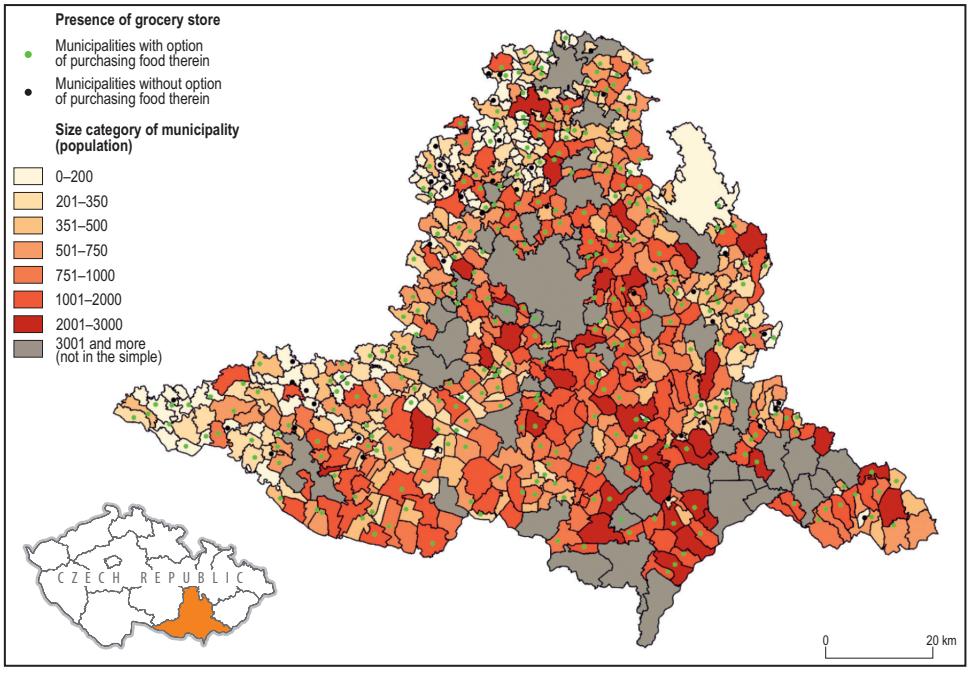

Fig. 1. Municipalities without option of purchasing food therein 2018, size category of municipality, 2018. *Source*: Czech statistical office and author's own elaboration.

with over-the-counter sales, self-service and mobile shops are then common for municipalities with a population of between 600 and 700. A supermarket can be found in municipalities or smaller cities with over 3,400 inhabitants. As it results from the previous analysis, order-based sale of groceries is relatively exceptional, but if it does exist it is typically in a municipality with 600 inhabitants. Specialized stores with groceries such as fruit and vegetables, fresh and smoked meat or bakeries can be found only in municipalities with around 2,000 inhabitants *(Figure 2).*

A functioning restaurant was identified in a total of 141 municipalities (39.7% of all 355 municipalities) *(Table 4).* The more population of the municipality increases, the more restaurants municipalities have; they are fully present in municipalities with a population of 2,000 and over. Hospitality facilities without meals like pubs and taverns are more common. In total, there was 216 municipalities (60.8%) registered with at least one pub. Again, the general rule applies that the larger the municipality, the greater presence of such facilities. There were 75 municipalities (21.1%) without any hospitality facilities whatsoever with or without meals. More specialized hospitality facilities represented by sweet shops/cafés appear in 45 municipalities, i.e. 12.7 per cent of all 355 municipalities.

Other most common services in rural areas include hairdressers (present in 173 municipalities, 48.7% of all 355 municipalities) and automobile repair shops (present in 134 municipalities, 37.7%). Both services begin to appear municipalities counting 200–350 inhabitants. These services appear in nearly all municipalities with a population over 1,000.

From the visualization of the size of municipalities *(Figure 3),* where individual services are found, using the box plot it appears that hospitality facilities without meals (pubs) can typically be found in municipalities with

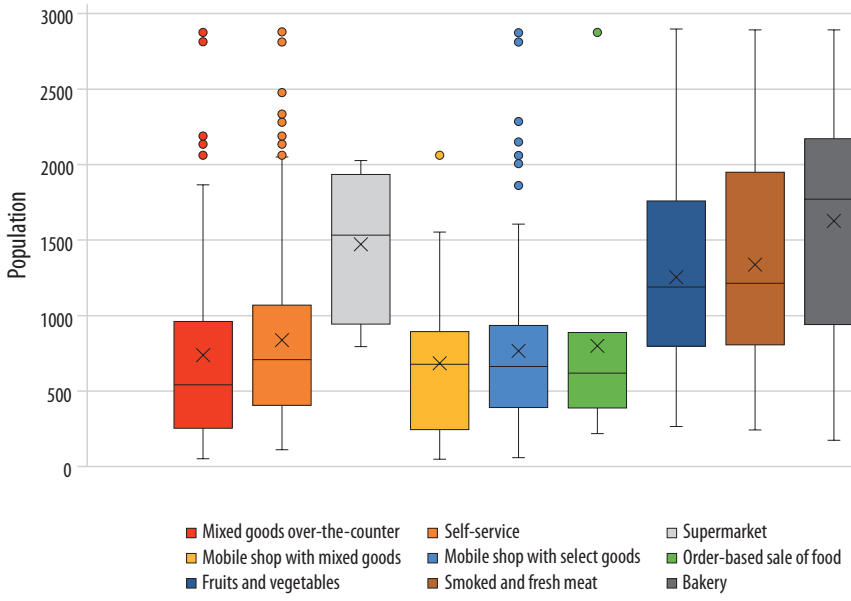

Fig. 2. Size of municipalities with presence of at least one operation of individual grocery stores. The line in the middle of the box = median size of the municipality where a service is present; cross = average; bottom line of the box = first quartile; upper line of the box = third quartile; bottom whisker = maximum; upper whisker = minimum; individual points = outliers. *Source*: Own research and elaboration.

Table 4. Typical representation of services based on a population size of a given municipality

Kind of service	Total, %	Share of presence of services in municipalities by size category, %						
		0–200	201–350	351–500	501–750	751–1,000	1,001–2,000	2,001–3,000
Hospitality facility without meals	60.8	19.3	64.2	62.7	72.1	65.4	76.9	80.0
Hairdresser	48.7	3.5	26.9	49.0	54.1	65.4	88.5	100.0
Restaurant	39.7	12.3	13.4	23.5	50.8	51.9	76.9	100.0
Automobile repair shop	37.7	10.5	22.4	23.5	47.5	44.2	69.2	86.7
Sweet shop/café	12.7	0.0	4.5	3.9	8.2	13.5	32.7	73.3

Source: Own survey and elaboration.

slightly more than 600 inhabitants (median). This is followed by hairdressers, automobile repair shops and restaurants, which are more common for municipalities with a population of around 850. One may designate sweet shops as higher services because it generally appears only in larger municipalities with roughly 1,700 inhabitants (see *Table 4*).

Other ascertained types of civic amenities are not typical for municipalities of the South Moravian Region and appear in larger centres with a population of 1,500 and higher, and inhabitants from smaller municipalities commute to them. An exception to this are wellness centres (sauna, whirlpool, solarium, etc.), which are present also in smaller settlements. According to the interviews, it reflects the trend affiliated with the growth of the standard of living of the inhabitants.

Changes in amenities of municipalities of the South Moravian Region (2002–2018)

While the 1990s were utterly crucial for complex economic transformation of retail and

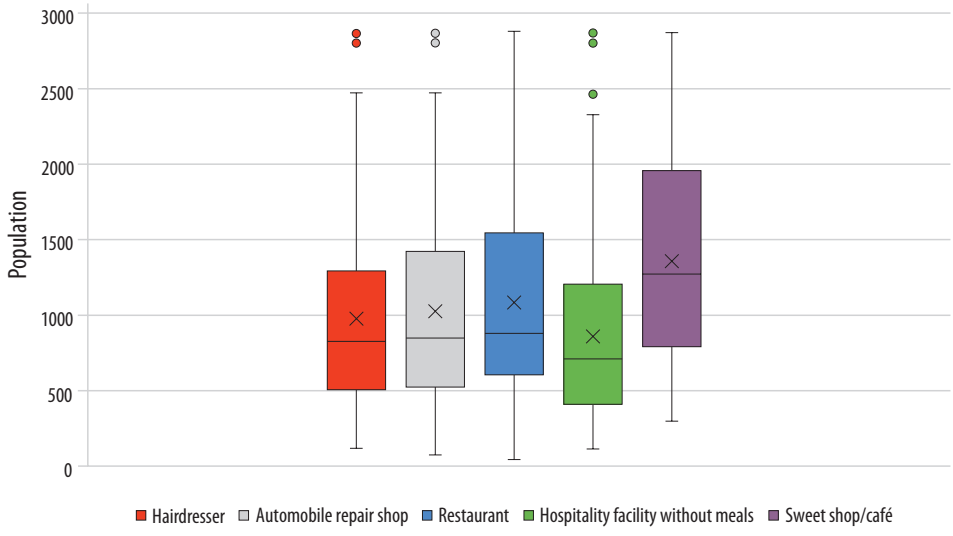

Fig. 3. Size of municipalities with presence of at least one operation of individual types of services. For legend see *Fig. 2. Source:* Own survey and elaboration.

services, the first two decades of the new century are a resonance of the most important transformations in terms of having retail and services in the rural environment. The often even unhealthy liberalization of the market environment, pressure from large chains, the lack of customers and overall incapacity to compete has caused the demise of over 6,000 small stores (up to 400 m^2) since 1990 in the Czech Republic, especially in rural areas. According to statistics of the Association of Czech Traditional Trade (AČTO), a total of 400 stores with sales space of up to 50 m^2 closed their doors for good. In the framework of the nationwide expansion of the group COOP, which is the best established on the Czech and Moravian markets, 125 stores went under or closed their doors in small municipalities in 2015–16. Another over 900 stores generated a negative financial result in 2016, whereas a series of them will have to be gradually closed (Klánová, E. 2018).

The number of municipalities with the presence of at least one grocery store (mixed goods and only over-the-counter sales, self-service with mixed goods, supermarket, discount store) decreased in the 355 monitored municipalities since 2002 by 10.6 per cent *(Table 5).* According to the interviews one of the main reasons may be mainly the increasing competition of multinational chains that open new local supermarket and discount stores. Also in decline are restaurants and hospitality facilities (with and without meals) by 13.4 per cent. According to the interviews, increasing costs for activity and the need to adjust to new trends comprised mainly of higher quality gastronomy play certain role.

From among other services between 2002 and 2018, it is possible to relevantly compare hairdressers and automobile repair shops. The proportion of municipalities with the presence of at least one hairdresser since 2002 has grown by 18 per cent; this was the only one of all monitored types of services to indicate growth. According to the interviews the hairdresser business is a commercial service that is much cheaper in rural areas than in cities, but it is still a sufficiently lucrative business. A substantial number of mainly women go to see "their" hairdresser out in the country. This is not typical case for monitored sample of automobile repair shops, which are on their decline (by 15.2%).

Based on the conducted interviews and looking at the territorial differences, it can be observed that development of amenities differs also according to location and socioeconomic characteristics. The worst off all is the situation with remote areas (away from the pole of growth of Brno with nearly 400,000 inhabitants) with sparsely populated municipalities. Often used in these territories are mobile stores with mixed goods. One may also register stagnating amenities near the city of Brno. The area does register positive demographic and economic indicators, but there is heavy competition of shopping opportunities in the city and people are used to taking advantage of them. According to conducted interviews, the situation is specific in Vranov nad Dyjí area due to cross-border shopping tourism from Austria. According to the change index, there was a decline, which, however, it partially slowed down due to shopping tourism. In particular, cigarettes

Table 5. Change in amenities of municipalities of the South Moravian Region between 2002 and 2018 expressed in a sample of 355 municipalities

Type of civic amenities	Number of municipalities with presence of at least one operation		Change index
	2002	2018	
Grocery store	329	294	89.4
Restaurant and hospitality facility	314	272	86.6
Hairdresser	170	173	101.8
Automobile repair shop	158	134	84.8

Source: Own survey and elaboration.

and alcohol are being bought by Austrians. The best results are achieved by areas with larger municipalities in terms of population at a greater distance from Brno, but not in the periphery. Peripheries with good results had low initial equipment in 2002. They had nowhere else to fall *(Figure 4).*

Support for retail and commercial services on the part of municipalities, regions and the state

When replying to the question "Does your municipality support retail and commercial services?", a strong majority of municipalities (73.0%) said "no". A total of 13.5 per cent of municipalities replied "yes", i.e. mainly by charging lower rent to private operators. Only a small fraction of municipalities (5.9%) provides a direct financial subsidy to private operators. Municipalities could indicate a different form of support, specifically the following:

– the municipality runs the operation directly (2x),
– the municipality purchases goods from the local shop for municipal events (3x),
– the municipality acquired furnishings for the store,
– the municipality supported them through marketing or advertising.

It is therefore possible to state that roughly a quarter of municipalities of the South Moravian Region supports in their territory in some way the existence of retail and commercial services. The amount of money that municipalities give as direct financial subsidizing to private operators fluctuates from around EUR 480 to EUR 6,000 annually. The median per municipality amounts to EUR 2,000 annually. Lower rent fluctuates in a wide range of from EUR 120 to EUR 5,600 annually. The median relief per municipality amounted to CZK 1,100.

Geographical differentiation of municipalities that support retail and commercial services

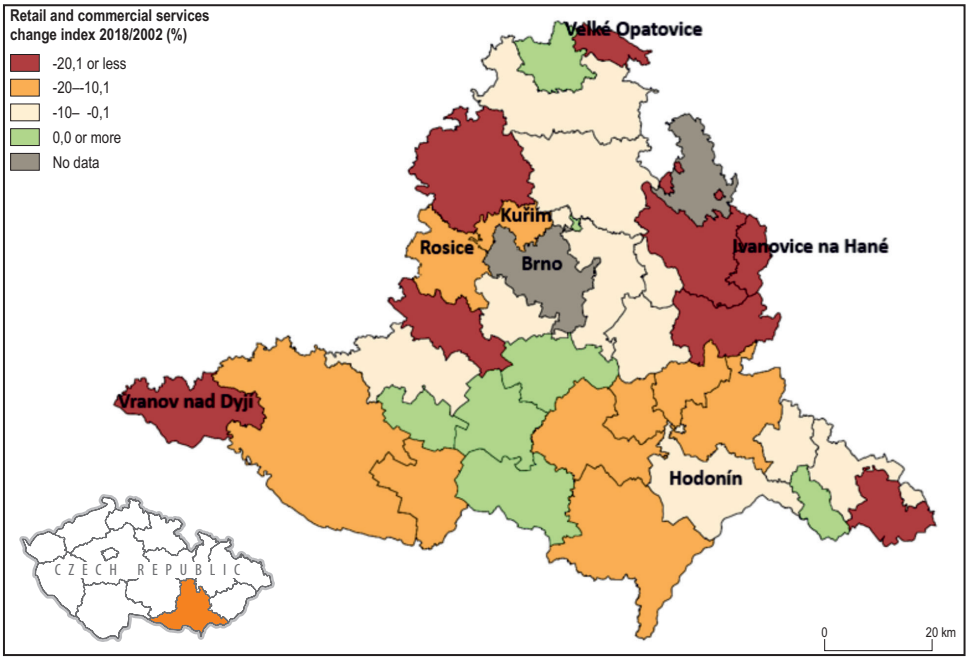

Fig. 4. Retail and commercial services change index 2018/2002. *Source:* Own survey and elaboration.

has not been identified. They seem to be distributed randomly. Discounted rent is most often provided in municipalities of the size categories 351–500 inhabitants –19.6 per cent of municipalities, and 751–1,000 inhabitants –17.3 per cent of municipalities. In other size categories it is about 10 per cent. Direct subsidies are mostly provided in municipalities of the size category 0–200 inhabitants (10.5%), and 201–350 inhabitants (13.4%). In municipalities above 751 inhabitants there is no direct subsidy.

Eight out of fourteen regions provide subsidies to municipalities in support of grocery stores (administrative level NUTS 3). The first region started this in 2009, with the remaining seven regions joining it in 2018 and 2019 along with the increasing pressure on the part of operators, which related to increased costs, administration and stagnating incomes. Municipalities may draw CZK 1,000 – EUR 6,000 annually for operation with 50 per cent co-financing. The Ministry of Regional Development also provides subsidy support to municipalities. It is possible to apply for EUR 4,000 – EUR 80,000 for reconstruction, conversion and construction of buildings for preparing a location to operate a store with 70 per cent co-financing.

According to our opinion opportunities for commercial serviceability of municipalities in rural areas are not only subsidies affiliated with the concept of social economics. Means and instruments can also be found in the context of an institutional or neoliberal economy. Neoliberalism mainly concerns measures affiliated with "laissez-faire" (e.g. decreasing the tax burden for employees and for sale of products and services, tolerance of club hospitality facilities, informal "back-street" sales – so-called "grey economy"). According to the interviews recommendations can also be directed right to entrepreneurs so they would adjust to market changes and alter their form of sales (mobile stores, delivery of ordered groceries), as well as the offer itself (combining various types of services into one operation, orientation towards more local, fresh, quality food), and adjustment of their marketing and promotion.

Interviews also show the institutional aspect. It makes it possible to appeal to independent traders to organize themselves into cooperatives and associations having greater negotiating power. They may share experiences, know-how and certain costs. On the part of municipalities, it is possible to support operators mainly through informal institutions by lending moral support, tolerance and assistance when dealing with state administrative bodies (e.g. the building authority). Municipalities may also regulate large multinational chains and their supermarkets discount stores through the instrument of town planning. The Ministry of Industry and Trade in this area is preparing a systemic decrease in the administrative burden of doing business.

Conclusions

In 2018, the authors performed an extensive survey of amenities in municipalities of the South Moravian Region, which linked back to survey from 2002. Post revolution market environment is created and altered by everyday human activities and political economy of certain country. Process continued throughout the 1990s, the most significant changes have occurred in approximately the last fifteen years in amenities of rural municipalities through retail and service facilities. There is a different development of commercial amenities in rural areas. In generally these changes reflected mostly negative in nature, and began to threaten rather intensely the position of some rural areas, their social and economic function and the overall attractiveness of the living space (see also Paddison, A. and Calderwood, E. 2007; Clarke, I. and Banga, S. 2010; Amcoff, J. *et al.* 2011; Karlsson, E.B. 2012 and others).

According to the conducted survey the presence of retail or services rather heavily depends on the size of the municipality. The interviews and territory differences proved only partial dependence between the demographic and economic characteristics of the territory and changes in amenities between 2002 and 2018,

which is in contrary to the conclusions Jussila, H. *et al.* 1992, or Smith, A. and Sparks, L. 1997).

It was seen that service functions of the South Moravian Region have been getting gradually weaker since 2002 in almost all types of operations, which confirms the conclusions of Czech and European authors (e.g. Paddison, A. and Calderwood, E. 2007; Páll, Z. and Hanf, J.H. 2013; Maryáš, J. *et al.* 2014). Retail has lost roughly 10 per cent of the share in the monitored municipalities, whose position is according to the interviews "improved" by the restoration of the existence of mobile stores or Internet retail, which is not as important as abroad (compare with Freathy, P. and Calderwood, E. 2013, or Singleton, A.D. *et al.* 2016). Communication partners also mentioned very good transport serviceability and accessibility (Integrated Transport System of the South Moravian Region) and intensive growth in individual automobile transport enable most of the population to shop and commute to services even in more remote localities. So more threatened are rather selected population groups such as old people, which confirms the conclusions (e.g. Powe, N.A. *et al.* 2009, or Schiffling, S. *et al.* 2015).

If we attempt to generalize the stated facts leading from interviews, educated people will by key for expansion or sustainable development of rural areas in municipalities. Possibly contributing to this would be not only development of infrastructure in municipalities, but also e.g. the next wave of digitalization and introduction of stable high-speed Internet (see also Freathy, P. and Calderwood, E. 2013, or Singleton, A.D. *et al.* 2016), which would enable people to work from home.

Another important fact that is based on interviews is the increase in decision-making authority among financing sources about which mayors would decide directly without being pressured from the regional and national level (compare with Peková, J. 2012). In addition, there is no long-term growth in wages associated with the economy of small stores, which in the form of wage costs form up to 75 per cent of total costs for a shop or store; it is essential, however, to respect the market environment. One of the most recent advised possibilities for sustainability of rural retail is cooperation between the group COOP and the Czech Post Office, the possible implementation of which of course would be far from simple. This conclusion confirms selected goals in public strategies, e.g. the Program of development of the South Moravian Region.

Facts mentioned in the text indicate ever-strengthening tendencies to support rural-based retail and basic services at the state, regional or municipal level. Municipalities that decide to support retail and services anchor their efforts in the Municipalities Act No. 128/2000, which determines that among the municipality's independent powers are matters that are in the interest of the municipality and its citizens. It is appropriate to target subsidy support as much as possible to bring the greatest effects. It is therefore essential to have available analytical bases that facilitate political representatives in their decision-making (Binek, J. *et al.* 2007).

Roughly a fourth of municipalities of the South Moravian Region support retail and commercial services, either through lowered rent or direct financial subsidy. According to our opinion it is highly probable that in the future, a series of small stores functioning today will not get by or survive without subsidy assistance, which may lead to expansion of a so-called food desert as described in the paper by Bilková, K. *et al.* (2017).

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REFERENCES

AČTO 2019. *Priority českého nezávislého obchodu pro rok 2019* (Priorities of Czech independent retail for 2019). Asociace českého tradičního obchodu (AČTO). [online] [cit. 2019-07-10] Available at https://www.acto.cz/aktuality/priority-ceskeho-nezavisleho-obchodu-pro-rok-2019

Amcoff, J., Möller, P. and Westholm, E. 2011. The (un) importance of the closure of village shops to rural

migration patterns. *The International Review of Retail, Distribution and Consumer Research* 21. (2): 129–143.

Association of the Czech Traditional Trade 2019. *Czech Independent Trade Priorities for 2019*. Available at https://www.acto.cz/aktuality/priority-ceskeho-nezavisleho-obchodu-pro-rok-2019

Båtevik, F.O. and Halvorsen, L.J. 2016. Den entreprenørielle distriktsbutikken som næringsog utviklingsaktør i små lokalsamfunn. In *Innovasjon og entreprenørskap.* Eds.: Kvangarsnes, M., Håvold, J.I. and Helgesen, Ø., Ålesund, Fjordkonferansen 2015, 82–101. Available at https://doi.org/10.18261/9788215027623-2016-05

Benedek, J. and Ivan, K. 2018. Remote sensing based assessment of variation of spatial disparities. *Geographia Technica* 13. (1): 1–9. Doi: 10.21163/GT_2018.131.01.

Bilková, K., Križan, F., Horňák, M., Bralík, P. and Kita, P. 2017. Comparing two distance measures in the spatial mapping of food deserts: The case of Petržalka, Slovakia. *Moravian Geographical Reports* 25. (2): 95–103.

Binek, J., Toušek, V., Galvasová, I., Věžník, A., Kunc, J., Seidenglanz, D., Halásek, D. and Řehák, S. 2007. *Venkovský prostor a jeho oživení* (Country area and its activation). Georgetown. Available at http://www.garep.cz/wp-content/uploads/2013/03/Venkovsky_prostor.pdf

Birkin, M., Clarke, G. and Clarke, M. 2010. Refining and operationalizing entropy-maximizing models for business applications. *Geographical Analysis* 42. (4): 422–445.

Cheshire, P.C., Hilber, C.A.L. and Kaplanis, I. 2014. Land use regulation and productivity – land matters: evidence from a UK supermarket chain. *Spatial Economics Research Centre Discussion Paper Series* 138. Available at http://dx.doi.org/10.2139/ssrn.2376175

Clarke, I. and Banga, S. 2010. The economic and social role of small stores: a review of UK evidence. *The International Review of Retail, Distribution and Consumer Research* 20. (2): 187–215.

Cunningham, J. 1999. *Farming jobs crisis expected to ripple*. The Scotsman 22. Oct. Edinburgh, Scotsman Publications Ltd.

Freathy, P. and Calderwood, E. 2013. The impact of internet adoption upon the shopping behaviour of island residents. *Journal of Retailing and Consumer Services* 20. (1): 111–119.

Haberman, H. and Danes, S.M. 2007. Father-daughter and father-son family business management transfer comparison: Family FIRO model application. *Family Business Review* 20. (2): 163–184.

Hruška, V. and Piša, J. 2019. Winning and losing rural localities of the post-socialist economic restructuring: Case study of Czechia. *Hungarian Geographical Bulletin* 68. (4): 373–389.

Illeris, S. 1991. Location of services in a service society. In *Changing Geography of Advanced Producer Services.* Eds.: Daniels, P.W. and Moulaert, F., Belhaven, Wiley-Blackwell.

Jihomoravský kraj 2017. *Program rozvoje Jihomoravského kraje 2018–2021* (Development strategy of the South Moravian Region 2018–2021). Brno, GaREP spol. s.r.o.

Jussila, H., Lotvonen, E. and Tykkyläinen, M. 1992. Business strategies of rural shops in a peripheral region. *Journal of Rural Studies* 8. (2): 185–193.

Karlsson, E.B. 2012. *Retail in Rural Regions. Exploring Ways to Support Rural Shops*. Centre for Retail Studies, Bifrost, Bifrost University, Iceland.

Klánová, E. 2017. *Venkovský obchod bojuje o přežití* (Rural retailing on the edge of survival). Retail news. [cit. 2019-06-30]. Available at https://retailnews.cz/2018/01/08/venkovsky-obchod-bojuje-o-preziti/

Križan, F. 2009. *Globalization of retailing: Definition of fundamental processes and their analysis in the retail geography of Slovakia.* Available at http:/www.regionalnageografia. sk/upload/personal/Kri% C5% BEan, % 20F, 20

Križan, F. and Lauko, V. 2014. *Geografia maloobchodu, úvod do problematiky* (Retail geography, basic issues). Bratislava, Univerzita Komenského v Bratislavě.

Križan, F., Bilková, K. and Kita, P. 2014. Urban retail market in Bratislava (Slovakia): Consumers perception and classification of shopping centres. *Management & Marketing* 9. (4): 483–500.

Križan, F., Zeman, M., Bilková, K., Kita, P. and Barlík, P. 2017. Cross-border shopping behaviour of consumers from Slovakia: Case study from Hainburg an der Donau (Austria). *Geographia Cassoviensis* 11. (2): 124–136.

Kubeš, J. and Nováček, A. 2019. Suburbs around the Czech provincial city of České Budějovice – territorial arrangement and problems. *Hungarian Geographical Bulletin* 68. (1): 65–78.

Kunc, J., Maryáš, J., Tonev, P., Frantál, B., Siwek, T., Halás, M. and Marvanová, J. 2013. *Časoprostorové modely nákupního chování české populace* (Spatio-temporal models of the Czech population shopping behaviour). Praha, Masarykova univerzita.

Kunc, J., Tonev, P., Martinát, S., Frantál, B., Klusáček, P., Dvořák, K.Z., Chalupková, M., Jaňurová, M., Krajíčková, A. and Šilhan, Z. 2018. Industrial legacy towards brownfields: Historical and current specifics, territorial differences (Czech Republic). *Geographia Cassoviensis* 12. (1): 76–91.

Kupper, P. and Eberhardt, W. 2013. Village shops: outdated or revived model? Relevance for local supply, social functions and economic viability. *Studies in Agricultural Economics* 115. 92–97.

Maryáš, J., Kunc, J., Tonev, P. and Szczyrba, Z. 2014. Spádovost za obchodem a službami v zázemí Brna: Srovnání období socialismu a současnosti (Shopping and services related travel in the hinterland of Brno: Changes from the socialist period to the present). *Moravian Geographical Reports* 22. (3): 18–28.

MAS partnertsví venkova 2020. *Strategie komunitně vedeného místního rozvoje* (Community-led local development strategy). [online] [cit. 2020-02-15] Available at http://www.maspartnerstvi.cz/component/phocadownload/category/3-sclld.html#

McEachern, M.G. and Warnaby, G. 2006. Food shopping behaviour in Scotland: The influence of relative rurality. *International Journal of Consumer Studies* 30. (2): 198–201.

Ministry of Agriculture of the Czech Republic and Czech Chamber of Commerce 2018. *Support for Rural Services*. Available at https://www.komora.cz/legislation/15817-revize-materialu-podpora-obsluznosti-venkova-t-17-10-2017/

Mirwaldt, K. 2010. Contact, conflict and geography: What factors shape cross-border citizen relations? *Political Geography* 29. (8): 434–443.

Mladek, J., Kacerova, M. and Stankovicova, I. 2018. Regional differentiation of population ageing in Europe. *Geographia Cassoviensis* 12. (1): 92–109.

Moseley, M.J., Parker, G. and Wragg, A. 2004. Multiservice outlets in rural England: The co-location of disparate services. *Planning Practice and Research* 19. (4): 375–391.

Nørgaard, H. 2011. Futures of rural and peripheral areas – Challenges, strategies and policies. *Danish Journal of Geoinformatics and Land Management* 46. (1): 81–95.

Paddison, A. and Calderwood, E. 2007. Rural retailing: a sector in decline? *International Journal of Retail & Distribution Management* 35. (2): 136–155.

Palermo, C., Gardiner, B., Gee, C., Charaktis, S. and Blake, M. 2017. A mixed-methods impact evaluation of the feasibility of an initiative in small rural stores to improve access to fruit and vegetables. *Australian Journal of Primary Health* 22. (6): 545–553.

Páll, Z. and Hanf, J.H. 2013. A multi-perspective analysis of food retail internationalization-insights from foreign retailers on the development of the Hungarian and Eastern European markets. *Management & Marketing* 8. (4): 593–606.

Patay, T. 2018. Immigration and regional competitiveness-relevant theories in the migration research and in the regional science. *Deturope – The Central European Journal of Regional Development and Tourism* 10. (1): 71–81.

Peková, J., Pilný, J. and Jetmar, M. 2012. *Veřejný sektor-řízení a financování* (Public sector-management and financing). Praha, Wolters Kluwer ČR.

Perlín, R., Kučerová, S. and Kučera, Z. 2010. Typologie venkovského prostoru Česka (Typology of the rural space in the Czech Republic). *Geografie* 115. (2): 161–187.

Powe, N.A., Hart, T. and Bek, D. 2009. Market town centres in England: Meeting the challenge of maintaining their contemporary relevance. *Planning Practice & Research* 24. (3): 301–319.

Ronse, W., Boussauw, K. and Lauwers, D. 2015. Shopping center siting and modal choice in Belgium: a destination-based analysis. *European Planning Studies* 23. (11): 2275–2291.

Schiffling, S., Karamperidis, S. and Nelson, J.D. 2015. Local shops vs. online retailers: competition or synergy? *Scottish Geographical Journal* 131. (3–4): 220–227.

Šilhan, Z. 2018. Vybavenost obcí Jihomoravského kraje (Municipalities amenity of the South Moravian Region). In *XXI. Mezinárodní kolokvium o regionálních vědách. Sborník příspěvků*. Brno, Masarykova univerzita, 374–380.

Singleton, A.D., Dolega, L., Riddlesden, D. and Longley, P.A. 2016. Measuring the spatial vulnerability of retail centres to online consumption through a framework of e-resilience. *Geoforum* 69. 5–18.

Smith, A. and Sparks, L. 1997. *Retailing and Small Shops.* Stirling, Institute for Retail Studies, University of Stirling.

Spilková, J. 2012. *Geografie maloobchodu a spotřeby: věda o nakupování* (Geography of retail and consumption: shopping science). Praha, Univ. Karlova, Nakl. Karolinum.

Spilková, J. 2018. "Tell me where you shop, and I will tell you who you are": Czech shopper profiles according to traditional, large-scale and alternative retail options. *Moravian Geographical Reports* 26. 3. 186–198. Doi: 10.2478/mgr-2018-0015.

Stanciu, S. 2015. The Romanian retail food market-survival or success for domestic companies. *Procedia Economics and Finance* 23. 1584–1589.

Szczyrba, Z., Fiedor, D. and Kunc, J., 2013. Služby ve venkovských regionech Česka – kvantitativní hodnocení změn v uplynulém transformačním období (Services in the rural regions of Czechia – quantitative assessment of changes in the elapsed transformation period). In *XVI. mezinárodní kolokvium o regionálních vědách. Sborník příspěvků*. Brno, Masarykova univerzita, 212–222. Doi: 10.5817/CZ.MUNI.P210-6257-2013-26.

Tonev, P., Halás, M. and Klapka, P. 2018. Prostorová neurčitost funkčních regionů: porovnání pracovní dojížďky v letech 1991–2011 (Spatial uncertainty of functional regions: comparison of work commuting in 1991–2011). In *XXI. Mezinárodní kolokvium o regionálních vědách. Sborník příspěvků*. Brno, Masarykova univerzita, 285–292. Doi: 10.5817/CZ.MUNI.P210-8970-2018-37.

Trebbin, A., Franz, M. and Hassler, M. 2013. Wholesale co-operations for small supermarkets in rural areas-the example of Central Hesse, Germany. *Zeitschrift für Wirtschaftsgeographie* 57. (3): 139–154.

DOI: 10.15201/hungeobull.69.1.5 Hungarian Geographical Bulletin **69** 2020 (1) 57–71.

Educational tourism and nation building: Cross-border school trips in the Carpathian Basin

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Abstract

Educational travel provides opportunities for participants to explore specific issues in unconventional ways. In Hungary, primary and secondary schools organise annual study trips as part of their curricula. The aim of these trips is to familiarise students with the main sights of the country, and to bring to life national narratives discussed in lessons. Furthermore, these trips often play a key role in students' socio-psychological development, both as future tourism consumers and as future citizens. Recognising the opportunity to influence students' worldview and way of thinking during their sensitive teenage years, the Hungarian government has created a national programme to financially support school trips organised to visit minority Hungarian communities living in the neighbouring countries. This paper is based on the content analysis of 256 detailed reports submitted by participants of school trips organised in 2013/14 with the aim to visit Hungarian minority communities in the Carpathian Basin. The analysis focuses on the detailed descriptions of the participants' personal memories of their experiences, the social construction of the visited destinations, and the influence of their memorable experiences on their sense of national identity. The research disclosed that the trips made to Hungarian territories outside the borders contributed to shaping the national sentiment of the students participating in the programme. The findings suggest that since participation in tourism is an effective means to experience nationhood and national identity, by financially supporting school trips abroad, the state may be able to exert political influence over national consciousness.

Keywords: ethnic tourism, educational trip, national identity, nation building, Carpathian Basin, Hungary, 'Without Borders!' project

Introduction

In the past decades, researchers have revealed several aspects of the symbiosis of tourism and politics (e.g. Burns, P. and Novelli, M. 2007). Most of the monographic work was economics- (Mosedale, J. 2011), controlling- (Pender, L. and Sharpley, R. 2005) and development-oriented (Brien, A. 2011), while among social approaches, several publications have dealt with the role of the state in social tourism (e.g. La Placa, V. and Corlyon, J. 2014) or the relationship of travel and national identity (Bhandari, K. 2014).

Generating and maintaining nationalism with the help of tourism occurs in domestic and in international tourism as well (Pretes, M. 2003). Through the development of the tourism industry after World War 2, both democratic and totalitarian states – with diverse motivations – took part in encouraging trips with the objective to strengthen national identity (Palmer, C. 1999). The establishment and expansion of the European Union, on the one hand, have gradually contributed to stronger national identities (McLaren, L. 2004), while, on the other hand, have facilitated unrestricted border crossings, based on the

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principle of the free movement of persons laid down in the Treaty of Rome. The integration of East Central Europe to the European Union revealed the suppressed dreams of countries in the Carpathian Basin concentrating on strengthening national identity (Young, C. and Light, D. 2001). What was unimaginable in the former socialist camp strictly controlled by the Soviet Union came true in the European Union. The EU's minority policy supports the establishment of cultural connections between minority groups and their motherland in many ways, which also opened the gates to political initiatives strengthening national identity in neighbouring countries under the auspices of cultural cooperation (Sasse, G. 2008). Tourism represents one aspect of mobility among euro-regions, in the framework of which – through the development of cultural and heritage attractions – many trips are realized with the motivation of nation-building.

Similarly, there is a growing body of literature focusing on the role and benefits of educational travel, partly as a means of connecting the theoretical world of academia with the realities of tourist destinations (Tarrant, M.A. *et al*. 2011) and to encourage critical reflection on behalf of the students (Boluk, K. and Carnicelli, S. 2015), partly as initiatives embracing the principles of experiential learning in the forms of study trips and field schools (Liang, K. *et al.* 2015). However, most authors concentrate either on university students (particularly on medium- and long-term study abroad programmes) (e.g. Juvan, E. and Lesjak, M. 2011; Abubakar, M. *et al.* 2014), and on the role of field visits in travel & tourism, or tourism & hospitality degree programmes (e.g. Sanders, D. and Armstrong, E.K. 2008; Arcodia, C. and Dickson, C. 2013), or on adults participating in educational experiences as a form of lifelong learning or as serious leisure (e.g. Pitman, T. *et al.* 2010; Kask, S. 2011), and there is a general gap in the literature when it comes to elementary or secondary schools' activities.

The present study tries to fill this gap by analysing a Hungarian governmental programme that aims to strengthen adolescents's national identity in the context of educational travel. In addition, it also proposes to contribute to the widening discussion on the relationship of tourism and politics, with special consideration to using tourism as a means to achieve political goals. The objective of the study is to discuss, using an exploratory approach, the phenomenon of financially supported school trips organised outside the borders with the motivation of reinforcing national identity. The paper reviews the historical and political antecedents of national identity building, presents the tourism aspects of the 'Without Borders!' programme, identifies the spatial and temporal characteristics of the trips carried out during the 2013/2014 school year, as well as evaluates the experiences of the student participants during these trips, with special emphasis on national identity, and the social, community-building role of travel. Based on content analysis of the participating students' reports, the primary objective of the study is to determine whether the government's intention to use travel as a means to national identity building is fulfilled with the 'Without Borders!' programme.

Theoretical background

National identity in the Carpathian Basin – the geopolitical context

Hungary occupies a special place in the processes of national identity building in the Carpathian Basin. According to the Trianon Peace Treaty signed in 1920, following World War 1, two-thirds of the territory of former historical Hungary, and half of its population were allocated to the neighbouring countries, leaving approximately 3 million ethnic Hungarians outside the new borders (Kovács, Z. 1989; Kocsis, K. and Kocsis-Hodosi, E. 1998). The Trianon Peace Treaty caused a trauma in the Hungarian society, a deeply rooted feeling of injustice that proved difficult to cope with and resulted in serious political consequences (Gerner, K. 2007). Among oth-

ers, the rising of nationalism and revisionism led Hungary to participate in World War 2 as an ally of Nazi Germany, and the defeat brought about another downfall. The Paris Peace Treaties signed in 1947 restored Hungary's borders, with a minimal modification, as laid down in the Trianon Peace Treaty.

Between 1947 and 1989, Hungary was a one-party dictatorial socialist state under the influence of the Soviet Union. After 1947, there was no place for condemning the Trianon Peace Treaty or the Paris Peace Treaties, the police of the Communist-Socialist party repressed systematically all nostalgic feelings about the greatness of former historical Hungary. In the Eastern Block controlled by the Soviet Union the notion of internationalism was promoted, preventing by all means possible the emergence of national identities. The regions located along state borders, which symbolized national identity, were deliberately underdeveloped, transforming them both economically and socially into peripheries (Erőss, Á. and Tátrai, P. 2010). Throughout the decades, the neighbouring states, despite proclaiming the ideology of peaceful coexistence, were trying to impede cross-border relationships, even between families and relatives. This was achieved not only by making crossing borders more difficult, but also by relocating ethnic minorities living along the frontiers across the country.

The fate of millions of Hungarian minorities trapped outside the motherland following the Trianon Peace Treaty varied greatly. Due to migration, assimilation and natural death, the number of Hungarians living outside the motherland was rapidly decreasing (Kocsis, K. and Tátrai, P. 2012): in 1989, the number of Hungarians living outside the borders of current Hungary only reached 2.3 million. A possible initiative to stop this unfavourable process might be the development of ethno-tourism in which Hungarians living in the motherland visit Hungarian territories outside of the political borders to nurture their national identity. As a result of economic growth in the areas involved in such ethno-tourism, due to the spending of visitors and their interest in local heritage, favourable demographic processes might be generated that benefit the Hungarian minorities living there (Ilyés, Z. 2006).

After the regime change in 1990, the strengthening of national identity and the cohesion of the 'core nation' – the motherland and the Hungarian territories outside the national borders – appeared in a privileged position in the rhetoric of the conservative political parties (A. Gergely, A. 2012; Kocsis, K. 2013). After gaining power in 2010, the current government has realized the potential of young people in reinforcing a sense of national identity that was artificially suppressed during decades of socialism, therefore, they created a programme with the aim to bolster the youngest generation's national identity (Pap, Sz. 2013). The 'Without Borders!' government programme provides financial support for study trips organised by primary and secondary schools to visit Hungarian communities living in the neighbouring countries.

Educational tourism and identity building

Schools play a role in formal and informal education on the one hand (conveying information, in situ deepening of knowledge, forming students into environment-conscious, responsible citizens), and in socialization (becoming tourists, adapting to foreign environments) on the other hand (Arcodia, C. and Dickson, C. 2009). The gap between theory and practice might be significantly lessened by creating experiences and by experience-oriented teaching outside the classroom (Falk, J. *et al.* 2012). During study trips organised for peer student groups, the young participants face several challenges and have specific tasks that promote the development of their creativity (Horváth, A. 2015). In secondary and tertiary tourism education, field trips represent an indispensable form of learning and expanding one's practical knowledge (Harris, J. *et al.* 2012). Trips to foreign countries exponentially increase the function of school trips in the field of education and socialization, and help

the internationalization of young generations (Huang, R. 2013). In case the cultural distance is too big between the sending country and the destination, or when students have insufficient knowledge about the destination, participants may find it challenging to adapt to the local circumstances, and the consequent negative experiences may limit the fulfilment of educational objectives (Klooster, E. *et al.* 2008). However, if the students' opinion is positive, they may soon return to the destination with their relatives or friends, or may repeat the trip later in their lives (Frändberg, L. 2010).

The protection and presentation of cultural heritage as a tourist attraction play a major role in national identity politics (Morgan, N. and Pritchard, A. 1998; Pitchford, S. 2008). What stands behind the intensification of daily nationalism is the efforts of offsetting European identity – promoted by the European Union and its predecessors –, embodied in the preservation of national solidarity (Park, H. 2010). Among the instruments of nation building widely used in Europe one can find the cultivation of mother tongue symbolizing national affiliation, the safeguarding of history and heritage based both on archaeological evidence and legends, the preservation of the iconography of the mutual past as well as the promotion of one's attachment to the national lands (Palmer, C. 1999; Hollinshead, K. 2009). Identity politics is often discussed in the context of centre-periphery narratives (Fonseca, F. and Ramos, R. 2012). In contrast of the cosmopolitan cities, the rural areas preserving traditions seem to embody national values and represent common roots (Silva, L. and Leal, J. 2015).

Ethnic tourism has a key place in the successful implementation of national identity politics (Yang, L. and Wall, G. 2009). One of the tools to maintain the connection between the majority nation and national minorities outside the mother country is travelling, which usually takes place under the aegis of cultural and heritage tourism, or visiting tourism of friends and relatives (VFR) (Irimiás, A. 2013). The goals of nation-building related to tourism can, of course, be served by other devices as well, such as by nurturing the relations of twin-cities, organizing student exchanges, and offering scholarship programmes (Altinay, L. and Bowen, D. 2006). Throughout the history, governments have used countless peaceful solutions which, symbolically, have contributed to the strengthening of national identity politics (Peters, K. 2011). However, the examination of cross-border school trips with the goal of national identity building represents an under-researched topic in the scientific tourism literature.

As already argued above, including school trips as an active component in an educational programme may have a wide range of objectives, but these are generally connected to the learning process. Possible forms include linking classroom-acquired knowledge with practical experience, e.g. as school excursions to historical or literary sites (Ayalon, Y. and Schnell, I. 2014), nature immersion programmes (Kövecsesné Gősi, V. 2009), or real-life foreign language practice (Drozdzewski, D. 2011). Another important educational benefit of travelling stems from the personal growth and attitudinal changes that the participants of field trips or voluntary activities undergo as a consequence of their broadened understanding of the visited destination's realities (Orpett Long, S. *et al.* 2010), which may also influence their perceptions of their home environment. And while it may be pointed out that the organisers of trips belonging to the latter category may have underlying soft political motives – such as increasing social sensibility and awareness of the impacts of tourism, supporting critical thinking, or encouraging responsible consumer behaviour during and after the trip (Boyle, A. *et al.* 2015) –, it is rather uncommon to use educational tourism as a state programme to directly support political objectives.

Although comparisons may be drawn by China's 'red tourism' concept – a nationwide political socialization programme launched in 2004 to promote patriotism and identification with the party-state (Zuo, B. *et al.* 2017) –, since it also gave priority to political goals over eco-

nomic considerations, a major difference is that the Chinese project focuses primarily on the supply side, i.e. the identification and development of sites associated with communist heritage and the revolutionary era, was initiated as a domestic tourism programme, and targets the whole population of the country, not only schoolchildren (Xu, K. 2015).

Methodology

A significant part of school trips belong to the sphere of invisible – or hidden or unobserved – tourism (Michalkó, G. and Rátz, T. 2013; De Cantis, S. *et al.* 2015). With respect of journeys like these, no statistical reporting requirements exist in Hungary. As a consequence, there is no scientific database available on one-day study visits or multi-day school trips using unregistered accommodation.

The 'Without Borders!' programme of the Hungarian government was launched in 2010 and is run by the Human Capacities Grant Management Office (EMET in Hungarian), a background institution of the Ministry of Human Resources. Although EMET has always imposed strict reporting requirements for schools supported by the 'Without Borders!' programme, the conditions have been modified during the project's history. Year 2013/14 was the period when the most detailed trip report had to be submitted – consisting of a completed form together with a travel diary and photo documentation –, so we selected this year's submissions (256 reports in total) for our analysis.

For processing the reports, the method of content analysis was chosen. The website of EMET provides detailed guidance for the participating schools concerning the mandatory content and format of trip reports, enabling us to define the range of available information and to visualise the data structure required for our project. The available information was categorised into three major groups:

– The first group of data represented information about the visited destinations as well as the spatial and temporal characteristics of the journeys: target country, visited settlements, location of accommodation, date of arrival and departure.
– The second group included data on the organisational aspects of the trips: use of tour operator or individual organisation, type of transportation and type of accommodation.
– The third group contained qualitative information on the excursions, such as the type and the characteristics of the programmes, activities organised at each visited site, and the participants' affective and conative experiences during these programmes.

Summarising the information in the first two categories did not mount any particular methodological challenge, since the data were recorded in the required form in the submitted reports. In order to examine in depth to the participants' activities and memorable experiences, inductive content analysis of the submitted travel diaries was employed to identify the key themes. The method was tested by analysing 15 reports, initial codes were classified under activity and experience categories, and themes were developed by expanding, merging or rearranging these initial categories.

The present study is based on the reports written by 7th grade (13–14-year-old) students of Hungarian primary schools who participated in the 'Without Borders!' programme during the 2013/2014 school year. After recording a total number of 256 entries into our database, the first major challenge was to identify and standardize the geographical names given in the forms. All the visited geographical areas are located in the territory of the 'historic Hungary' (as the Kingdom of Hungary before 1920 is often referred to), thus practically all the visited settlements have a traditional Hungarian name widely used in colloquial speech besides their official administrative name in the national language of the given country (e.g. Košice in Slovakia is called Kassa in Hungarian). Although Hungarian speakers living in the territory of Hungary tend to use the Hungarian settlement names almost ex-

clusively (many of them, especially the children, are not even familiar with the official Romanian, Slovakian, Ukrainian etc. names), in the trip reports, probably due to their official character, mixed usage was found.

Another difficulty was using the shortened, conversational forms of geographical place names instead of the complete forms (for instance, using Gyergyó instead of Gyergyószentmiklós, i.e. Gheorgheni in Romania). In the end, the standardised database contains the (historical) Hungarian as well as the official (administrative) place names of the visited settlements and other geographical entities.

Research findings

Nation-building strategy: the present-day political setting

In the years leading up to the fall of the socialist system in 1989-1990, a significant aspect of social and political change was the erosion of internationalist ideology and the growing emphasis on national identity (Csepeli, Gy. 1991). Solidarity with the fate of the Hungarian minorities living outside the borders, and strengthening their ties with the motherland formed the ideological cornerstone of both the party that won the first free elections in 1990 (the Hungarian Democratic Forum) and the subsequent right-wing and extreme right parties (Bárdi, N. 2008). The political elite – in cooperation with the World Federation of Hungarians – supported the social and economic progress of the Hungarian minority by various means (Székely, I.G. 2019), and travel has become an integral part of a national reterritorialisation process (Feischmidt, M. 2008). Furthermore, the cooperation between twin cities has gradually become more intensive, and the position of Hungarian-language higher education institutions was strengthened in the minority regions (Csete, Ö. *et al.* 2010).

In the meantime, due to the higher living standards, a considerable number of persons of Hungarian origin migrated to Hungary from the neighbouring countries (especially from Romania), and since they could settle down and integrate into the mainstream society easily, their example was followed by subsequent waves of friends and relatives. Since the Hungarian government intended to preserve the minority communities outside the borders (Ablonczy, B. and Bárdi, N. 2010), in doing so, a so-called 'status act' (Act LXII of 2001 on Hungarians living in neighbouring countries) was accepted in 2001 that granted various benefits and assistance (in e.g. employment, travel, culture, education, social security or health care) for those who declared themselves to be of Hungarian nationality and claimed a so-called 'Hungarian identity card'. Following the accession to the European Union, the transport infrastructure has improved, crossing the borders has become easier, which resulted in the increase of VFR tourism.

In 2003, the World Federation of Hungarians proposed a referendum in order to promote the preferential naturalization of Hungarians without Hungarian citizenship. Although in the referendum held on 5th December 2004 the majority (51.6%) of votes were cast in favour of granting dual citizenship to ethnic Hungarians living in the neighbouring countries, only 37.5 per cent of the eligible voters participated, thus the motion failed, since it had to be supported by at least 25 per cent of the electorate. The failure of the referendum and the razor-close results caused shock and disappointment among those who felt responsible for the fate of Hungarian minorities and who stood for the unity of the Hungarian nation. As an aftermath, the psychological state of the Hungarian minorities and their representatives was characterized by desperation and frustration for a long time.

The role of the 'Without Borders!' programme in achieving nation-building goals

The lessons of the failed referendum encouraged decision-makers who came to power in 2010 to use more creative measures to strengthen the sense of national identity in

the Hungarian society. Since those born after World War 2 were socialized in an educational environment where the 'Trianon issue' was suppressed and the ideology of internationalism dominated, generations grew up feeling disinterested in the fate of Hungarians living outside the borders. Considerable change in this general attitude can most probably be achieved among the youngest age groups, students of primary and secondary schools, by awakening them to the fact that the Hungarian nation is not limited to those who live in Hungary, that there are many communities outside the borders who have preserved their mother tongue, culture and traditions. The most effective way to reach this goal is through personal experiences, so the government decided to support and encourage encounters with Hungarians living in the territory of the former Kingdom of Hungary in the Carpathian Basin (Csete, Ö. 2011). A journey full of experiences, made together with one's school community, may create long-lasting memories in 13-16 years old youth. If the trip focuses on components of national identity that were previously included in lessons on history, geography, Hungarian literature, arts or music, then the participants are more likely to grow up as conscientious citizens who feel a certain sense of responsibility for the fate of Hungarian minorities outside the borders.

The programme was first announced in 2010, with the objective of giving chance to students of primary (7th grade) and secondary (3rd grade) schools to visit and to get acquainted with Hungarian communities living in the Carpathian Basin, in the hope that the personal experiences gained during these trips will be shared with the participants' friends and family, thus reducing the general ignorance about Hungarian minorities living outside the borders. (Resolution 101/2010. (X. 21.) of the Hungarian Parliament introduced the Day of National Unity, partly with the objective to establish and strengthen relations between Hungarian and trans border youth.) An additional aim of the initiative was to encourage students to later revisit these or similar areas, or return to these destinations as adults in the future (Csete, Ö. 2011). The Hungarian government supported the implementation of the programme by funding a certain number of trips each year: 177 excursions were realized in the school year of 2010/2011, and 393 trips in the school year of 2013/2014. The present study is based on the analysis of 256 journeys made by 7th grade (13-year-old) primary school groups in 2013/2014.

The application procedure as a complex orientation tool

The tender dossier of the 'Without Borders!' programme published in 2013 (BGA-13-HA-01) specified the countries eligible as destinations for state-supported school trips to Hungarian-inhabited areas. The applicants could choose all the neighbouring countries but Austria as their destination. The targeted age group was 13 years-old. However, no other restrictions were applied: the programme was open to all applicants from private or public schools, from all around the country.

In the school year of 2013/2014, 256 excursions were successfully completed. The participating schools represented 155 towns or villages in Hungary: 14.8 per cent of the participants travelled from Budapest, 18.4 per cent from major cities, 44.2 per cent from towns and 22.6 per cent from villages. Thus, most successful applicants were located in cities or towns (77.4%), which generally have more developed educational institutions with more experience or higher capacity in procuring external funding. The analysis of the regional distribution of the participating schools revealed a significant spatial imbalance within the country: while Central Hungary and Transdanubia accounted for 66–66 successful applications respectively, in Eastern Hungary this figure reached 124. This result might be explained, one the one hand, by the relatively unfavourable financial situation of the students in the economically less developed Eastern Hungary region

(they might have been more motivated to travel abroad within the framework of this programme, due to the lack of alternative options). On the other hand, the geographical location, i.e. the proximity and the accessibility of the potential destination areas might have also influenced the higher involvement of schools located in Eastern Hungary.

An important condition of successful applications was to spend at least one night in the visited country (making the programme relevant from a tourism point of view). In addition, participants were obliged to organise activities that fulfilled at least one of the following criteria: be directly connected to the students' schoolwork (1), or have an educational (2), or cultural focus (3). Furthermore, the government urged participants to take on various optional assignments that could help cultivating the relationship with Hungarian minority communities living abroad. The programme of each group had to be built in three stages: before the trip, the students participated in preparatory, motivational activities, while after the excursion, in the evolution stage they discussed their experiences and shared them with the public (usually on their school's website). The success of an application was significantly influenced by its compliance with the government's objectives of nation-building, i.e. by the extent of planning activities and ceremonies jointly organised with Hungarians living abroad. Although the timing of the trips was not determined by the tender dossier, certain dates strongly associated with Hungarian national identity were preferred, such as the Day of Hungarian Inventors (13th June), the Day of Hungarian Science (3rd November), the Day of Hungarian Culture (22nd January), and the following national holidays or remembrance days endorsed by the state:

– 6th October (Memorial Day for the Martyrs of Arad);
– 23rd October (Memorial Day of the 1956 Revolution);
– 15th March (Memorial Day of the 1848 Revolution);
– 4th June (Day of National Unity).

The spatial and temporal characteristics of the trips

Despite the fact that the tender dossier specified Ukraine as a preferred destination, the detailed analysis of the trips reveals that the majority of the participants avoided Hungary's north-eastern neighbour (which might have been related to the country's political conflict with Russia since March 2014). Romania, on the other hand, proved to be the obvious winner of the 'Without Borders!' programme, as 70 per cent of the participating schools chose the country as their destination. Slovakia was ranked second, with 22.3 per cent of the trips realised in its territory, followed by Serbia (4.7%), Slovenia (2.0%), Croatia and Ukraine (0.4–0.4%, respectively). These results are strongly linked to the geographical location of the Hungarian minority communities living outside the borders as well as the historic value and the cultural heritage of the visited regions. Practically all (99.2%) the analysed trips took place in the second semester of the 2013/2014 school year (8.7% in March, 16.2% in April, 44.8% in May and 30.3% in June) *(Figure 1).*

Following the general practice of school excursions, the organizers tended to prefer the month of May as it is near the end of the school year and is likely to provide optimal weather conditions. However, the detailed assessment of the departure dates clearly reflects the nation-building objectives of the trips. 86.5 per cent of the excursions in March were scheduled to leave between 12th and 14th March, providing participants with the opportunity to celebrate the national holiday together with the trans-border Hungarian communities. While April and May did not show any temporal concentration, 88.4 per cent of the June trips started between 1st and 4th June, in order to include the Day of National Unity in the programme.

The spatial analysis of the realised trips in two most popular target countries, Romania (*Figure 2*, a) and Slovakia (*Figure 2*, b) shows that the range of settlements visited by the participating students is extremely diversified.

Although we can identify certain concentrations in both countries, the high overall

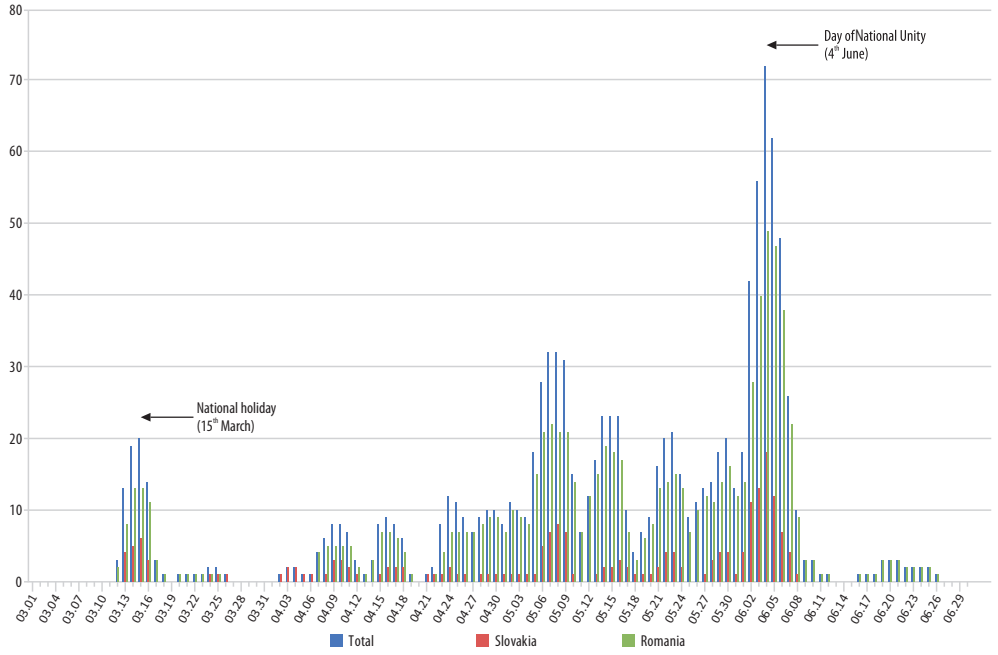

Fig. 1. Temporal characteristics of the analysed trips by calendar date. *Source*: Edited by the authors based on data collected by EMET.

number of settlements suggests that the groups made a conscious effort to optimally use the available funds and to maximise their experiences. The total number of visited places was 231 in Romania and 115 in Slovakia, while the average number of settlements visited during one trip reached 11 in Romania and 9 in Slovakia. The most popular destinations were major cities and/or places with significant cultural, historic heritage, such as Oradea/Nagyvárad (visited by 57.2% of groups travelling to the country), Cluj/Kolozsvár (56.7%) and Miercurea Ciuc/Csíkszereda (46.1%) in Romania; Rožňava/Rozsnyó (43.9%), Košice/Kassa (40.4%) and Bratislava/Pozsony (36.8%) in Slovakia.

Nation-building tourist programmes and experiences

The trips taken within the framework of the 'Without Borders!' programme helped strengthen the participants' national identity and contributed to nation-building. The programmes of the excursions generally complied with the project's objectives, and thus included various activities that could increase the value of the applications during the review process. Consequently, the trips followed a predetermined theme, the information provided was linked to the school curriculum, and the teachers used a variety of pedagogical and methodological tools to create experiences and deepen the students' knowledge acquired during their stay abroad. The programmes often included joint activities with local peers as well as initiatives to contribute to the visited community. Sharing celebrations were particularly important elements of certain trips, especially if the dates of the journey coincided with that of a Hungarian national holiday or a remembrance day.

Considering that national identity is rooted, on the one hand, in glorious historic events and personalities as well as in

Fig. 2. Romanian (a) and Slovakian (b) destinations of "Without Borders!" school trips, 2013/2014. *Source*: Edited and designed by the authors based on data collected by EMET.

past traumas and victims and, on the other hand, in nurturing the mother tongue and its dialects, preserving literary monuments and material and immaterial cultural traditions, the thematic design of the trips was also based on these values. Most of the trips had general, broadly defined themes, such as *'Searching for literary and historic facts in Transylvania'*, *'Cultural-historic adventures in Upper Hungary'*, and *'The relationship of the natural and the built environment'*, in order to comply with the requirements and, at the

same time, preserve a certain degree of flexibility in planning the itinerary and the activities. However, many historic and cultural figures[4] were also highlighted in the themes: icons whose lives and activities were strongly connected with areas outside the current Hungarian borders. Only a relatively small number of trips had an explicitly national identity-building theme (e.g. *'Joint celebration of national unity – forming a responsible community'*) or an overtly religious theme (e.g. *'Exemplary co-existence: religious diversity in Transcarpathia'*).

A classification of the activities described in the trip reports reveals that visiting historic and cultural sites (such as battlefields, birthplaces, cemeteries), sacred places (churches, pilgrimage sites), and the frontiers of historical Hungary were included in almost every excursion (in 255 out of 256). In addition, meeting Hungarian-speaking peers, joining classes in the local schools, sharing meals, participating in cultural events, singing and dancing were also essential elements of the programmes (245/256). Forest hiking, climbing, caving and walking also had an important role (209/256). The participants also tried to find ways to contribute to the local community e.g. by gardening, cleaning or giving gifts (181/256). Doing sports together, especially playing football, was also reported as a popular activity (119/256), however, joint celebrations with trans-border Hungarians were less common (85/256).

[4] Among others: Árpád, leader of the Hungarian tribes who conquered the Carpathian Basin in the 9th century and founder of the House of Árpád (895–1301); Saint Ladislaus I of Hungary (1040–1095); János Hunyadi, general and governor, leading commander against the Ottoman army (1407–1456); Matthias I, a renaissance king and a popular hero of Hungarian folk tales (1443–1490); Prince Ferenc Rákóczi II, leader of the 1703–1711 uprising against the Habsburgs (1676–1735); Sándor Petőfi, poet, one of the key figures of the 1848–1849 revolution against the Habsburgs, who died in the battle of Sighişoara/Segesvár (1823–1849); Kálmán Mikszáth, novelist, journalist and politician from Upper Hungary (1847–1910); Áron Tamási, Transylvanian novelist (1897–1966); János Bolyai, mathematician, one of the founders of non-Euclidean geometry (1802–1860).

The analysis of the various activities described in the trip reports resulted in the following classification of the core components of the students' memorable experiences: the conscious appreciation of Hungarian identity (A), the excitement of their first trip abroad (B), and the expression of joy of being in a community (C).

A) During the trips, the participants had the opportunity to experience and to consciously reflect on Hungarian identity on many different occasions. Meeting Hungarians living outside the borders and spending time in a Hungarian-speaking environment increased the students' awareness of a greater national-cultural community. This experience was further reinforced by following the footsteps and encountering the heritage of icons and symbols of Hungarian history and culture 'abroad'.

"It was a great experience that everybody was happy to speak in Hungarian with the children." (HAT/198/2014, trip made from Lepsény to Slovakia.)

B) Most of the participants could also enjoy the excitement of their first tourist experience. Some students had never travelled before, so for them this trip was the first step into the world of tourism, while for many others this was their first international journey, and crossing a border and spending time abroad were the factors that made the excursion truly memorable (during the analysed period, Slovakia and Slovenia were already members of the Schengen Area, but as the analysis of the trip reports indicates, even crossing an 'invisible' border was seen as an adventure by many students).

"For most of us this was the first chance to leave our country, thus crossing the border was a big experience for us." (HAT/103/2014, trip made from Gyomaendrőd to Slovakia.)

C) All the participants could benefit from the joy of community life. Casual encounters outside the classroom, the birth of new friendships or the deepening of existing ones, participating in shared activities, sports, games, meals, social work or giving gifts all contributed to experiencing positive feelings among the students.

"We were really happy to give gifts to poor children. They were almost in shock of joy and we also felt the same as we saw the light in their eyes." (HAT/27/2014, trip made from Hódmezővásárhely to Romania.)

The three types of experiences strengthened each other in a synergic manner, and together led to reinforcing and intensifying the students' sense of national identity. Sharing them with one's friends and family as well as disseminating them in the form of jointly designed websites also helped in creating long-lasting impressions and memories.

Conclusions

The end of the socialist regime in 1989–1990 brought about significant changes in the relationships between the mother nation and the Hungarian communities living outside the country's borders. The partly concealed, predominantly culture- and education-oriented dialogue of the previous decades was gradually replaced by a publicly voiced intent of political and legal relations with the mother country. The increasing political engagement of the Hungarian state with the Hungarian communities located beyond the borders, based on the earlier repressed principles of national solidarity and responsibility for the fate of minorities, included supporting ethnic Hungarian political parties in the neighbouring countries, encouraging different levels of autonomy aspirations, assisting the development of higher education institutions and study programmes in Hungarian language, and granting dual citizenship to persons of Hungarian origin.

However, the reception of the government's national policy aiming to create a trans-border sense of cohesion was ambiguous in the mother country, particularly with regard to the preferential granting of citizenship and the subsequent ability of non-residents to vote in the Hungarian elections. It was thus realised that deeper changes in the Hungarian population's inherited attitudes concerning national identity and kinship with communities living beyond the borders could only be achieved gradually, through the education of young generations. Since personal experiences may powerfully affect one's beliefs and attitudes, organised school trips offering personal encounters with Hungarians living outside the country were expected to contribute to a stronger sense of national cohesion and identity among the future generations, enhancing their adherence to the government's political commitment to minorities.

The 'Without Borders!' programme was launched by the Hungarian government to give students of public education a chance to visit Hungarian territories outside the borders within the framework of state-sponsored school trips. The aims of the project were clearly defined: creation and strengthening of national identity in 7th grade primary school students and 3rd grade secondary school students. The programme urged the implementation of activities that directly promoted the awareness of national unity. Most of the participants of the programme chose Romania, more precisely Transylvania as their destination, a region that has the largest population of Hungarian minority and is rich in Hungarian historical and cultural monuments. The settlements visited during the supported school trips were iconic pilgrimage sites of Hungarian culture. The journeys were scheduled throughout the spring semester, with a temporal concentration around politically and culturally important dates such as the 15th March national holiday and the 4th June remembrance day of National Unity. The organised activities and the consequent experiences were considerably pre-determined by the tender dossier, providing the participants with a wide range of opportunities to appreciate national identity. Sharing these experiences with their classmates in a foreign country, and later with their friends, family and the public, contributed to the development of memorable experiences.

Due to the fact that the educational tourism-related activities of adolescents are a

significantly underrepresented topic in the international literature, the findings of this paper have contributed to filling an existing gap. Although the analysis of trip reports submitted in one single year does not allow us to conclude whether the 'Without Borders!' programme is an effective tool in achieving long term national policy objectives, the results suggest that sharing celebrations of national holidays and memorial days as well as visiting settlements related to iconic figures of Hungarian culture, science and history promoted Hungarian consciousness among the participants. Whether the trips made by the investigated school groups into Hungarian territories outside the borders indeed brought about long term changes in their sense of national identity would require repeat studies focusing on the same sample. However, this would only be possible with the active involvement of both EMET and the students in question. Since the original reporting framework was not created with a follow-up study in mind, a mostly qualitative methodology could be used to compare, on the one hand, the participants' post-trip perceptions on the visit's impact on their national identity with their current attitudes and, on the other hand, their levels of acknowledgement, then and now, of the minority communities' role in the development of Hungarian culture. Complemented by a quantitative component to register any further visits following the first study trip to Hungarian territories outside the borders, a more complex and more accurate picture could be created concerning the effectiveness of national identity development through school trips.

It has been acknowledged since the early ages of scientific tourism research that the tourism system exists in a complex environment and its development is heavily influenced by a wide range of factors including politics. The political environment's impacts may be observed in a variety of shapes including, among others, state ownership of tourism facilities, national development plans and marketing campaigns, visa systems, travel warnings, exchange rate manipulations, or providing holiday opportunities for disadvantaged social groups via social tourism. However, the political environment generally influences the tourism phenomenon in an indirect, regulatory manner, based on predominantly economic considerations, by limiting the state's involvement to providing the necessary framework which, in turn, may affect individuals' travel behaviour. The intention or actual practice of ideological influence on the tourism system is usually found in societies where consumer behaviour is perceived as a moral or political act – such as in the former socialist countries –, and the state considers its mission to educate its citizens to ensure their 'correct' attitudes, behaviour and identity (e.g. in the case of pioneer camps, the World Festivals of Youth and Students organised since 1947, or the current development of 'red tourism' in China).

Generally, participation in tourism is considered a leisure activity as well as a contribution to economic development, and the indicators of success are e.g. guest nights, per capita spending or occupancy rates. Although many countries seem to promote staycations and domestic tourism as a special form of patriotism, these campaigns are also usually built on financial arguments. In the case of the 'Without Borders!' programme however, ideological principles were given priority over economic considerations, and the fact that adolescents, an especially sensible social segment, were involved, made the project particularly relevant for further investigation. As the findings confirmed, the political influence was indeed observed in the preparatory phase of the trips as the itineraries and programmes complied to a high extent with the project's requirements, thus making the feeling of national unity a crucial element of the students' memorable tourist experience.

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REFERENCES

Ablonczy, B. and Bárdi, N. 2010. Határon túli magyarok: mérleg, esély, jövő (Hungarians abroad: balance, chance, future). In *Határon túli magyarság a 21. században*. Ed.: Bitskey, B., Budapest, Köztársasági Elnöki Hivatal, 9–32.

Abubakar, A.M., Shneikat, B.H.T. and Oday, A. 2014. Motivational factors for educational tourism: A case study in Northern Cyprus. *Tourism Management Perspectives* 11. 58–62.

A. Gergely, A. 2012. Hazatérések: nemzeti integráció, önazonosság, identitáspolitika egység és különbség erőterében (Returns: national integration, identity, identity policy in the power of unity and difference). *Múltunk* 57. (4): 6–19.

Altinay, L. and Bowen, D. 2006. Politics and tourism interface: The case of Cyprus. *Annals of Tourism Research* 33. (4): 939–956.

Arcodia, C. and Dickson, C. 2009. ITHAS: An experiential education case study in tourism education. *Journal of Hospitality and Tourism Education* 21. (1): 37–43.

Arcodia, C. and Dickson, C. 2013. Tourism field studies: Experiencing the carnival of Venice. *Journal of Hospitality & Tourism Education* 25. (3): 146–155.

Ayalon, Y. and Schnell, I. 2014. German youth educational travel to Israel. *Journal of Hospitality & Tourism Education* 26. (4): 188–197.

Bárdi, N. 2008. A budapesti kormányzatok magyarságpolitikája 1989 után (National politics of Budapest governments after 1989). In *Kisebbségi magyar közösségek a 20. században*. Eds.: Bárdi, N., Fedinec, Cs. and Szarka, L., Budapest, MTA Nemzeti és Etnikai Kisebbségkutató Intézet – Gondolat Kiadó, 368–375.

Bhandari, K. 2014. *Tourism and National Identity – Heritage and Nationhood in Scotland.* Clevedon, Channel View Publications.

Boluk, K. and Carnicelli, S. 2015. Activism and critical reflection through experiential learning. *Journal of Teaching in Travel & Tourism* 15. (3): 242–251.

Boyle, A., Wilson, E. and Dimmock, K. 2015. Transformative education and sustainable tourism: The influence of a lecturer's worldview. *Journal of Teaching in Travel & Tourism* 15. (3): 252–263.

Brien, A. 2011. *The Politics of Tourism Development – Booms and Busts in Ireland*. London, Palgrave MacMillan.

Burns, P. and Novelli, M. 2007. Tourism and politics: Introduction. In *Tourism and Politics – Global Frameworks and Local Realities*. Eds.: Burns, P. and Novelli, M., Oxford, Elsevier, 1–4.

Csepeli, Gy. 1991. Competing patterns of national identity in post-communist Hungary. *Media, Culture & Society* 13. (3): 325–339.

Csete, Ö. (ed.) 2011. *Határtalanul! – Nemzeti összetartozás az oktatásban* (Without borders! – National cohesion in the education). Budapest, A Határon Túli Magyar Oktatásért Apáczai Közalapítvány.

Csete, Ö., Papp, Z.A. and SeténYi, J. 2010. Kárpát-medencei magyar oktatás az ezredfordulón (Hungarian education in the Carpathian Basin at the turn of the millennium). In *Határon túli magyarság a 21. században*. Ed.: Bitskey, B., Budapest, Köztársasági Elnöki Hivatal, 125–165.

De Cantis, S., Parroco, A.M., Ferrante, M. and Vaccina, F. 2015. Unobserved tourism. *Annals of Tourism Research* 50. 1–18.

Drozdzewski, D. 2011. Language tourism in Poland. *Tourism Geographies: An International Journal of Tourism Space, Place and Environment* 13. (2): 165–186.

Erőss, Á. and Tátrai, P. 2010. Ethnic features of symbolic appropriation of public space in changing geopolitical frames: the case of Oradea/Nagyvárad. *Hungarian Geographical Bulletin* 59. (1): 51–68.

Falk, J., Ballantyne, R., Packer, J. and Benckendorff, P. 2012. Travel and learning: A neglected tourism research area. *Annals of Tourism Research* 39. (2): 908–927.

Feischmidt, M. 2008. The Hungarian Transylvania: Symbolic reconstruction of lost territories. *Hungarian Studies* 22. (1–2): 119–133.

Fonseca, F. and Ramos, R. 2012. Heritage tourism in peripheral areas: Development strategies and constraints. *Tourism Geographies* 14. (3): 467–493.

Fründberg, L. 2010. Activities and activity patterns involving travel abroad while growing up – The case of young Swedes. *Tourism Geographies* 12. (1): 110–117.

Gerner, K. 2007. Open wounds? Trianon, the Holocaust, and the Hungarian trauma. In *Collective Traumas. Memories of War and Conflict in 20th-Century Europe*. Eds.: Mithander, C., Sundholm, J. and Holmgren Troy, M., Brussels, P.I.E. Peter Lang, 79–110.

Harris, J., Lee, S. and Lepp, A. 2012. England, Whales, and Princess Diana – A case study of US students' perceptions of Wales. *Journal of Hospitality, Leisure, Sport and Tourism Education* 11. (2): 87–92.

Hollinshead, K. 2009. 'Tourism state' cultural production: The re-making of Nova Scotia. *Tourism Geographies* 11. (4): 526–545.

Horváth, A. 2015. A nemzeti identitásturizmus kreativitásigénye (The need for creativity in national identity tourism). In *Kreativitás és innováció a turizmusban*. Eds.: Rátz, T. and Michalkó, G., Székesfehérvár–Budapest, Kodolányi János Főiskola, 151–167.

Huang, R. 2013. International experience and graduate employability: Perceptions of Chinese international students in the UK. *Journal of Hospitality, Leisure, Sport and Tourism Education* 13. (1): 87–96.

Ilyés, Z. 2006. Researching and interpreting diaspora. – Remarks on social science research into the diaspora communities of the Carpathian Basin. In *Perspectives of Diaspora Existence. Hungarian Diasporas in the Carpathian Basin – Historical and Current Contexts of a Specific Diaspora Interpretation and its Aspects of Ethnic*

Minority Protection. Eds.: Balogh, B. and Ilyés, Z., Budapest, Akadémiai Kiadó, 45–63.

Irimiás, A. 2013. Traveling patterns of Chinese immigrants living in Budapest. *Journal of China Tourism Research* 9. (2): 180–190.

Juvan, E. and Lesjak, M. 2011. Erasmus exchange program: Opportunities for professional growth or sponsored vacations? *Journal of Hospitality & Tourism Education* 23. (2): 23–29.

Kask, S. 2011. Modeling tourist and community decision making. The SAVE model. *Annals of Tourism Research* 38. (4): 1387–1409.

Klooster, E., Wijk, J., Go, F. and Rekom, J. 2008. Educational travel: The overseas internship. *Annals of Tourism Research* 35. (3): 690–711.

Kocsis, K. 2013. Historical predecessors and current geographical possibilities of ethnic based autonomies in the Carpathian Basin. *Hungarian Geographical Bulletin* 62. (1): 3–46.

Kocsis, K. and Kocsis-Hodosi, E. 1998. *Ethnic Geography of the Hungarian Minorities in the Carpathian Basin*. Budapest, Geographical Research Institute, Hungarian Academy of Sciences.

Kocsis, K. and Tátrai, P. 2012. *Changing Ethnic Patterns of the Carpatho-Pannonian Area.* Budapest, Geographical Institute, Research Centre of Astronomy and Earth Sciences, Hungarian Academy of Sciences.

Kovács, Z. 1989. Border changes and their effect on the structure of Hungarian society. *Political Geography Quarterly* 8. (1): 79–86.

Kövecsesné Gősi, V. 2009. Az erdei iskola a környezeti nevelés szolgálatában (Forest school for environmental education). *Iskolakultúra* 19. (5–6): 3–10.

La Placa, V. and Corlyon, J. 2014. Social tourism and organised capitalism: Research, policy and practice. *Journal of Policy Research in Tourism, Leisure and Events* 6. (1): 66–79.

Liang, K., Caton, K. and Hill, D.J. 2015. Lessons from the Road: Travel, life-wide learning, and higher education. *Journal of Teaching in Travel & Tourism* 15. (3): 225–241.

McLaren, L. 2004. Opposition to European integration and fear of loss of national identity: Debunking a basic assumption regarding hostility to the integration project. *European Journal of Political Research* 43. (6): 895–911.

Michalkó, G. and Rátz, T. 2013. Rejtett dimenziók a Kárpát-medence turizmusában (Hidden dimensions of tourism in the Carpathian Basin). In *Kárpát-medence: természet, társadalom, gazdaság*. Eds.. Frisnyák, S. and Gál, A., Nyíregyháza–Szerencs, Nyíregyházi Főiskola, Turizmus és Földrajztudományi Intézet – Bocskai István Gimnázium, 463–476.

Morgan, N. and Pritchard, A. 1998. *Tourism, Promotion and Power: Creating Images, Creating Identities*. Chichester, Wiley

Mosedale, J. (ed.) 2011. *Political Economy of Tourism*. Oxon, Routledge.

Orpett Long, S., Akande, Y.S. and Purdy, R.W. 2010. Deepening learning and inspiring rigor: Bridging academic and experiential learning using a host country approach to a study tour. *Journal of Studies in International Education* 14. (1): 89–111.

Palmer, C. 1999. Tourism and the symbols of identity. *Tourism Management* 20. (3): 313–321.

Pap, Sz. 2013. *Encountering the nation beyond borders – Hungarian secondary school students, tourism and the micromanagement of nation-building*. Unpublished MA thesis. Budapest, Central European University.

Park, H. 2010. Heritage tourism: Emotional journeys into nationhood. *Annals of Tourism Research* 37. (1): 116–135.

Pender, L. and Sharpley, R. 2005. *Management of Tourism*. London, Sage.

Pitchford, S. 2008. *Identity Tourism – Imaging and Imagining the Nation*. Bingley, Emerald.

Pitman, T., Broomhall, S., McEwan, J. and Majocha, E. 2010. Adult learning in educational tourism. *Australian Journal of Adult Learning* 50. (2): 219–238.

Peters, K. 2011. Negotiating the place and 'placement' of banal tourist souvenirs in the home. *Tourism Geographies* 13. (2): 234–256.

Pretes, M. 2003. Tourism and nationalism. *Annals of Tourism Research* 30. (1): 125–142.

Sanders, D. and Armstrong, E.K. 2008. Understanding tourists' perceptions and experience of a tourism management field trip: The need for a graduated approach. *Journal of Hospitality & Tourism Education* 20. (4): 29–37.

Sasse, G. 2008. The politics of EU conditionality: The norm of minority protection during and beyond EU accession. *Journal of European Public Policy* 15. (6): 842–860.

Silva, L. and Leal, J. 2015. Rural tourism and national identity building in contemporary Europe: Evidence from Portugal. *Journal of Rural Studies* 38. 109–119.

Székely, I.G. 2019. Mobilizing strategies of Hungarian minority parties in Romania, Serbia and Slovakia. In *Populism, Memory and Minority Rights: Central and Eastern European Issues in Global Perspective*. Ed.: Bíró, A-M., Leiden, Brill-Nijhof, 145–185.

Tarrant, M.A., Stoner, L., Borrie, W.T., Kyle, G., Moore, R.L. and Moore, A. 2011. Educational travel and global citizenship. *Journal of Leisure Research* 43. (3): 403–426.

Xu, K. 2015. Types of red tourists in China: Evidence from Shaoshan. *Annals of Tourism Research* 51. 51–63.

Yang, L. and Wall, G. 2009. Ethnic tourism: A framework and an application. *Tourism Management* 30. (4): 559–570.

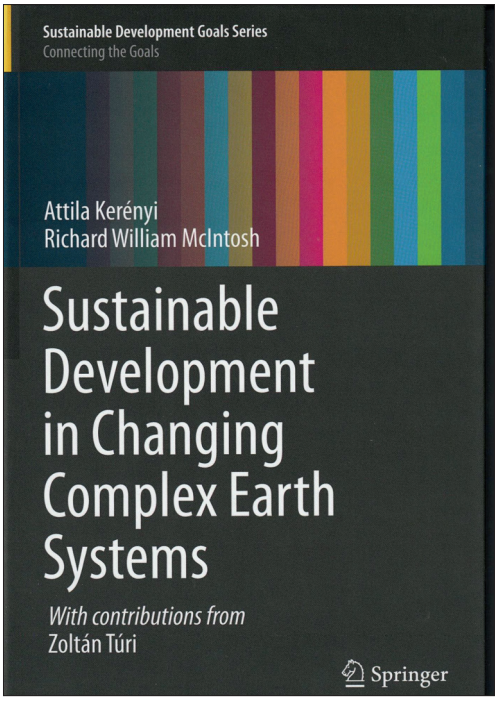
Young, C. and Light, D. 2001. Place, national identity and post-socialist transformations: An introduction. *Political Geography* 20. (8): 941–955.

Zuo, B., Gursoy, D. and Wall, G. 2017. Residents' support for red tourism in China: The moderating effect of central government. *Annals of Tourism Research* 64. 51–63.

BOOK REVIEW SECTION

Kerényi, A. and McIntosh, R.W.: Sustainable Development in Changing Complex Earth Systems. Springer, Cham, 2020. 292 p.

Extracting and collating relevant information from the vast amount of knowledge revealed by science is the key to ensure the sustainability of human-influenced future. The Sustainable Development Goals (SDGs), formulated as part of the 2030 Agenda for Sustainable Development, identify 17 focus groups – sets of challenges – across different disciplines. Springer has organised a series of publications around these 17 major topics, dedicated 17+1 subseries to them. As part of the Sustainable Development Goals Series the global processes are measured by means of general system theories in this book. The foreword by Dénes Lóczy (University of Pécs, Hungary) reminds the reader of the fundamental problems of the terrestrial environment and of conflict situations resulting from the activities of human society which significantly shape the chances for sustainable sevelopment.



The purpose of the authors, Attila Kerényi and Richard William McIntosh (University of Debrecen, Hungary), is to introduce and systematise all factors (geographical, environmental, social, economic and geopolitical issues) influencing sustainable development. The book summarises in seven chapters the state of knowledge using system theory tools and provides a clear logical approach to the background of the present environmental, geographical, socio-economic and geopolitical state of the world. In addition to examining the status quo based on the interactions between society and environment, it also presents the international trends of development. When they describe and explain relevant processes, the authors move a step back and examine the same processes from a distance. They clearly present their personal point of view in a number of topics throughout the work and often point out essential shortcomings in the internationally accepted views on global trends as well.

Chapter 1 explores both the process of the changing terrestrial environment and the historical evolution of the sustainable development concept. It provides a comprehensive picture of the geopolitical and economic efforts and achievements of global institutions such as the World Committee on Environment and Development of the United Nations (UN) that have achieved a major shift in social and economic attitudes along globalisation trends and have pushed long-term economic development processes in a more positive direction towards sustainable progress.

Chapter 2 introduces in detail and in a textbook style General System Theory and its applicability to better presenting and understanding Global Earth Systems. This chapter is not just a summary for professionals familiar with system theory. In addition to providing definitions, the necessary mathematical contexts, examples of the operation of systems is highlighted to illustrate the basic system theory principles needed for a comprehensive understanding the oncoming chapters of the book (classification, topology, system models and model making, Earth models). It describes different types of Earth Models, such as the PREM Model, Global Climate Simulation Models, GAIA, the "World Models", the Models of the Global Human Society, without discussing the deeper mathematical and physicochemical relationships in detail. Supplemented with explanations in the text, the illustrations in this chapter are easy to comprehend. Complex topics are presented in a clear language to the reader.

In chapters 3–5, using system theory, the book provides the subsystems that make up Global Earth Systems, their processes as well as the operation of the social and political systems that control them. Chapter 3 focuses exclusively on the presentation of impact processes in the geosphere, manifested by a few widely-known events (natural catastrophes) in the past, along with the effects of the impact processes originating from the geosphere hotspots. This chapter concludes with the theory presented by authors that post-disaster reconstruction entails the potential for sustainable development. It would be interesting as well to present a systematic examination of this theory – similarly to other cases treated in the book – so that the audience can gain a deeper insight into the motivations of the actors involved in the reconstruction works and what kind of influence they have on the processes of implementation of the relevant SD tools. Chapters 4 and 5 introduce and examine the internal processes of the Global Environmental System based on physical and chemical principles in different spheres along with the effects that determine human interactions in global and local human communities (Anthroposphere).

Subchapter 4.1.1, written by McIntosh, displays the general internal changes caused by natural and anthropogenic processes in the crust. It discusses the physical effects caused by energy and raw material demand, as well as the main cross-system processes (e.g. CO_2 emissions, acid rain, deforestation and groundwater overuse) between spheres induced by the extraction of raw materials through the example of major fuels (coal, natural oil, gas and uranium) and key industrial feedstock (minerals of modern technology). Each subchapter describes the main geopolitical and economic background and driving forces as well.

The following subchapters analyse, from the viewpoint of General System Theory, the material flows of a population, the expected population growth and, as a consequence, the negative interactions and conflicts between the shrinking natural environment and the expanding built environment, such as loss of territory or loss of ecological corridors which maintain landscape connectivity. It is claimed that the tendency of spatial evolution of human society is clearly recognisable: based on infrastructural and economic factors „cities became a dominant place of life and their significance will only rise". These will lead to a range of conflicts since urban infrastructure cannot be expanded further and badly needed sustainable solutions (appropriate sewage treatment and green areas, overloaded traffic infrastructure indicated air pollution and noise loads) will not be found within such a short time. Afterwards the reader receives abundant information on the evolution of the sustainable development approach in cities, mentioning the background institutions and international associations, civil engagement which provide a platform for good practices to increase the liveability of settlements.

In subchapter 4.2, with the tools of system theory, authors describe soil degradation as a result of multiple anthropogenic impacts and the principle environmental problems induced by intensive agriculture. System diagrams illustrate the processes that exceed the primary systems. The author mentions the problems of intensive animal farming, leaching and acidification of soils and the use of wide-range pesticides, describes the material flows, but does not consider water demand in the study of material flows (Figure 4.4), despite the fact that one of the fundamental issues of intensive plant cultivation and cattle breeding is sustainable water use. (In other contexts, however, water issues are mentioned in subchapter 4.3.) Subchapters 4.4 and 4.5 focus on human-induced changes in the carbon cycle and on its inevitable consequences on climate change. It informs about the changes in biodiversity during the five most significant periods of extinction of the geological history, and cites the results (Living Planet Index) of WWF's observations of recent times. The book also tackles geographically large-scale changes e.g. loss of vegetation cover (deforestation), vanishing coral reefs through oil and chemical pollution, increasing water temperature and physical destruction, and provides detailed information on the efforts towards biologically sustainable fishing. A significant part of these regional changes are the result of anthropogenic modifications in the atmosphere associated with increased concentrations of greenhouse gases. Kerényi presents the development of global climate models; the IPPC's efforts to provide a broad, detailed multidisciplinary process review, as well as a very topical issue: the economically generated geopolitical aspirations of new resource-rich areas made accessible by climate change.

Although authors examine Earth-scale models, in order to illustrate the impact processes, several examples are listed from around the world. Amongst the international cases, it would be interesting for the Hungarian reader to learn about positive examples from Hungary, such as the good practice of Pécs city creating a low traffic and partially strict pedestrian zone in the entire city centre, which was a progressive local measure to improve air quality and quiet area similar to those cited for New York, London, Sydney and Vancouver.

In Chapter 6 the various SDGs related to proposals for solutions based on geopolitical conventions of the UN and engagement are outlined. A number of significant goals and their feasibility are discussed, e.g. renewing education, sustainable economic growth, decreasing inequalities, making peace among different religious and cultural civilisations. Besides this, the main issues are highlighted in a more complex view (in subchapter 6.7), in which the essential approaches are discussed in the context of the predictable evolution scenarios of human society. Authors devote a separate chapter to the description of the

Theory of the "Second Curve" as the development scenario of human society, as well as to the favourable globalisation of higher education through open online courses and to the achievements of Meadows and his research team (Massachusetts Institute of Technology) in the field of establishing SD criteria in the early 20th century. In addition, the possible development paths and their general criteria, shortcomings and the remaining (quite a few) unresolved issues, such as stabilising population growth are also highlighted.

The Conclusions (Chapter 7) focuses on these unresolved problems. By examining the 17 areas of acting identified by UN regarding the 2030 Agenda for Sustainable Development, it points out the shortcomings of systems and institutions needed for implementation, the inherent and human-based weaknesses, and the conflicts of interest of relevant actors. Authors see the potential for advancing local and regional solutions of problems arising from social differences and inconsistencies in religious and political views. They use the "Think global, act local" approach repeatedly in their suggested solutions, but they fail to provide a real solution either. They also observe sceptically the real long-term benefits of increased global connectivity and stability, and, in general, the long-term sustainability of the current globalised system. The chapter concludes that humanity, despite technological evolution, cannot neglect the continuous development of the individual through an advanced education system. It shows that speeding up environmental and social changes leads to accelerated changes in the probability and risk severity top charts of threats – presented in Tables 7.1 and 7.2 as results of World Economic Forum's risk assessment –, meanwhile the speed of problem recognition cannot keep pace which makes adequate intervention difficult. It proves, that the technocratic approach alone does not respond to the negative processes of the late 21st century, but it can also result in significant, unpredictable social changes, to the realisation that small achievements in different areas are important but might not be sufficient for an effective global solution.

The book itself is structured proportionately as regards topics and navigates easily between subchapters. The size of the figures, tables and pictures does not hinder their interpretation, and the references to them are correct. The experience of reading is enhanced by the application of grey-coloured boxes that supply easy-to-understand, actual background information from context, providing examples and insights from public life that are related to the topic of the chapter.

The relevance of the book is confirmed by the enumeration of the conventions and institutions that have emerged in recent decades as a result of the global economic and world political endeavours also presented in the book. The most important ones, such as the Brundtland Report and IPPC, appear repeatedly in the relevant chapters, not only as mentions, but adequately explained in each chapter. This increases both the general readability of the book and the understanding of finer details.

Based on the above remarks, this book is well suited for shaping the attitudes of diverse expertise of the thematic areas of sustainable development. In addition, it can be used as a widely disseminated educational material in higher education, since it summarises the knowledge of certain disciplines, and encourages the reader to synthesise and to disclose the relationships between them. You should not be an expert in every subject to understand the essential messages of the book, because it is logically well structured and presents all required information from a wide range of areas of expertise. The system processes presented through widely known examples encourage the reader to think beyond and may induce excellent discussions between experts.

The opinions and remarks of the authors emphasise the importance of Sustainable Development Goals implementation throughout the book, while consistently advocating the importance of peaceful solutions and tackling social inequalities.

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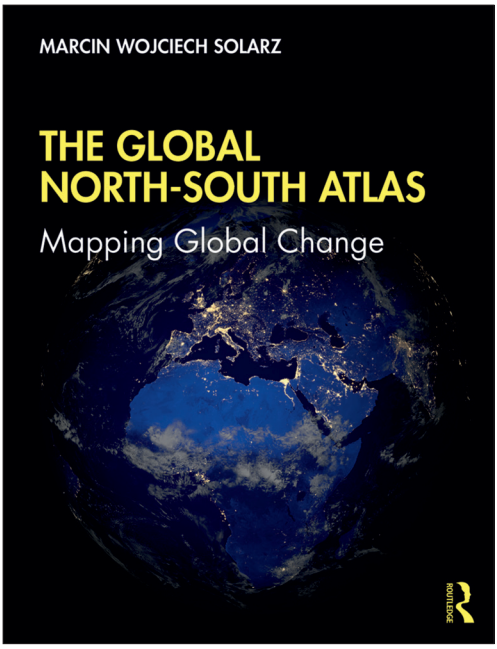
Solarz, M.W.: The Global North-South Atlas. **Mapping Global Change.** Routledge, London, 2020. 167 p.

People are constantly categorising to make it easier to navigate the world. Nevertheless, there are several problems with social categories (Alex Gillespie, A. *et al*. 2012): rigid boundaries and reifications can make human-aggregates real and endows with an ability to act for a long time, while they are often just imagined communities. Not only societal but also space division and categorisation is a significant characteristic of humanity. The most obvious result of this phenomenon is the nation-states' borders clarity visible on the political map of the world. Social scientists have many problems with ossified borders: thinking in nation-states creates a methodological nationalism (Wimmer, A. and Schiller, G.N. 2002) that can enclose research and shift results in one direction. In addition to that, different manners of dividing the globe can create rigid boundaries also. Besides, simplifications in the division of space construct binary oppositions such as North-South, poor-rich, East-West distinctions. This book critiques these simplifications, contextualises and modulates the problem of what humanity thinks of development, progression, and well-being.

The book's chapters are organised around the topics of geography and development, the global North-South disparities, and the author endeavours to visualise global inequalities on world maps. They appear in a total of 121 different charts and maps.



The volume was published by Routledge in 2020 by Marcin Wojciech Solarz, an associate professor at the University of Warsaw, Faculty of Geography and Regional Studies. Solarz's major research topics are related to political and development geography, his prior book (*New Geographies of the Globalised World*) is also discussed global development issues (Solarz, M.W. 2018a).

The book's basic premise is that of all the attempts to divide the world based on development, the so-called Brandt Line (boiled down to the 1980 Brandt Report) remains the most enduring and continues to influence our thinking about the world. In this book, Solarz does not focus on presenting the Brandt Report; others have already done so (Williams, G. 1980; Wionczek, S.M. 1981), but instead, tries to outline the international context of the Report while also paying attention to political and personal motivations. After depicting the Brandt Line for the reader, he introduces its misleading nature deploying new aspects and indicators. With the help of the new indices, he presents a plethora of maps on many aspects of development utilising the most recent data.

The Introduction (*The Brandt Line: Political or Developmental Boundary*) provides useful ideas on how the Brandt Report has been evolved and has been received. The Report and the boundary between global South and North named after the German politician, Willy Brandt, was criticised at the time of its creation. Despite this fact, the Brandt Line has become the most typical and well-known representation of the global developmental divide on map. There has been an abundance of reproduction, it was picked up by the media, due to – among other reasons – the fact that maps are highly regarded and seemed neutral while conveyed complex knowledge. It lent trustworthiness and reliability to this division. This special status may have arisen because maps present information clearly and unambiguously. However, Solarz claims that the Brandt Line was much more political than a developmental boundary and he provides arguments for this as well. The 'northern club' has the members of NATO (without Turkey), the Warsaw Pact, the Pacific Security Treaty (ANZUS) and the US-Japan security treaties, while the global South is the rest. But if it is approached from a political-civilisational perspective, it can be noticed that the 'successful' European and Anglo-Saxon dominance (plus Japan) is considered to be the opposite of the rest of the world.

The author does not forget about the human factor either. He points out that most of the participants in the Brandt Commission came from the political sphere. These people had ethnical, political, philosophical, personal, etc. background which affected the Report as well.

An important part of the *Introduction* is the Cold War confrontation and its spatial impact on a global scale: East-West dichotomy. Solarz finds many similarities between the philosophy of the East-West and North-South subdivision, and the Brandt Line is, in fact, "a political relic of the Cold War period" (Solarz, M.W. 2020, 9). In its time, the birth of the Brandt Line was influenced by the power of novelty as it began to put an end to the hegemonic East-West opposition, furthermore it supported Willy Brandt's *Ostpolitik*, weakening the Iron Curtain in Europe.

The author deals with the international interest in developmental boundaries preceding the Brandt Report, from the Sauvy Line (1961) to the Wolf-Philips Line (1979), and places these on maps and graphs. The graphs linked to the Introduction clearly show that while the world has universally become richer (1960–2017), but the gap between the poor and the rich has steadily increased. The most important milestones of development research and long-term socio-political trends, such as the Afro-Asian decolonisation wave and the Cold War, are also represented in the graphs.

While analysing the perceptions of the Brandt Line and putting it into context, Solarz points out that it seemed obvious that the synergy among the industrial revolution, population explosion, and globalisation (geographical proximity) has created an unprecedented interest in the rift between the world of the rich and the poor. However, the hope that the underdeveloped countries could break out of their situation was increasingly diminishing, so their status seemed to be congealed. Following the dissolution of the Second World by 1993 the world political map had stabilised. The position of the newly formed countries in the development map of the world had to be also redefined (Quilligan, J.B. 2002). A "new Brandt Line" was demanded, thus the 1980 line could be slightly modified. This also confirmed that the division is acceptable, but the boundary between North and South can be flexible.

Most of the maps can be found in the chapters following the Introduction. Each map is accompanied by a detailed explanatory description along with the map legend, but the skilled eye will find plenty to analyse by scrutinising the maps. According to the author these maps "enable a multifaceted and multidisciplinary analysis of the international situation, including the composition and organisation of the international community. They can form the basis for analysing changes in both political and the socio-economic order" (Solarz, M.W. 2020, 32).

The *Mapping Global Change* chapter introduces the differences in development and wealth from the 1st to the 21st century. Spatial representation provides an opportunity for analysis over time. Historical GDP data are retrieved from Angus Maddison's database (Maddison, A. 2010), allowing the reader to compare the economic development of regions in the ancient, medieval, and modern worlds. The author also faced the problem that the borders of empires, regions, and countries had changed throughout history. The Polish writer demonstrates this in the example of Poland since the Polish territories used to belong to several countries. Therefore, geographical regions change over time, but for the sake of comparability, Solarz always uses only one specific global division in each map series. The first series of maps spans the longest time horizon, depicting 13 countries and regions between 1 A.D. and 2008. It shows the recent state borders for the sake of clarity and aggregates them into regions adapted to historical times. These areas are: Western Europe; Central Europe; Former USSR countries; Western Offshoots (Australia, Canada, New Zealand, USA); China; Japan; India-Pakistan-Bangladesh; Other Asia (Middle East, South-East Asia, Mongolia, Korea, Nepal, Bhutan); Egypt; North Africa; Sahel and West Africa; Other Africa (mainly Sub-Saharan Africa) and Latin America.

The superiority of India and China in the Ancient and the Middle Ages is visible on the maps, added these old empires to 'Other Asia', the economic superiority of Asia is unquestionable at that time.

Analysing the second series of maps we can witness the progressive enrichment of the world. Solarz always adjusts the regions to the start-up period, to indicate the temporal shift and the evolution of the enrichment of the European empires due to the Age of Exploration. For this reason, Western Europe is no longer united on the second series of maps, with UK & Ireland (British Isles), Spain & Portugal (Iberian Peninsula), Italy, France, and Germany listed separately. (Definitely, it is arguable that interpreting Scandinavia & Greenland, Benelux, Switzerland, Austria, and Greece as one region as "Other Western Europe" is a good idea.)

The third series of maps depicts countries by region between 1870 and 2008. Solarz represents our world in more detail during this period due to the reliability of data and the impact of the Industrial Revolution and colonisation, dividing the world into 69 countries and regions. Following the same logic, the fourth series of maps (1950–2008) works with even more detail, while the fifth series (1980–2017) uses HDI data (Conceição, P. *et al.* 2019) and, according to the author, "directly refers to the quality of life" (Solarz, M.W. 2020, 79).

Chapter Two (*Different Philosophies of Development*) introduces hypothetical scenarios related to development and progress that have already appeared in his previous book (Solarz, M.W. 2018b). The writer interprets eleven philosophers' and scholars' concepts on development from Plato to Jared Diamond and represents them on maps. For instance, because Plato believes knowledge is the key element of progress ("If Plato had drawn a North-South divide in 2019" see Solarz, M.W. 2020, 99), Solarz creates a map that

shows the differences among the countries of the world based on PISA results, building a mosaic of "northern" and also non-uniform "southern" groups of countries. The author of the *Theory of Justice*, John Rawls, believes that freedom and equality are the most important, thus Solarz calculates data from Freedom in the World index and parliamentary seats held by women. This is where the most stunning results come from, as the global North includes only Benelux, Scandinavia (with Iceland), Slovenia and Serbia.

In the third chapter (*Towards a New Global Line*), the author attempts to depict selected social, economic and political indicators that are important for development and progress. Fifteen 4-class composite choropleth maps present the world's developmental differences with 26 indicators. Those include innovativeness, education, concern for the younger generation & the elderly, Internet and mobile phone users, gender equality and social development, etc. The four summary maps based on synthetic indicators refer to all 26 partial indicators. The reference map compering the Human Development Index and Freedom in the World indicators with his own maps validates their outcomes.

In the last chapter (*Conclusions*), Solarz makes a distinction between hard and soft boundaries, calling attention to the fact that soft boundary always allows an in-between world between the developed and the underdeveloped parts. The list of developing countries will always be arbitrary to some extent and cannot be defined in such a way that satisfies everyone. The world is more complex than to be able to divide it with a single line and it is more like an "archipelago of highly developed islands dispersed in an underdeveloped ocean", which is constantly changing. The Brandt Line has a place in political and economic history rather than contemporary 21st-century atlases.

Solarz's work explores the geographic aspects of development in great detail, focusing on the discourse around the Brandt Line. By contributing to the discussion, he resolves the opposition of the global South and North with multiple approaches and offers new alternatives for presenting development on a global scale. The considerable number of pseudocylindrical and azimuthal maps provides a visualisation frame not only for the professional audience.

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REFERENCES

Alex Gillespie, A., Howarth, C.S. and Cornish, F. 2012. Four problems for researchers using social categories. *Culture & Psychology* 18. (3): 391–402.

Conceição, P. 2019. *Human Development Report 2019. Beyond income, beyond averages, beyond today: Inequalities in human development in the 21st century.* New York, UNDP.

Maddison, A. 2010. *Maddison Database. Historical Statistics of the World Economy 1–2008 A.D.* Groningen, Groningen Growth and Development Centre.

Quilligan, J.B. 2002. *The Brandt Equation.* Philadelphia, USA, Brandt 21 Forum.info.

Solarz, M.W. (ed.) 2018a. *New Geographies of the Globalised World.* London–New York, Routledge.

Solarz, M.W. 2018b. Many worlds, one planet. In *New Geographies of the Globalised World*. Ed.: Solarz, M.W., London–New York, Routledge, 54–76.

Solarz, M.W. 2020. *The Global North-South Atlas*. London, Routledge.

Williams, G. 1980. The Brandt report: A critical introduction. *Review of African Political Economy* 19. 77–86.

Wimmer, A. and Schiller, G.N. 2002. Methodological nationalism and beyond: nation-state building, migration and the social sciences. *Global Networks* 2. (4): 301–334.

Wionczek, S.M. 1981. The Brandt report. *Third World Quarterly* 3. (1): 104–118.

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Manuscript reviewers

2017–2019

The editors of the Hungarian Geographical Bulletin would like to thank the following experts who have offered their assistance in reviewing manuscript submissions to our journal issues between Number 1 in 2017 and Number 4 in 2019. Their efforts and useful comments have been of great service for the authors and the journal.

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